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Department of Land, Environment Agriculture and Forestry

Corso di laurea magistrale/Second Cycle Degree (MSc)
in Food and Health

Scaling Up Insect-Based Products: Exploring Innovative Business Models for Sustainable Growth

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Abstract

By 2050, the global population is projected to reach 9.1 billion. It causes a notable challenge to food security due to the estimated 70% rise in food demand. This demand cannot be met by traditional agricultural and industrial practices. This demand points to sustainable sources for protein since traditional animal-based proteins are not environmentally friendly. Insects offer nutritional benefits, low environmental footprints and more sustainability to meet protein demand.

This research aims to explore scaling up insect-based products and its uncertainties through the lens of an innovative business model (BM). Through a literature review and an empirical study, this research aims to find out how uncertainties in insect-based companies impact their scaling-up process and which strategies they used by altering their BM to address these uncertainties. The findings underscore the pivotal role of these uncertainties as a constraint on the upscaling process and the benefits of innovating business models to reduce these uncertainties.

It has been discovered that the main uncertainty for some companies was the EU regulation of placing insect-based products in the market, following other uncertainties such as consumer perception, social acceptance, safety, logistics chain and scaling up operations. However, business model innovation and adoptable strategies could help companies reduce these uncertainties.

Table of Contents

List of Tables

List of Figures

CHAPTER I
INTRODUCTION

1.1 Background Information

In the introduction, we explore four components of our background information: Firstly, address food security challenges and the innovative shift towards insects as novel proteins. Secondly, understand the different barriers to upscaling insect-based products. Thirdly, explore consumer preference and acceptance regarding insect consumption. Finally, discuss the role of innovating businessmodel in an industry in driving forward sustainable solutions to global food challenges.

1.1.1 Food Security Challenges and Shifting to Insects as Novel Protein Source

In 2050, it is estimated that there will be between 8.0 and 10.4 billion people on the planet, with the average estimated to be 9.1 billion (Maggio et al., 2016; USAID, 2008) (United Nation, 2009). Moreover, researchers from the Joint Research Center of the European Commission (EC) predict a significant increase in global food demand, which may reach 50% by 2030 and 60% to 110% by 2050 (Maggio et al., 2016). As a result, future food security is at risk (Maggio et al., 2016; Premanandh, 2011; Prosekov & Ivanova, 2018). FAO (Food and Agriculture Organization) defines *food security* as a state in which every individual consistently has access to an adequate, safe, and nutritious food supply that meets their nutritional needs and preferences for a healthy and active life (Cafiero, 2014; Molotoks et al., 2021; Uribe, Álvarez et al., 2010; USAID, 2008).

In recent years, the hunger level is increasing in the world. One of the primary drivers of this resurgence is climate change, which is also a significant contributor to severe food shortages. Global food security is expected to be severely impacted by anticipated future climate fluctuations combined with population growth and land use changes (Molotoks et al., 2021). Global dietary needs will pose a significant challenge to society in the future (van Dijk et al., 2021). The demand for food, feed, and fiber is expected to grow by 70% in the first half of this century (FAO, 2009). A 70% increase in food production is needed to satisfy the needs of this increasingly urbanized, wealthy, and larger population. In addition to increasing cereal production by approximately 3 billion tonnes, meat production must increase by over 200 million tonnes to reach 470 million tonnes (FAO, 2009).

Furthermore, researchers from the Joint Research Center of the European Commission (JRC) expect protein demand in Europe to increase significantly. By 2050, meat demand in Europe is anticipated to increase from 37 kg per person per year in rich countries to 52 kg per person per year in impoverished countries(Committee, 2015). Traditional animal protein sources are mammals, poultry, and fish in Western diets, but their production needs remarkable natural resources (FAO, 2009). Food production already consumes more than one-third of the Earth's surface (Dury et al., 2019), and it is difficult to feed approximately 10 billion people while lining up with sustainable development goals (Prosekov & Ivanova, 2018; Rickards & Shortis, 2017). In order to meet the growing demands of the global population, food production must develop innovative solutions (Henchion et al., 2017).

Animal-based protein sources have been subject to ongoing efforts to minimize their environmental footprint since the 1960s, as Henchion et al., 2017 outline. For the purpose of lowering greenhouse gas emissions and environmental footprints, society needs to transform toward alternative, more sustainable and environmentally friendly sources of protein (Hoes et al., 2020). As a result, alternative protein options are becoming more popular in the food industry. Several alternative protein sources, such as algae, seaweed, cultured meat, and

insects, appear as substitution for traditional protein sources (Bleakley & Hayes, 2017; Henchion et al., 2017; Hoes et al., 2020; Zarbà et al., 2020).. Insects are a new, alternative food source that offers many benefits, is highly nutritious, easy to cultivate, and has a smaller environmental impact than livestock-based proteins (Henchion et al., 2017; Davis et al., 2016).

There has been a fast growth in investment in alternative proteins, with lots of new companies coming into view, according to Buschmann et al. 2017. By 2035, alternative proteins are projected to reach a market value of a little less than $300 billion (Pilling, 2001; Wood & Tavan, 2022). Insects as food in the EU are regulated by the Novel Food regulation. In 2018, the new Novel Food regulation (EU 2015/2283)[1] replaced the original regulation (EC 258/97). The original regulation was interpreted in different ways by EU Member States, so insects were accepted as food in some countries and not in all other counties. The new Novel Food regulation clearly interprets insects as Novel Food. Business operators willing to place insect products as food on the EU market should first apply for an authorisation by the European Commission, after a safety assessment by the European Food Safety Authority (EFSA) (Veldkamp et al., 2022).

1.1.2 Scaling up: uncertainties

Novel proteins should be produced on a large scale to have a considerable positive impact on the environment. Furthermore, scaling up brings some uncertainties. There are various aspects that must be considered when scaling up a novel protein source, including production costs, food safety, consumer acceptance, and other scalability concerns (Henchion et al., 2017).

It is currently the case that various actors in the insect chain in Europe have a demand-supply mismatch (or gap). Insects must be available in a consistent quantity and at a predetermined quality if feed and food processors intend to use them as ingredients. A constant quality is not achievable at the moment on insect farms (Veldkamp et al., 2022). Compared to established sources of protein, such as soybean meal, insect protein products are not cost-competitive (Veldkamp et al., 2022). The cost of insects is becoming increasingly competitive with other sources of alternative proteins (Veldkamp et al., 2022).

The following issues are most likely to cause significant uncertainties about scaling up:

a) **Practical logistic chain:** it is important to develop a practical logistics chain providing stable storage and transportation of insects without compromising quality (Veldkamp et al., 2022).
b) **Food safety:** identifying chemical and microbiological food safety hazards and controlling them, as well as issues related to worker and consumer allergenicity.
c) **Scaling up operations:** scale, technology, supply, data, insect pests and insect disease.
d) **Regulations:** insect production licensing regulations, restrictions and issues associated with obtaining a license.
e) **Social acceptance:** access to finance and social acceptance of insect production/products are key uncertainties to insect production and sale; financial, price, and market obstacles: inputs, costs, and demand. Although social acceptance

[1] Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001, OJ L 327, 11.12.2015, p. 1–22, ELI: http://data.europa.eu/eli/reg/2015/2283/oj.

of insect products in the case of familiarity is one of the uncertainties, it is possible to industrialize edible insects (Wade & Hoelle, 2019).

f) **Consumer perception and acceptability:** insect production as human food is developing in many countries (Elhassan et al., 2019; Wendin & Nyberg, 2021). However, consumer acceptance in many Western countries is questionable, and insects are often considered disgusting, even though the taste of insects has been found to be mild and easy to accept. Social and cultural aspects have been shown to be the main explanations for humans' feelings of disgust (Elhassan et al., 2019; Pozharliev et al., 2023; Wendin & Nyberg, 2021).

As stated by (Stull et al., 2018)(pp. 867), 'the benefits of edible insects cannot be realized if people do not choose to eat them'. Consumer acceptance is influenced by various factors such as geographic location, legislation, gender, occupation, and socio-economic status (Roma et al., 2020). There are more than 2000 different types of edible insects offering a range of taste and texture, acceptance also depends on insect type, processing methodology and marketing strategies (Mishyna et al., 2020; Van Huis, 2013). Taste education and sensory pleasure are critical to achieving consumer acceptance (Mishyna et al., 2020).

Using insects as human food offers a great future opportunity as a sustainable protein alternative source that reaches the quality demands of nutrition, climate, and environmental sustainability, which are all crucial goals in Agenda 2030 (Wendin & Nyberg, 2021). However, this industry is still struggling with the uncertainties of consumers' acceptance and preferences (Anusha Siddiqui et al., 2023). Since there is an interaction between consumer acceptance and industry growth, consumer attitudes are crucial for the success of alternative proteins. As mentioned by Van Huis, to navigate consumer perceptions, there is a need for adaptable businesses. Additionally, a study by La Barbera et al. 2020, shows that consumer preferences are dynamic in the case of alternative protein sources. In conclusion, it is critical for the insect sector to address uncertainties in order to scale up successfully.

The imperative to address uncertainties in scaling up is intrinsically linked to the concomitant need for innovative adjustments to the business model (BM). As highlighted by Chesbrough 2007, in his seminal work on open innovation, the adaptability of a firm's business model becomes pivotal during phases of expansion and growth.

1.1.3 Business model innovation (BMI)

According to the literature, business models are used as a structure for a company to develop their business (Bachmann & Jodlbauer, 2023; Clauss, 2017; Spieth et al., 2014; Teece, 2010; Zott et al., 2011; Zott & Amit, 2013). Business model understanding helps to understand company's way of creating, delivering, and capturing value. The definition of a business model is a framework that contains nine elements in four dimensions: First, value proposition which means the added value for the customer (Massa & Tucci, 2013), and the element is 1) products and services that is valuable to the customers (Bachmann & Jodlbauer, 2023; Latifi et al., 2021). Second, value delivery for target customers offering customer service and support. The related elements are 2) target customer segments, 3) customer channels, and 4) customer relationships. Third, value capture that means the value-added for the company itself, for instance how to minimize costs and improve financially and guarantee the continuous financial success of the business. The elements are 5) revenue model and 6) cost structure (Johnson et al., 2008).

Lastly, value creation simply means meeting customer needs. Value creations' elements: 7) Key activities and key processes, 8) key resources, key technologies, key capabilities, and key control elements, and 9) key partners and ecosystems (Bachmann & Jodlbauer, 2023).

Business model innovation (BMI) means developing, evaluating, and implementing a new business model to create value for the company and its customers. Start-ups are distinguished from incumbents when it comes to business model innovation, referred to as business model design, which involves creating a completely new business model, and incumbents who are undergoing business model reconfiguration, which involves modifying a previously existing business model (Bachmann & Jodlbauer, 2023; Carnahan et al., 2010); Massa, L., & Tucci, C. L. (2013). New product and service development, developing new distribution channels, adopting new technologies, and creating new partnerships are all part of business model innovation (Bachmann & Jodlbauer, 2023; De Reuver et al., 2013).

Developing an innovative business model gives firms an edge over their competitors, dramatically affecting their performance (Heij et al., 2014). Developing comprehensive and innovative business models has been gaining traction in recent years (Foss & Saebi, 2017). An industry's business model is essentially the manner in which value is generated and delivered to its customers (Täuscher & Abdelkafi, 2017). In a nutshell, innovation within a business model refers to implementing new strategies in order to meet consumer demand (Teece, 2010). Through business model innovation, competitors can be prevented, new opportunities can be created, and consumer behaviour can be influenced (Juntunen, 2017) (Sniukas Marc, 2020). Innovating business models can give the industry a competitive advantage, as well as protect the environment, promote equity, and satisfy basic human needs (Holden et al., 2014).

Across organizations, including the food industry, there has been an increasing interest in the development of sustainable business models (Nosratabadi et al., 2020; Schaltegger et al., 2012). Several stakeholders concerned with the environment are embracing sustainable business models, which involve managing and executing actions that align with sustainability in business processes (Bocken et al., 2014).

In conclusion, in the rapidly evolving landscape of the insect-based protein industry, the imperative for scaling up production to meet the growing demand is clear. However, the journey towards successful scalability in this field is laden with multifaceted challenges. At the heart of this transformation lies the need for business model innovation.

1.2 Problem Statement

The European Commission, in collaboration with various organizations, has recognized the urgent need to address the escalating demand for meat protein while concurrently mitigating its detrimental environmental consequences by the year 2050. Consequently, the food industry is faced with the challenge of meeting the growing protein demand in an ecologically sustainable manner to reduce environmental harm (Maggio et al., 2015). This requires a shift in production practices towards more sustainable methods, along with the incorporation of alternative protein sources, such as insects, to meet changing consumer preferences. These alternative protein sources must be produced on a substantial scale to effectively contribute to addressing the prevailing demand.

The insect-based products industry has its own uncertainties related to consumer acceptance and preferences. These uncertainties make this industry so special that we are not able to use more general literature on business models and scaling up in this sector. The aim of this study is to explore the impact of these uncertainties on scaling up process and how business model innovation can address these uncertainties.

1.3 Demarcation

In this study, the choice of insects as an environmentally sustainable alternative protein source underscores the necessity of mitigating the environmental impact of animal-based protein production. As the demand for alternative proteins continues to grow, scaling up production becomes imperative. Successful scaling entails innovative adaptations of existing business models to effectively address production, safety, sustainability, labour, and legal considerations.

Our research centres on the specific context of insect-based protein production scalability, with a keen focus on Italy. To underscore this perspective, we have selected Alia Insect Farm, and Italian Cricket Farm. These companies are particularly well-suited due to their status as innovative start-ups actively engaged in the production of insect-based proteins and their utilization in the development of novel food products. Their dedication to pioneering alternative protein sources aligns with the central focus of this research. Furthermore, these companies represent the emerging landscape of insect-based protein production in Italy, a region with growing significance in the global food industry, and are noteworthy for their contributions to insect-based protein production and the development of novel food products.

1.4 Research Aim and Questions (RQ)

In this study, we explore scaling up insect-based production. Our primary objectives are to identify the uncertainties for enlarging insect-based production, to understand the business model innovation changes and to examine the practical approaches and strategies employed by companies in effectively managing and improving this scaling process.

- How uncertainties in insect-based companies impact their scaling-up process, and which strategies they used by altering the BM to address these uncertainties.

CHAPTER II
METHODOLOGY

2.1 Research design

This study used a dual exploration approach, delving both into literature and empirical data. Initially, we conducted a literature review to comprehend the uncertainties influencing the scaling-up process in the insect industry and to explore the wider literature on business model innovation (BMI). We conducted an empirical study to explore the impact of uncertainties on the upscaling process and their potential to alter the business model. The empirical study was performed by conducting interviews with experts working in the companies. Following the data collection, we formulated a conclusion to enhance our understanding of the impact of uncertainties on business model innovation scaling up. In order to analyze the data gained from the interviews, the transcript from the recording of each interview, combined with notes, was used. The quantitative data was carried out via Excel to illustrate diagrams. At the same time, qualitative insights gained from experts were processed in a tabular format, as detailed in Appendix 8.7.

2.2 Literature review

2.2.1 Performing the systematic literature review

The literature review followed a systematic approach, utilizing reputable datebases like PubMed, Science Direct and Google Scholar. Carefully selected keywords and search terms like food security, food loss, food demand, food safety, novel food, novel proteins, alternative protein, sustainable protein sources, protein demand, insect-based food, disgusts AND insect, scaling up insect, consumer acceptance AND insect, social acceptance AND insect, unfamiliar food, insect AND marketing, insect regulation, novel food regulations, business model, business model innovation (BMI), sustainable business model. We then selected literature that was relevant to the research questions and included recent publications from 2000. This process ensured the inclusion of studies focusing on consumer perception and scalability regarding insect-based products, and the dynamics of businessmodel innovation.

2.2.2 Snowballing

To expand the systematic literature review, snowballing was conducted to discover pertinent information through existing literature (Wohlin, 2014). Most related publications were identified based on their importance to the research aim. Furthermore, the bibliographies and references of those relevant studies were systematically explored to find more relevant publications. The snowballing method was used because of its convenience and efficiency.

Figure 1: Conceptual framework on the Uncertainties that influence Business Model

CHAPTER III
EMPIRICAL STUDY

3.1 Questionnaire and interview design

This section explains the research tool, which was an interview with companies' experts. We designed the interview questions to gather insights into the uncertainties of scaling up and the changes in business models for insect-based products. The interview contains qualitative and quantitative approaches to obtaining information from industry experts.

3.1.1 Interview Framework

Participants share their knowledge, experiences, and perspectives on the scaling-up process during the interview. We designed the interview questions to capture both qualitative and quantitative aspects of the research. We introduced quantitative questions with a scoring system ranging from 0 to 5, emphasizing the extent to which uncertainties influence the scaling-up process. We conducted qualitative questions to understand how these uncertainties impact the business model and innovation.

3.2 Selection of respondents

We chose Alia Insect, BugsLife, and Italian Cricket Farm to collaborate on this research because they are well-known in Italy as industry leaders. They were willing to collaborate. Their products include pet food, feed, powder, live insects, and so on. The respondents were the business developers and CEOs of these companies, as they had a clear understanding of the

CHAPTER IV
FINDINGS

Based on the interview analysis and company responses, the key findings are the following:

4.1 Overview of companies

Respondents: three companies named Italian Cricket Farm, BugsLife, and Alia Insect Farm were interviewed for this research. The respondents were the business developer and CEO, the co-founder, and the CEO of those companies respectively.
Size: 2 out of 3 companies (Italian cricket farm and BugsLife) were small (Italian Cricket farm: 9 employees and BugsLife: 14 employees) and the other one (Alia insect farm) was still in the R&D phase with zero employees, waiting for approval to produce for the market.
Years of business: the companies were all established in 2019 for approximately 4 years, so they are frontrunners in this industry.
Products and services: The companies offer various products to their customers. Italian cricket farm offers pet food, feed, plant and vegetable stimulants (huge market share in Italy but very niche market), while BugsLife works on services and consultancy for people wanting to build their plants in this industry and they have not sold any food by themselves yet, just like Alia insect farm, which is waiting for approval to sell insects as food for human nutrition.
Target costumers: Italian cricket farm mentioned 90% of their sales coming from pet food, in the form of B2B and B2C, BugsLife sells their packages to agro-industrial companies, beer and pasta; and variant customer personas, unlike Alia Insect Farm, which has no consumers at the moment because they are not authorized by EU law to be on the market.

4.2 Key Insights from Questions

Scaling Up is a Major Focus: Companies are actively seeking ways to scale up their operations, however, they face challenges such as regulatory and market acceptance. They mostly focus on increasing production capacity and manpower.
Companies have different purposes of scaling up, Italian cricket farm and Alia insect farm expanding production capacity and BugsLife tried to increase the number of employees, however, they all believe that business model innovation strongly helps them out.

Business model innovation (BMI): companies are trying to make their business model as flexible and adaptable as possible, thinking about challenges that might happen, delivery systems, offering packages, branding and targeting consumers, operation and automation for having the highest yield.

Uncertainties and BMI

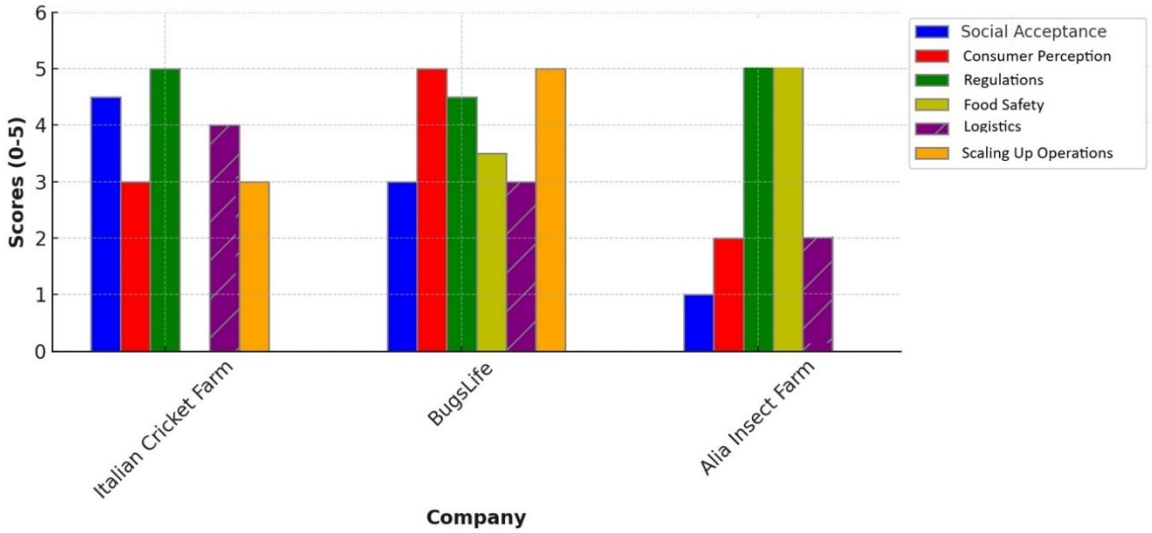

Figure 2: scores on various uncertainties provided by the companies.

The figure above gives the responses from the companies' experts on a 0-5 scale for various uncertainties in the insect sector named social acceptance, consumer perception, regulations, food safety, practical logistics chain, and scaling-up operations that can impact the upscaling process. Each bar represents the score given by a participant for a particular uncertainty, showing the extent of a type of uncertainty concerning scaling up in the business.

4.2.1 Each uncertainty

Social Acceptance: There's a range of perceptions about social acceptance that indicate that while Italian cricket farm sees this as a major uncertainty, BugsLife has a moderate opinion (score=3) and Alia insect farm believes it is not such a big uncertainty (score=1). This variability suggests that consumer acceptance and preference may differ based on marketing strategies and product offerings. For instance, Italian cricket farm said: «We have to put more efforts in convey right messages to our customers, market and the general population for example, participating in public event/speech». BugsLife company had a different strategy: «We tried to lower the price but it is kind of impossible so we are trying to optimize the production to have the most for example protein from the insects».

Consumer Perception: just as with social acceptance, consumer perception scores vary. BugsLife counts consumer perception as the main uncertainty by score 5. In contrast, Alia insect farm found it less important, so the score was 2. Their low score was due to the fact that they had not yet started selling their products and were focusing on other priorities. Italian cricket farm has moderate insight with a score of 3.

Regulations: This factor frequently received high scores (4.5 and above), highlighting the same concern among the companies about the regulatory hurdles. Italian cricket farm and Alia insect farm consider regulations the most uncertain factor by scoring 5 and BugsLife gives it 4.5. It strongly impacts the business as they are not able to continue without being authorised as Alia Insect farm said: «We cannot produce and sell until we do not end the regulatory part and

obtain the Novel Food Approval». And 2 others mentioned: «As soon as you talk about food, you have to comply with a series of new regulations».

Food Safety: Responses varied significantly, from 0 to 5, which reflects various levels of concern about food safety measures. Alia insect farm sees it as a major uncertainty, while BugsLife has a modest point of view and Italian cricket farm scores it as 0. Italian cricket farm believes «If you want to run a regular business, you have to comply. So basically, it is not a business model choice, it is mandatory».

Practical Logistics: This factor also showed variability in responses. Italian cricket farm sais thatthey invested a lot of time, money and energy on logistics for live insects. BugsLife prefers to employ 3rd parties instead. As a result, based on the products they offer, they face different challenges for logistics and they have different approaches to reducing them.

Scaling up Operations: Scores ranged from 0 to 5, indicating a wide range of experiences among the companies. BugsLife scored 5 and Italian cricket farm gave 3. However, Alia insect farm thinks that they are not in the scaling up phase, so they are not facing this uncertainty right now (score=0). Italian cricket farm highlighted machinery, optimization, and employee training improvement, while BugsLife said: «Mostly we are working on the new technologies to optimize our operations».

4.2.2 Each company

Italian Cricket Farm: this company shows concerns for regulations, social acceptance, logistics with scores of 5, 4.5, and 4, respectively. And consumer perceptions have the same score as scaling up operations, which was a moderate concern (score 3) while they feel no concern about safety. For consumer perception and social acceptance, it is found that this company plans to educate consumers via participating in events, etc., and innovative marketing strategies, including advertisement and good packaging, to convey the right, clear message about insects to gradually change consumer perceptions and increase interest in sustainable and alternative protein sources. In their business model, they focus mostly on putting more efforts into educating their customers. >The respondent stated: «If you talk about insects as food, expanding actually means creating the customer base», convey effective advertisement, devote some resources to get the approvals to offer new products, as well as create logistics chains to expand the delivery services. The company was not very worried about operations as they already did it in smaller scale.

BugsLife: With a score of 5, this company experienced the highest level of concern for consumer perception and scaling up operations, followed by regulation, safety, and social acceptance, which were scored 4.5, 3,5, and 3 separately. This implies that they confront a range of uncertainties at different levels, transforming their business into a more adaptable model. They urged investors to invest not only in the quality of their products but also in production automation to facilitate the scaling-up process for the highest quality and the highest yield.

As they said: «In case any challenges come, we design business models that are very flexible to adopt». The company has already progressed beyond its initial concept. For example, when it comes to scaling up, they added: «We already did it, but if we need it in the future, it is doable». They spoke. Even so, they do not want to add anything to what they offer, but they want to modify it based on the feedback from customers.

Alia Insect Farm: This company strongly believes that regulation and safety are the most influential factors for their business, while they feel more confident about the rest of the factors by scoring them 2 or less. This company did not share a lot of details about how they want to address uncertainties in their business model, as they believe it is an internal strategy that they don't want to willingly share. But due to the limited information, we could understand that they have plans to build and expand their customer base by having an improved production process and the highest food safety standards. However, they don't see any urge to change their business model to include new offering packages and the way they market them.

According to the presented evidence, companies employ diverse ideas and approaches to mitigate uncertainties in their business models. Among all uncertainties, regulation was identified as the most important uncertainty, and all companies agreed about it. Obtaining legal authorization posed the greatest uncertainty, given that they were pioneers, in Italy, in this field. Therefore, these companies lead the way, delaying the majority of their operations until they receive the EU authorisation, as Alia Insect Farm stated: «We cannot commence production and sale until we complete the regulatory process and secure the Novel Food Approval». Regarding the remaining uncertainties, each company employs unique strategies to mitigate them, none of which appear to follow a consistent pattern. An adoptable business model was one of the key advantages of these companies. They use a dynamic, flexible, and adoptable business model to have the opportunity to change in case of new uncertainties, as mentioned above in detail.

CHAPTER V
CONCLUSIONS AND DISCUSSION

In conclusion, scaling up insect-based products presents a unique landscape with both benefits and challenges. The advantages of sustainability, health, and nutritional value shows the industry's potential to transform our approach to food production and consumption. However, the novelty of this sector causes uncertainties, such as social acceptance, regulatory frameworks, logistical complexity, safety concerns, and the crucial factor of consumer acceptance. These uncertainties, in turn, necessitate an innovation in conventional business models to adapt to the insect industry's unique nature.

The current research aims to investigate the impact of various uncertainties on the insect industry, such as social acceptance, consumer perception, regulations, safety, the logistic chain, and scaling up operations. It also aims to determine the extent to which these uncertainties affect scaling-up processes and highlight the significance of innovation in business models to mitigate these uncertainties.

Because this industry is new (approximately 4 years for the researched companies, as mentioned in Chapter 4.1), it appears that there is not much experience with scaling up. The insights gained from interviews with companies expose a shared experience of struggling with the same uncertainties, but to varying degrees, which literature has already discussed. These uncertainties influence the business model at different levels in each company. Regulations, for instance, exert the most significant influence on the business, whereas other factors exhibit variability. Innovating business models and employing different strategies to address these uncertainties were the keys. The literature (Roma et al., 2020) suggests that a larger sample size with diverse geographical locations could provide a better understanding of the uncertainties. Therefore, the small sample size of the companies involved in this research is a limitation. These uncertainties forced companies to innovate their business models. Each company has its own strategies to be able to reduce these uncertainties and have a successful scaling-up process. According to the findings, there is not much in common between companies, and each of them thinks and acts differently. The only similarity is that they tried to be as flexible as possible and change their business in a way that faced fewer uncertainties. Details of each company’s point of view regarding each uncertainty and their strategies have been widely discussed in Chapter 4.

APPENDIX

1. -List of abbreviations

Table 1: List of Abbreviations

Abbreviation	Term
BM	Business Model
BMI	Business Model Innovation
CEO	Chief Executive Officer
EC	European Commission
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organization
RQ	Research Question

2. -Expert research for the empirical study

Table 2: Overview of experts' relevant information

Participant	Company's Name	Participant's Name	Expert Specialisation
A	Italian Cricket Farm	Emanuele / Evan	Business Developer/CEO
B	Bugs Life	Giacomo Grini	Co-Founder
C	Alia Insect Farm	Carlotta Totaro Fila	CEO and founder

3. -Email for companies

Email caption: Thesis project: Scaling Up Insect based products and Business Model Innovation

Dear Sir/Madam,

I am sending you this email to invite you to collaborate in this research as a follow-up of the introduction by Professor Valeria Paganizza of this research and myself as the researcher
In the pursuit of sustainable solutions, insect-based products have emerged as influential contributors to global well-being. Many companies aim to develop insect-based products, however not much is known how to upscale insect-based products. sadly, this lack of knowledge can lead to failures. My research is about scaling up insect-based products for the sustainable growth and it's evident that your company holds a distinctive position in steering this transformative journey.
I am Mahdieh Saeidi Nia, currently engrossed in research that delves into the realm of insect-based products. Specifically, my study is cantered on comprehending the challenges associated with scaling up and its impacts on business model innovation.
Your participation in this endeavour would not only contribute to enriching insights into scaling up in the insect sector but the results could also inspire you to deal with the challenges.
If you are open to sharing your experience, I would be honoured to interview you. The interview will take place via Microsoft teams, and it will last approximately one hour. The date can be arranged according to your availability, preferably between January 15th and January 30th. Please note that all information shared during the interview will be treated with strict confidentiality, and your responses will remain anonymous in the final research report.

Thank you for considering this collaboration. Looking forward to your positive response and the opportunity to interview you.

Best regards,
Mahdieh Saeidi Nia

4. -Interview Consent Form

Research Title: "Scaling Up Insect-Based Products: Exploring Innovative Business Models for Sustainable Growth."

Please tick the appropriate boxes	***Yes***	***No***
Taking part in the study		
I have read and understood the study information dated _____, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse. to answer questions and I can withdraw from the study at any time, without having to give a reason.	□	□
I understand that taking part in the study involves an audio-recorded interview, which will be transcribed and that notes will be taken during the interview. These recordings will be securely stored on the private device of the students involved in this study. After evaluation the audio files will be deleted, and the transcripts will be anonymized.	□	□
Use of the information in the study		
I understand that information I provide will be used for thesis research for the. MSc Thesis with course code BMO80424 of the Wageningen University that will be developed by the student of this thesis project.	□	□
I understand that personal information collected about me that can identify me [e.g. my name, occupation] will not be shared to any individual apart from the student	□	□
I agree that my information can be quoted in research outputs.	□	□
I agree that my real name can be used for quotes.	□	□
I want all my data to be anonymised. This will be done by the researcher changing my name to the title of the occupations I occupy and numbering them, if several people have the same occupation.	□	□

Signatures

_____	_____	_____
Name of participant	Signature	Date

For participants unable to sign their name, mark the box instead of sign.

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____ _____ _____

Researcher name Signature Date

5. -Interview Guide

Hello,
Thank you for participating in this interview. The questionnaire is structured into 3 parts, each designed to delve into different aspects of your organization's journey and strategies. Let's briefly outline each part:

PART 1: Introductory Questions
In this section, we aim to gather basic information about your organization. Please provide details that will set the context for a deeper understanding of your business landscape.

PART 2: SCALING UP
This part delves into your organization's scaling-up journey. Its challenges and opportunities.

PART 3: UNCERTAINTY AND BM (Business Model)
Here, we explore your perspectives on uncertainties faced by your organization. Share insights on how you identify, assess, and navigate uncertainties within the industry.
We are interested in understanding the adjustments made to your business model and the strategies employed for successful growth.

Feel free to provide detailed responses, and if applicable, share specific examples or instances that illustrate your organization's experiences. Given our time constraints, I may interject to keep us on track. Additionally, please note that this interview will be conducted anonymously to ensure your privacy.
Thank you for your time and candid input!

6. -Questionnaire

Table 3: Conceptual framework of uncertainties and related questions

Concepts framework	Definition concept	Interview questions	References for concepts and possibly for interview questions
Social acceptance	Eating behaviours are likely to be influenced by the group (and related characteristics) with whom people eat considering that each group comes with a series of social norms, as well as positive emotions which may set the	6,20,24	(Berger et al., 2019; Higgs & Thomas, 2016; Motoki et al., 2020)

	stage for eating (Higgs & Thomas, 2016) (Berger et al., 2019)demonstrated that social norms or conformity (i.e., other people's food evaluations) affect the likelihood of people accepting insect-based foods. It remains unclear.		
Consumer acceptance and preferences	consumer acceptance of insect-based foods still poses a big challenge in many societies. The Lensvelt and Steenbekkers framework (Lensvelt & Steenbekkers, 2014)for consumer acceptance of entomophagy identified three categories: (1) product attributes (e.g., price, quality, health benefits/risks, naturalness, and convenience); (2) trust and social norms; and (3) psychological factors (attitudes and culture). Kauppi et al. (Kauppi et al., 2019)identified two categories: consumer factors and the product's commercial potential.	5,7,8,10,11,20,22,23	(Alhujaili et al., 2023; Kauppi et al., 2019; Lensvelt & Steenbekkers, 2014; Motoki et al., 2020; Veldkamp et al., 2022)
regulations	The legislation for placing insects on the market as food in the EU member states is regulated by the Novel Food regulation. In 2018, the new Novel Food regulation (EU 2015/2283) replaced the original regulation (EC 258/97). The original regulation was interpreted differently in the member states, so insects were marketed as food in some countries and not in others. The new Novel Food regulation clearly defines edible insects as Novel Food.	20	(Veldkamp et al., 2022)
Food safety	Insect products can be applied for approval to be placed on the market	20	(Committee, 2015; Meyer et al., 2021; van der

	in all member states upon a scientific evaluation for safety by the European Food Safety Authority (EFSA). Evidence on the safety of using insects as feed and food has been gained in recent years, but knowledge gaps still persist. Potential food safety concerns in insects for food and feed, including the presence of microbiological and chemical hazards, allergenic compounds, and prions, were recently reviewed.		Spiegel et al., 2013; Vandeweyer et al., 2021; Veldkamp et al., 2022)
Practical logistic chain	With the expansion of the industry, the development of practical logistic chain is required to enable stable storage and transportation of insects with little or no quality degradation. The evaluation of insect transport and processing procedures at an industrial scale is an unequivocal step in the development of the industry.	9,11,20,24	(Veldkamp et al., 2022)
Scaling up operations	It is related to processing such as enzymatic treatment of insects followed by industrial centrifugation to separate insects into liquid and solid fractions, which can be applied as feed, food, or pet food ingredient, or the fractions can be subjected to biochemical purification. Processing methods have a big impact on protein digestibility, so finding the right value	16,17,18,19,20,25	(Veldkamp et al., 2022)

	for raw material digestibility is critical for formulation. Performance experiments have mostly been carried out at a laboratory or pilot scale so far, with high and non-commercial inclusion levels.

PART 1, Introductory Questions

Personal

1. Could you please introduce yourself.
2. what is your role/function in the company?
3. How many years are you working in this field?

Company

4. To better grasp the scale of the organization, could you share details about the overall number of employees at your company?
5. Can you provide an overview of your company's current position and activities in the insect-based food sector in terms of market share?
6. Looking ahead, how does your company anticipate its role and impact in the insect-based food sector in the coming years?

Current state of your company

7. What is your current targeted consumer/customer?
8. What do you offer to your current consumer/customers? (What kind of products? which characteristics?)
9. How you deliver your products to your consumer/customer? Directly or by distribution? via supermarket, other shops, online …??

Envisioned future state of your company

10. Are you going to enlarge your targeted consumer/customers in future?
11. Are you going to change what you offer in future?
12. Is there going to be any changes in delivery system in future?

Changes

13. Based on change 1 you mentioned in previous part, I want to ask how do you adapt your business with it?
14. Based on change 2 you mentioned in previous part, I want to ask how do you adapt your business with it?

PART 2, SCALING UP

15. Does your company have a vision to scale up?
16. If yes, could you provide a timeframe for when you anticipate it?
17. Considering scaling up, what particular aspects are you focusing? For instance, increasing production capacity, expanding market reach, or enhancing product/service offerings?
18. What are the key challenges that your company is currently facing in terms of scaling up process?
19. How do those challenges affect the scaling up process?

20. What are the opportunities that your company is currently have in terms of scaling up process?

PART 3, UNCERTAINTY AND BM

21. Due to the literature, there are some factors that affect Business Model (BM) such as social acceptance, Consumer acceptance and Preferences, Regulations, Food safety, having a Practical Logistic Chain and Scaling-up Operations. In the following questions we are going to discuss the effect of each factor on the changes you already mentioned:

Changes no	Uncertainty	To which extend do you find them influential for your business? Scale 0 to 5	Did this make you change your business?	In which manner?
1	Social Acceptance			
	Consumer perception and acceptance			
	Regulations			
	Food safety			
	Practical logistics chain			
	Scaling up operations			

BM

22. How has your business model been designed to be adaptable in the face of uncertainty?
23. Were there considerations for adjusting or expanding your target customer/consumer as part of the business model modifications?
24. Do these changes add more feature/characteristics to what you are offering?
25. Do these uncertainty and changes affect how you commercialize your insect-based products?
26. What modifications have been made in your production processes to achieve scalability?
27. This is the end of interview; is there any additional information you would like to share about what we discussed?

7. -Data from expert interviews

Table 4: An overview of experts' answers during interview

Questions no	Name	Answers
1	A	Emanuele / Evan
	B	Giacomo Grini
	C	Carlotta Totaro Fila
2	A	Business Developer/CEO
	B	Co-Founder
	C	CEO and founder Alia Insect Farm
3	A	Several months/since 2019
	B	Since 2019
	C	4 years
4	A	9 direct employee/collaborations/students
	B	4 FTE & 10 PTE
	C	Zero employees, we are still in the R&D phase
5	A	Pet food, feed, plant vegetable stimulant (a huge market share in Italy but it is a very niche market), have not sold any food yet
	B	Have not sold any food yet
	C	Research and Regulatory aimed to obtain the Novel Food Authorisation
6	A	for sure we were the first to be authorized and to obtain all the authorization from the ELF authorities from the ministers and so on, So I think we are in pretty good position from that perspective and we will keep leading it in the future.
	B	Growing up to be in the medium scale (10,000 ton per year in 3 years)
	C	Being a pioneer in Italy for insect based novel food adopting spray drying as main technology
7	A	90% of pet sale (B2B/B2C)
	B	Agro-industrial companies, Beer and Pasta companies, variant costumer persona
	C	We do not have consumers at the moment, as we are not yet authorised to sell our product in EU.
8	A	Live insects, pet food and feed (currently work on insect protein for human food)
	B	Industrial Plant, live insects, services to run an insect company like soft/hard wares, technological packages, experience, employee
	C	we will offer spray dried cricket powder, 100% made in Italy

9	A	our consumers may order are small and you are able to ship it by conventional means. But for me to be orders which are larger in size, we deliver directly using our van(trucks).
	B	It is like we are advertised by people (people to people) and now mostly working on the packages so it will deliver by ourselves.
	C	Not yet know, but it will likely to be mainly on line.
10	A	Yes, our new kind of product which will open up also other kind of shops that today are not our primary our primary target. So yes, we will.
	B	Yes, we assume that more people will work in this industry and they will be our future potential costumers
	C	Leveraging on brand communication and category communication.
11	A	We are introducing for example dried insects, so we are obtaining all the permissions to do it and then so we'll facilitate the operations from the logistic point of view of course. Also, you can store dried product because they have a one-year shelf life. So you can buy a bigger order in advance or I mean it's easier.
	B	Yes, we need to evolved but the fundamental thing is the same
	C	We might explore feed sector
12	A	I can say I can assure you that we are thinking about it every day practically because it's one of the major challenges here.
	B	We do not have any plan yet. We hope that after having couple of companies as a costumer, the others will be aware.
	C	Not known at the moment
13	A	constantly working on improvements. Now we are improving the farming section. Some parts are quite automatic, but we need to improve in order to grow the number of farmed insects. And when you want to enlarge your costumers, there are two effects, one is the feel of disgust, the second one is that insects are quite expensive compared to other kind of feeds so, if you fail in convey the right message a customer and do not understand why he has to pay more. We are working on that as well.
	B	I am not sure to answer properly but we work on optimization, better industrial soft/hard wares, maybe some deep changes like collaborating with different companies and sell the one product together to make it premium (it probably takes like 10 to 15 years)
	C	Not yet defined

14	A	Yes, we had a vision to scale up since the first day. One is to improve the efficiency because some species are too sensitive. I don't know if it is scaling up or not, but bureaucratic thing, the compliance, the policy is a scaling up issue cause yeah you can be authorized in a lab scale in a smaller scale, but to be authorized for an industrial scale is another long and complex process and you have to comply with.
	B	Absolutely, we using technologies that are able to be scale up.
	C	yes
15	A	of course, we have an idea where to go, but it could happen something, especially Because we are in the innovative industry, from the policy point of view of that could change everything in good or in bad. so our business has some flexibility to adopt.
	B	We have a plan to have 70 plant per year by 2030.
	C	After the Novel Food Approval.
16	A	the production capacity is one of the things, but we are not thinking of expanding the insect patches that we are actually farming. but we will see because the market is evolving day by day.
	B	Scaling up accordingly Human part like our Employees, we need more engineers, supply chain technologist and project managers.
	C	Expanding production capacity as first priority
17	A	the people who want to work the efficiency the bureaucratic law and certifications.
	B	Identify the general conductor, feed design, cash flow from the pool of by products(operations), financial challenges
	C	Novel food approval and new investors
18	A	If we don’t have people to work in holidays, we cannot up scale, or if the bureaucratic things go bad. So, we are not sure about during or end of scaling up right now but we are studying it.
	B	it is more difficult for the first plant but we mostly need financial adaptations
	C	Because of lack of regulatory authorisation and because of the financial resources needed to scale up a fixed cost driven activity.
19	A	Industry evolution, when we started, we had to invent ourselves our machineries. there is a lot of innovations also from the supply side so I think the this is the main opportunity.
	B	If we scale up, we can have a better deal with suppliers so it could be cost efficient.

	C	….			
20	Uncertainty	Company	To which Extend from 0-5	Did this make any changes in your business?	In which manner?
	Social Acceptance	A	4_5	YES. the social acceptance it is the is one of the most problematic aspects right now.	We have to put more effort in convey right messages to our customers, market and the general population. So I mean it's not a business model change but you have to devote time and resources to for example participating in in public event/speech. So as soon as you do these kinds of activities you cannot do other things. in that sense, it's a business model impact, yes.
		B	3	YES.	We tried to lower the price but it is kind of impossible so we are trying to optimize the production to have the most for example protein from the insects.
		C	1	no	Social acceptance cannot be properly estimated until the product is available on the market

	Consumer perception and acceptance	A	3	YES, I can say what is my personal opinion, but it is not based on actual reaction because we do not sell food yet but I have talked to many buyers. They are more optimistic than I am personally. Professionals are less sceptical than me because they think that everything new has to be tested.	We are working on conveying more clear messages on our packaging and we educate our stores and business clients.
		B	5	YES.	Tried to keep the quality as high as possible in the production.
		C	2	no	As above.
	Regulations	A	5	YES.	as soon as you talk about food, human and a human food, you have to comply to a series of new regulation that you have not to comply. So basically, you have to devote some resources also there.
		B	4_5	YES.	You have to it anyway. We crossed our fingers!
		C	5	yes	We cannot produce and sell until we do not end the regulatory part and obtain the Novel Food Approval

	Food safety	A	0	NO. if you want to run a regular business, you have to comply no matter what. So basically, it's not a choice, a business model choice. It is mandatory.	Commercial product that are currently on the market would not be an approved as novel food today because we novel food rules are so strict, I mean safety is not an issue.
		B	3_4	YES.	You need to pass some rules we have some people to take those certificates for us and talk to politicians.
		C	5	yes	We modulated and improved our production process in order to get the highest standard of food safety
	Practical logistics chain	A	4	YES. it's so difficult because some insects should be alive as they delivered. But please keep in mind that this is would not be true for food. For food, you will work with powder, so it's not the case.	We invested a lot of time and money and energy on logistic for live livestock because It's quite tricky.

				if we consider food logistic is of insect food is not different from logistic of any other food.	
		B	3	YES.	Working with good 3rd parties and have a long good collaboration.
		C	2	no	We are not completely on it
	Scaling up operations	A	3	YES, but you already know what you have to do because you have done in a smaller scale. So just a couple of trial and then you are done.	cost optimization automation machinery employee trainee
		B	5	YES.	Mostly we are working on the new technologies to optimize our operations.
		C	0	no	We are not there yet
21	A	you can design a company to be as much flexible as you want in your dream, but then there is the reality. doing things on a smaller scale gives you more flexibility but maybe less speed and so flexibility is against a big investment.			
	B	In case of any challenges come we design it very flexible to adopt. It is already developed comparing to the first idea of the company.			
	C	It is an internal strategy			
22	A	If you talk about insect food, expanding the customer actually means creating the customer base.			

	B	We were developing our packages very adoptable due to our future costumers.
	C	yes
23	A	We are working on the delivery services to expand, automation, and for the future human food product we are trying to offer a cricket flour/powder that will be used in different industries like pasta, bread, protein bars etc.
	B	We should not add any other things in our packages but we modify to deliver in a better way as soon as we start selling and getting feedback from our customers.
	C	no
24	A	No commercialization is done traditionally.
	B	we are going to affect people by the use of branding, educate social.
	C	…..
25	A	Basically, I would answer with the automation. automation trials and then scaling up the automation the process of farming insects.
	B	We already done it but if we need in the future, it is doable.
	C	In continuum production process

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