To what extent is it possible to produce potato-based pasta products with by-products of the potato value chain?

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Date: 27-05-2025
Subject: MSc Thesis

Acknowledgments

I would like to thank EatWasted for collaborating with me on this research project. At the beginning of the research, it was difficult to find companies to interview, which made it difficult to stay motivated for this project. However, EatWasted was one of the companies I emailed that was open for an interview. This allowed me to analyse their current business model and compare it to an expansion of future practices. Thank you for keeping this project interesting for me and allowing me to make it applicable to the Danish context.

I would also like to express my gratitude to Christiaan Oei from Duynie, Kristian Wallays from Agristo, and Marc Laus from Avebe, who were all interviewed for this thesis. This helped to open up the field and specify the direction of this thesis.

I would also like to thank my supervisor, Michael Søgaard Jørgensen, for the meetings we had regarding the process of my thesis. These meetings gave me a clear direction, and helped me define the scope of my thesis. However, Michael helped to guide me in the right direction. So, thank you for making this thesis process a success.

Abstract

The objective of this thesis is to research

To what extent is it possible to produce potato-based pasta products with by-products of the potato value chain?

By researching this, this thesis contributes to waste reduction at the producers' site in the potato value chain, as well as, potentially producing a gluten-free alternative to rice noodles, namely potato-based pasta products. A potato-based alternative would be environmentally more sustainable than rice noodles, because the current system of producing and consuming rice noodles leads to a CO_2 emission of 5,12 kg per kilo, while a potato-based alternative emits 1,68 kg CO_2 per kilo.

To upcycle by-products of the potato value chain, it is important to make these potato by-products into a usable ingredient for pasta products, such as potato flour or potato starch. Potato flour is made by dehydrating the potato and blending it into flour, while potato starch is extracted from the potato pulp. Potato flour does not have any baking properties, meaning that a mixture of another flour, for example, semolina flour, and potato flour needs to be used to produce pasta. Therefore, the production method of producing pasta this way is similar to the production of wheat-based pasta. Potato starch, on the other hand, does have baking properties and has the potential to substitute wheat flour 1:1 in pasta production. However, since the main ingredient would be starch and not flour, the production method would differ from pasta that is made from potato flour.

To make the outcomes of this research more applicable to the Danish business context, a collaboration with EatWasted, a company that upcycles bread into pasta, was established, to see if they can expand their practices into upcycling by-products of the potato value chain.

Two pathways were established for EatWasted to make it easier to expand their practices.

1. Picking up whole potatoes from the potato-processor/wholesaler and blending them into flour.
2. Starting a collaboration with a company that produces side-stream starch and use this starch for pasta production.

Since pathway 2 uses starch, the production method would differ from the current production of wheat-based pasta. For pathway 1, a mixture of potato flour and semolina flour would be used, making the production method similar to that of wheat-based pasta.

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1.0 Introduction

The entry point of this thesis was to research to what extent it would be possible to set up a value chain for potato-based noodles. This entry point can be derived from my personal motivation regarding this topic. During the research process, for further elaboration, see Chapter 2, the focus of the thesis shifted towards pasta-based products.

1.0.1 Personal motivation

As a gluten-intolerant consumer who is passionate about sustainability, I often feel conflicted when purchasing rice noodles because of their environmental impact. Compared to wheat noodles, which contain gluten, the emissions from rice noodles are much higher. For further elaboration, see Chapter 1.1.2. I can tell myself to stop buying rice noodles, as I don't consider them sustainable, but I cannot ask other gluten-intolerant consumers to stop buying rice noodles. This dilemma sparked my interest in investigating whether Danish supermarkets could offer a more sustainable, gluten-free noodle option. Since potatoes are grown locally and require less water than rice, I was driven to explore whether potato-based noodles could serve as a viable and eco-friendly alternative.

1.0.2 Disclaimer

Although the entry point of this thesis was to research the viability of a gluten-free alternative to rice noodles, the literature does not make a clear distinction between pasta and noodles. Therefore, the term pasta products will be used to refer to the general terms noodles and pasta. However, as the entry point of this thesis concerned noodles, this thesis compares rice noodles to potato-based pasta products, and does not look to other gluten-free flours suitable for pasta production.

Since the production methods of noodles and pasta differ, the terms pasta and noodles refer to a specific production method whenever they are used separately.

1.0.3 Reading guide

This report is structured according to the double diamond approach, which will be explained in detail in Chapter 2.

Following this reading guide, a first draft of the research question will be given, which serves as the entry point of the thesis. Next, the research design outlines the research process, and the draft of the second research question will be presented.

For this thesis, a collaboration with EatWasted was established, and they will be introduced after the research design. The research design is followed by the theories and the

methodologies. After comparing the production processes of wheat-based pasta and potato-based pasta products, the analysis focuses on EatWasted's sustainable business model as part of the second phase of the double diamond framework.

Chapters 6 and 7 each conclude with a summary of their key findings related to the research question. The report concludes with a discussion, conclusion, and bibliography.

1.1 Framing of the research questions

The following chapter explains how the research question was framed. Framing this research question was done according to the RIN. AFE framework. This framework helps to explain the relevance to the field of this research to sustainable design engineering. This chapter ends with the first draft of the research question, as this was developed further during the research process.

1.1.1 RIN.AFE framework

The framework used in this research is the RIN. AFE framework, developed by Goldschmidt and Matthews (2022). The RIN component—standing for Relevant, Interesting, and Novel—supports the framing of the research question and shows the importance of the topic to the research field by explaining these elements. The AFE component—representing Appropriateness, Feasibility, and Ethics—addresses the methodological part of the research, ensuring that the methods are suitable, achievable, and ethically sound.

The RIN. AFE framework derives from the FINER (feasibility, interesting, novel, ethical, relevant) framework used in clinical research, and is made more applicable to sustainable design engineering by adding the A for appropriateness. This A concerns the methodologies and addresses whether the methodologies match the research question (Goldschmidt & Matthews, 2022).

Since the RIN component concerns the framing of the research question, and the AFE component concerns the methodological approach, the RIN component will be explained in this chapter, whereas the AFE component will be elaborated in Chapter 3, Methodology.

1.1.2 RIN

The entry point of this thesis states that the current system of consuming rice noodles as a gluten-free noodle alternative, is not sustainable. Therefore, a sustainable transition needs to be made to a new system, where the noodle alternative can be considered more sustainable. The following paragraphs will research the sustainability of rice noodles vs. a potato-based alternative in depth.

When comparing the emissions of rice flour to the emissions of wheat flour, which is usually used for the production of gluten-containing noodles, the total CO_2 emissions of rice flour (5,12 kg of CO_2) are much higher than those of wheat flour (1,24 kg of CO_2) (*Den Store Klimadatabase Version 1.2*, n.d.). Therefore, rice noodles can be considered less environmentally sustainable than wheat noodles when it comes to CO_2 emissions. This statement emphasizes the importance of finding a gluten-free alternative to rice noodles, which would be comparable with the emissions of wheat noodles.

Figure 1 shows the total CO_2 emissions for rice flour (rismel)

Kategori	Fødevare	kg CO2e/ pr. kg	Landbrug	ILUC	Forarbejdning	Emballage	Transport	Detail
Korn og kornprodukter	Rismel	5,12	4,37	0,17	0,00	0,20	0,38	0,01

Figure 1 CO2 emission of rice flour

In comparison to wheat flour (hvedemel), which is shown in Figure 2.

Kategori	Fødevare	kg CO2e/ pr. kg	Landbrug	ILUC	Forarbejdning	Emballage	Transport	Detail
Korn og kornprodukter	Hvedemel, grahamsmel, fuldkorn	1,24	0,86	0,07	0,03	0,20	0,07	0,01

Figure 2 CO2 emission of wheat flour

Cultivating rice is water-intensive, and rice flour is transported over long distances, usually from Asia, which is part of the reasons why rice has a high number of kg CO_2 per kilo emitted (Mallareddy et al., 2023) (Li et al., 2021).

Comparing the emissions of potato flour are similar to the emissions of wheat flour. Therefore, potato flour could be considered to be a more sustainable option than rice flour for gluten-free noodles.

Figure 3 shows the emissions of potato flour.

Kategori	Fødevare	kg CO2e/ pr. kg	Landbrug	ILUC	Forarbejdning	Emballage	Transport	Detail
Grøntsager og grøntsagsprodukter	Kartoffelmel	1,68	1,00	0,07	0,14	0,20	0,26	0,01

Figure 3 CO2 emission of potato flour

This thesis talks about flour and starch. Since there are no separate sources found on the kg CO_2 emitted of starch, and the raw materials for the flour and the starch are the same, it could be assumed that the emissions of starch and flour are similar.

A sustainability transition is a transition towards a socio-technical system that is 'greener' and can be sustained over multiple generations (Yang Keija; Andersen Allan Dahl; Sovacool Benjamin K, 2024). Producing gluten-free noodles/pasta from potato by-products seems to be environmentally more sustainable because of the lower CO_2 emissions, as well as the usage of by-products of the value chain. Therefore, this movement is considered to be a sustainable transition (Yang Keija; Andersen Allan Dahl; Sovacool Benjamin K, 2024).

As potato-based noodles are not widely produced in Denmark and sold in the supermarkets, this research topic is considered to be a novel topic.

1.1.3 First draft of the research question

As this research is an iterative process, the research question has evolved through different drafts. The research question presented here is the initial research question, which was derived from the entry point for this thesis.

The potential environmental sustainability of potato-based pasta suggests a promising opportunity to develop and market this product on a large scale in Denmark. This observation leads to the primary research question:

To what extent is it possible to produce potato-based pasta products in Denmark?

It is important to find out if more companies in Denmark, that are currently producing pasta, would be open to the idea of producing potato-based pasta products. Before going into dialogue with these companies, it is important to know the limitations at the production site. Therefore, the first sub-question would be:

Can potato-based pasta products be made from the same processing plant as pasta and (wheat) noodles?

It should be researched if more companies inside/ outside Denmark work with potatoes. This should be done to analyse the possibilities of using the potato for pasta production. Hence, the second sub-question is:

Are there companies inside and/or outside Denmark that produce potato-based pasta products?

This research would support the creation of negotiation spaces for companies to produce potato-based pasta products in Denmark. Thus, the final sub-question is:

Are there companies in Denmark that see themselves doing it?

The scope of this research is Denmark and the target group are companies in Denmark.

2. Research design

After completing the first draft of the research question, it is crucial to plan the research and develop the methods. For this study, the double diamond approach is used to illustrate the research process.

The knowledge development table is used to strengthen the illustration of the double diamond approach.

2.1 The double diamond

The double-diamond approach is used to illustrate different phases of the research, and it consists of two parts. These parts are visualized as diamonds and help open the solution space by dividing the research process into the discovery, define, develop, and delivery phases. This approach allows for continuous iteration and increases transparency in the research design (Pandey, 2024). Iteration leads to a high level of research transparency and allows for generalization. Generalization allows the results of the research to be applied in different contexts (Pérez Bentancur & Tiscornia, 2024). Therefore, generalization leads to knowledge development in different fields (Flyvbjerg, 2006).

Figure 4 displays the double diamond made applicable to this research.

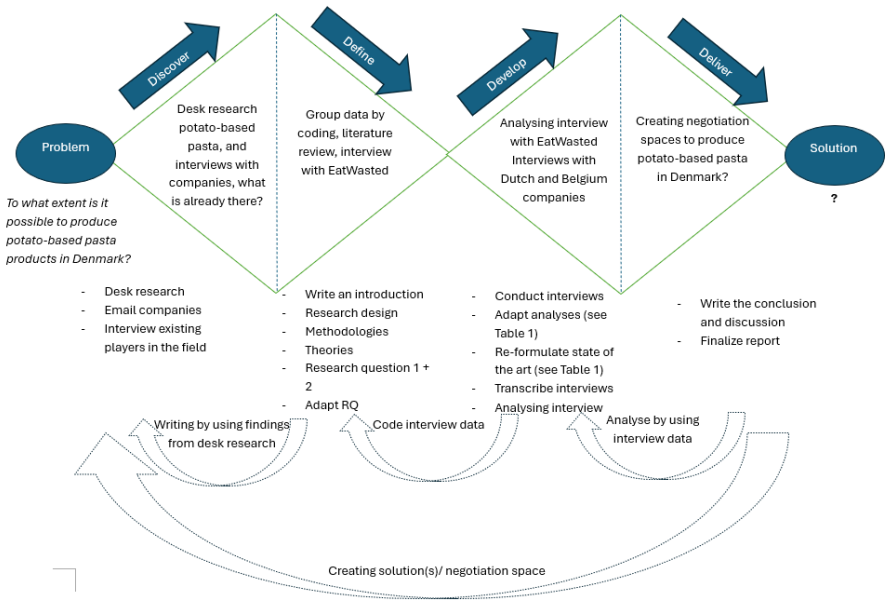

Figure 4 Double diamond approach

2.1.1 Discovery and defining phase

A draft of the state of the art was sketched in the discovery phase, using literature research. This state-of-the-art helped open up the field and helped determine which companies to contact. Literature research also provided information on different concepts that are considered to be important for understanding the state of the art.
In this phase, it was also discovered that there was only one pasta-producing company, EatWasted (for further elaboration, see Chapter 2.2), that wanted to be interviewed by me. A lack of other pasta-producing companies that wanted to be interviewed by me led to a re-formulation of the research question

To what extent is it possible to produce potato-based pasta products with by-products of the potato value chain?

This was done to make the research more applicable to EatWasted, as they are currently working with upcycling old bread into pasta, and they want to expand their practices into upcycling by-products of the potato value chain.

As the focus of the research question shifted, the contribution to the sustainable design engineering (SDE) field shifted as well. The entry point of this research was still to make a more sustainable gluten-free alternative to rice noodles, since the system of consuming rice noodles is less sustainable compared to the consumption of wheat noodles, the focus shifted more towards reducing waste in the potato value chain.
Making a system more sustainable by reducing the amount of waste is still contributing to the field of SDE, but it is important to notice that with the focus shifting, the contribution to the field shifted as well.

After it became clear that this collaboration was established, the research question for this thesis was brought back to two sub-questions

1. *Can potato-based pasta products be produced from the same processing plant as wheat pasta?*
2. *What is needed for EatWasted to expand its practices?*

2.1.2 Develop and delivery phase

EatWasted was being interviewed, and their current practices were being analysed. Meanwhile, the company Avebe, a company that produces potato starch and tries to utilize the whole potato in making other products as well in the Netherlands, was being interviewed. Agristo, a company that produces deep-frozen potato products in Belgium, was being interviewed. And

later, the company Duynie, which produces side-stream starch, for further elaboration see Chapter 7.2, was also being interviewed.
Based on the data from the companies in the Netherlands and Belgium, the analysis was adapted, meaning that the pathways were further elaborated, and the state of the art was finalized.

In the delivery phase, a final conversation with EatWasted should lead to the creation of negotiation spaces, where the designer acts as a facilitator of change. Creating negotiation spaces is, as well as the rest of the project, an iterative process, where one goes back and forth between problem identification and user testing (Pedersen, 2020).

This interview will be held after the hand in of the thesis.

2.1.3 Knowledge development table

Table 1 summarizes the activity being done in these 4 phases.

Month	Activity	Findings	Contributed to
December	- Desk research - Start writing the conceptual framework		
January	- Desk research - Writing - Start mapping relevant companies		
February	- Mapping and contacting relevant companies - Writing	- There were no pasta-producing companies in Denmark that wanted to talk to me, except for one, EatWasted	- Because EatWasted currently produces pasta from upcycled bread, the scope of the research shifted to upcycling potato by-products-> Defining the scope

March	- Mapping of other relevant companies in other countries and contacting them - Interview with EatWasted - Desk research	- Found a company in the Netherlands and a company in Belgium that I could talk to - Started analysing the SBM of EatWasted and the market	- Started the analysis after the interview with EatWasted
April	- Interviews with other companies relevant to the field	- Found out about the side-stream starch from a company in the Netherlands-> emailed this company, planned an interview with them, and conducted an interview - Found out that it is not possible to produce starch from potato peels and adapted the analysis based on this-> From extracting starch from potato peels to a collaboration with a company that produces side stream starch	- The interviews with the companies in Belgium and the Netherlands contributed to a more precise shaping of the state of the art - Adapted the analysis based on the data I got from the side-stream starch company-> Pathway 2: From focusing on potato peels to focusing on side-stream starch
May	- Writing and re-writing		

Table 1 Knowledge development

2.2 EatWasted

As can be seen in chapter 2.1, establishing a collaboration with EatWasted led to a re-formulation of the research question. This was done to make the results of this research more applicable to the context of EatWasted, as they were interested in expanding their practices into upcycling potato by-products into pasta.

EatWasted is a Danish company founded in 2022 that produces pasta by upcycling discarded bread. Emphasizing social, economic, and environmental sustainability, EatWasted donates a portion of pasta to charity for every kilo sold. According to LinkedIn, the company currently employs between 2 and 10 employees.

Based on conversations with Alessio Tomarelli (Pers. Comm., 2025), a partner of the company, the website, and the fact that the product is made from upcycled produce, it can be concluded that EatWasted's core value is sustainability. Therefore, the sustainable business model (SBM) will be used to illustrate their current business model. For further elaboration on the SBM as an analytical tool, see Chapter 4.1, theories.

Eatwasted has partnered with an industrial bakery to collect bread. Earlier, they collected bread from multiple bakeries in Copenhagen. However, due to logistical problems, they decided to work with one big industrial bakery.
The bread at the industrial bakery would originally be discarded as animal feed because it does not meet the quality standards (it is too large, too small, etc.). However, instead, this bread is frozen by the bakery and collected by EatWasted.
Since this bread used to be sold to farmers, that paid a certain price for this bread, EatWasted needs to pay a slightly higher price than the farmers for this bread, to make it attractive for the bakery to sell to EatWasted. After the bread is collected, it is taken to a mill where it is shredded. This shredded bread is spread out on trays to dry. When the breadcrumbs are dry, they are mixed with semolina flour to form the pasta dough.

To ensure food hygiene by avoiding rancidity, during the pasta production process, EatWasted only collects bread made from flour and water.

EatWasted has a small production facility in Denmark. Since this small production site can produce +/- 100 kg of pasta per week (Tomarelli, Pers. Comm., 2025), EatWasted has decided to collaborate with a company in Italy that produces pasta for them as well. Scaling up their production facility in Denmark would be too expensive, therefore, EatWasted has decided to collaborate with a company in Italy.

Tomarelli states, however, that it might not be the most sustainable from an environmental perspective to transport the pasta that is produced in Italy to Denmark, but it was economically considered to be the most sustainable option, and therefore the only feasible way to scale up for EatWasted at that time (Tomarelli, Pers. Comm., 2025)

The pasta that is produced in Italy is produced according to the same method as in Denmark, and the leftover bread is collected from bakeries in Italy. After production, the pasta is transported to Denmark by truck. Thus, all the pasta that is produced in Italy is sold in Denmark. Another common problem for food companies is logistics, since upcycling of products usually requires different value chains. As Alessio Tomarelli stated in an interview:

Cause it is easy, well it is not easy, but now it seems easy, to do it with one or two bakeries here, you know keep it small. But then you want to grow the impact and make a change, save a potential amount of waste from being thrown away, or fed to animals, you need to grow the supply chain very well. And you need to make sure you are growing it on an economic scale, because otherwise the whole process, the risk is that the whole process is more expensive than buying the normal flour and then the consumer will have to pay more (Tomarelli. Per. Comm., 2025)

Figure 5 illustrates the SBM of EatWasted.

<table>
<tr>
<td rowspan="2">Key partners
- Industrial bakery
- Milling company
- Pasta factory in Italy
- Logistic company</td>
<td>Key activities
- Producing pasta from upcycled bread
- Selling the product to customers
- Selling the product to businesses</td>
<td rowspan="2">Value proposition
- Reducing food waste
- Reducing food insecurity
- Bringing people together</td>
<td>Customer relationships
- Showing the value of food ‘waste’
- Creating value for the community
- Improving the product based on their feedback</td>
<td rowspan="2">Customer segments
- Consumers who want good pasta
- Consumers who care about the environment</td>
</tr>
<tr>
<td>Key resources
- Semolina flour
- Leftover bread
- Water
- Human capital</td>
<td>Channels
- Online platforms: Instagram, YouTube, TikTok
- Events</td>
</tr>
<tr>
<td colspan="3">Cost structure
- Human capital
- Production facility in Denmark
- Production facility in Italy (collaboration)
- Leftover bread
- Semolina flour
- Transportation</td>
<td colspan="2">Revenue streams
- Selling the product to businesses
- Selling the product to customers
- Selling the product via events</td>
</tr>
<tr>
<td colspan="3">Eco-Social costs
- Transportation costs from the production facility in Italy to Denmark
- Water usage (cooling pasta machine), energy, and flour-> On the facilities
- Water and energy usage of the milling company</td>
<td colspan="2">Eco-Social benefits
- Letting people appreciate the value of upcycled food
- Donate pasta to charity for every kilo sold</td>
</tr>
</table>

Figure 5 SBM of EatWasted

2.2.1 EatWasted and the waste hierarchy

EatWasted wants to reduce food insecurity. Before they entered the field, the bread of the industrial bakery went to farmers and was used as animal feed. EatWasted states that upcycling food for human consumption is more desirable than upcycling food for animal consumption. This is in line with the waste pyramid as depicted in Figure 6.

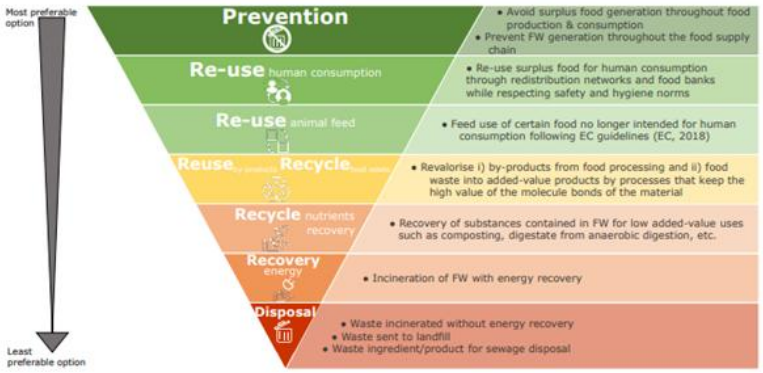

Figure 6 Waste pyramid Retrieved from https://www.nri.org/images/images/nri-news/2021/Food-waste-hierarchy-pyramid_Sanchez-Lopez-et-al-2020.png

This waste pyramid shows the most preferred option (top), to the least preferred option (down). The impact is determined by looking at economic, environmental, and social benefits. Since the societal value of upcycling food for human consumption is higher compared to animal feed, and therefore upcycling food for human consumption probably has a higher economic, as well as social value, it is more desirable (Teigiserova et al., 2020).

3. Methodology

According to Creswell (2009), the choice of methodology is influenced by the researcher's worldview. Creswell (2009) argues that a researcher can have an advocacy and participatory, pragmatic, social constructivist, and/or postpositivist worldview. Choosing your methodology is influenced by the way the researcher perceives the world (Collins & Stockton, 2018).

3.1 Theory of science

In general, I would like to get my research on the action agenda. Thus, I want my research to result in a plan of action. A product of this thesis is an action plan for EatWasted to expand its practices. By interviewing EatWasted about these possible action plans, this research should support the implementation of their practice expansion.

Initially, I would think that the research I have conducted might not apply to all companies that want to work with the upcycling of by-products of the potato value chain. This makes my worldview partly pragmatic, stating that the results of research work when they work, and therefore, the results might not work for every company.

By writing this thesis and making it available for other people to read, I assume that everyone wants to understand the world, which corresponds to the social constructivist worldview.

By using literature to answer my (sub) research question(s), the postpositivist worldview is shown, since this worldview is based on science.

Overall, my worldview is mostly advocacy and participatory-based, a bit pragmatic and social constructivist, and somewhat postpositivist.

3.2 Strategy of inquiry

The strategies of inquiry for this research are: open-ended interviews, which will be used to sketch a state-of-the-art (interviews with Dutch and Belgian companies), as well as for the analyses (interview with EatWasted), and desk research, which is used for literature review.

Depending on the specific research topic the following inclusion criteria were used. Potato AND waste, Potato AND processing methods, Potato AND Waste valorisation, Potato Starch AND Potato flour, Potato value chain, Potato value chain AND Denmark, Potato consumption, Potato consumption AND Denmark, Potato waste AND usage, Potato peels. The search engines that were used were: Science Direct, Elsevier, and Aalborg University Library.

Exclusion criteria were articles that were not written in English, Danish, or Dutch, as these are the languages understood by the researcher. Since there are not a lot of articles being found on

the potato value chain in Denmark, the oldest article that is being used dates back to 1950. No articles from before this period have been used.

3.2.1 Literature review

The inclusion criteria outlined in Chapter 3.2 guided the literature review process. Relevance of the articles that were being used was determined by the article's title and abstract; if the articles were found relevant, based on the title and abstract, they were used. The relevancy of the article was dependent on the specific topic that was being researched.
For example, when researching potato starch, the abstract and the title should mention something about potato starch for the article to be considered relevant.
Key sentences and takeaways were recorded in a document to create a concise summary for each article. This systematic approach not only provided a clear overview of each source but also allowed for efficient reference to specific topics when needed.

3.3 Methods being used

To sketch a state-of-the-art of what is happening in the potato-based pasta products field, this research combines open-ended interviews from companies in the Netherlands and Belgium with comprehensive desk research. In open-ended interviews, the interviewer prepares a list of topics that they want to discuss, called the interview guide, and lets the interview flow naturally from these topics. The interview guides, as well as the transcribed interviews, can be found in the appendix.

In addition, this study employs a qualitative phenomenological method to explore the relatively new phenomenon of potato-based pasta in Denmark. This approach is particularly valuable for clarifying concepts such as the roles of potato starch and potato flour, which are essential components of this emerging food product (Creswell, 2009).

Furthermore, grounded theory is integrated into the analysis to develop theories based directly on the participants' worldviews.
For example, insights gained from interviews with EatWasted will be analyzed through this lens, ensuring that the resulting theories are firmly rooted in the data (Creswell, 2009).

3.4 AFE

The AFE part of the RIN. AFE framework (for further elaboration see Chapter 1.1) stands for appropriateness, which assesses whether the methodology is suitable for this kind of research; feasibility, which refers to the likelihood of the research's implementation; and ethical, which refers to whether the research question and the way it is being researched are ethical. This

means that it should not discriminate, rule out people, etc. (Goldschmidt & Matthews, 2022). The AFE component of this framework assesses if the methodology complies with the research.

This research uses qualitative methods. As described in the methodology, case studies will be used, which are in this case qualitative, open-ended interviews, which are also a qualitative method. Combining different perspectives by using different gathering methods leads to a more nuanced perspective than when using one method only (Creswell, 2009). Therefore, the methodology is appropriate to this research.

This research examines the creation of a value chain for pasta products based on potato by-products. It is made applicable to a company that already upcycles a by-product into pasta, namely discarded bread, and wants to expand their practices into upcycling potato by-products. Collaborating with a company that was already interested in the topic of upcycling potato by-products into pasta before starting this thesis collaboration increases the feasibility. By discussing the action plan with EatWasted after formulating it, the feasibility of the results of this research increases.

The interviews are all done with consent, and this research does not discriminate. Therefore, this research can be considered ethical. Another aspect that can be argued to be ethical is the fact that this research focuses on upcycling, which is sustainable. The goal of upcycling is to deplete the earth's resources less, making it ethical from the perspective of the earth as well.

4. Theories

Theories derive from methodology and are a way to explain how the world around us works (Bacharach, 1989) (Sovacool & Hess, 2017). This chapter will start by explaining the analytical tools of this research, whereafter it shows how these analytical tools derived from certain theories.

4.1 Analytical tools

A value chain analysis will be conducted to identify and quantify potato waste within the production process. This analysis is presented in Chapter 5. This value chain analysis focuses on potential losses on the producers' side of potato production rather than the consumers' side (Zamora, 2016). This is because numbers on production waste at the producers' side can be identified in literature, and it makes it logistically more feasible for EatWasted to upcycle by-products from the producers, rather than from consumers.

A central aspect of EatWasted's approach is its sustainable practice of upcycling discarded bread into pasta. To assess both current operations and future opportunities, the Sustainable Business Model (SBM) will be used. While resembling the business model canvas, the SBM incorporates eco-social costs and benefits, thereby acknowledging the sustainability dimension of the business (Pinto, 2017). This analysis will first be used in Chapter 2, to analyse EatWasted its current practices, and later in Chapter 7, to analyse an expansion of EatWasted its practices.

An actor network analysis is used to identify (critical) actors and actants in the potato value chain, so that EatWasted knows with whom to communicate when they enter the market.
To understand power dynamics and engage in the field, it is important to know who the actors are in this field (Blasco-Arcas et al., 2020). Therefore, an actor network analysis of the actors (humans) and actants (non-humans) will be used to visualize the actors in the field.

As there is no potato-based pasta market currently in Denmark, the pasta, as well as the potato-processing market will be analysed using Porter's five forces model. This model shows the value of entering a market for a company. This way opportunities for EatWasted to enter the market are identified (Hansen, 2013).

4.2 Theories used

4.2.1 Value chain analysis

Value chain analysis originates from competitive advantage theory and supply chain management theory. The supply chain management theory shows the flow of materials in a supply chain, and the competitive advantage theory focuses on how bigger companies can have a bigger competitive advantage on the market compared to smaller companies, as bigger companies have a higher disposal of cash flows than smaller firms (Zamora, 2016).

In this thesis, the value chain analysis will be depicted from 'farm to fork' (from the moment the potato is farmed, to the moment it ends up on the consumers' plate) (Kiran et al., 2023), in Chapter 5.2.2. The value chain analysis here is used to identify the part of the value chain that this research is focused on.

4.2.2 Actor-network analysis

Actor-network analysis originates from the actor-network theory. A table is created to analyse the current actors and actants on the potato-processing market, and it states the different actors that would enter the market if a potato-based pasta product market were created. By showing these actors and the relationship to their actants, the interests of the actors are represented to a certain extent (Storni, 2015).

The actor-network analysis is explained in Chapter 7.3 and is used in this research to identify actors that EatWasted has to consider collaborating with if they want to expand their practices into producing pasta from upcycled potato waste. This analysis also shows the difference between the current players in the field and the 'future' (expansion of practices) players in the field. This way, EatWasted can see which actors need to be taken into account when transitioning.

4.2.3 Sustainable business model (SBM)

The SBM describes partners, activities, resources, propositions, relationships, channels, customer segments, and structure; it is no surprise that this analytical tool finds its origin in multiple theories. A review conducted by Pinto (2017) shows that this tool originates from the resource-based view or natural-based resource view, showing which resources are used by the company; institutional theory, showing how the different interactions from the company relate to society; and stakeholder theory, which is similar to actor-network theory (Pinto, 2017).

In this thesis, the SBM will be used to analyse the current practices of EatWasted in Chapter 2.2, and in Chapter 7.1 and 7.2, it is used to analyse the 'future' (expansion to upcycling potato by-products) of EatWasted. This way, an action plan can be created for EatWasted to see what is needed to expand their practices.

4.2.4 Porter's five forces

Porter's five forces model shows how the threat of new entrants, the threat of substitute products, the bargaining power of the buyer, and the bargaining power of suppliers lead to rivalry amongst existing firms. This model shows whether it is profitable to enter a market. Since this model consists of many different elements, different theories contributed to this model. The rivalry amongst existing firms, for example, can be explained using game theory. The industrial organization economic theory, microeconomics theory, and strategic management theory all contribute to explaining the dynamics within an organization regarding the market (Yu, n.d.).

Porter's five forces model is being used as an analytical tool in Chapter 7.4. This model, in combination with the actor-network analysis, emphasizes the importance of collaborating with certain actors for EatWasted.

Table 2 summarizes the theories that have been used in this research, and the analytical tools that derive from these theories.

Theories	Analytical tools	Described in
Supply chain management theory	Value chain analysis	Chapter 5
Actor-network theory	Actor network analysis	Chapter 7
Resource-based theory, Institutional theory, Stakeholder theory	Sustainable business model canvas	First used in Chapter 2.2 to describe EatWasted their current practices, then analysed in Chapter 7
Industrial organization economics theory, Microeconomic theory, Game theory, Strategic management theory	Porter's five forces	Chapter 7

Table 2 Theories used

5. Conceptual description of the potato value chain

Two products from the potato value chain are potato flour and potato starch. While there are additional products along the potato value chain, potato flour and potato starch serve as potential ingredients for potato-based pasta. Therefore, the following section will explain potato starch and potato flour.

This explanation of the difference between potato flour and potato starch should also help in understanding the potato value chain better, as potato flour and starch are two main ingredients in this value chain. A state-of-the-art gives an overview of current developments in potato-based pasta products in Denmark and Europe will be presented.

5.1 Potato flour vs. potato starch

Potato starch is extracted from the potato, while the flour is made by milling the whole potato into flour (Boyette, 2022).

5.1.1 Processing of potato starch

Potato starch is extracted from potato pulp, which is produced by washing the potato, optionally peeling the potato after this step, and rasping it into pulp. This is called the grinding phase (BeMiller, 2009). The different parts of the potato are separated into juice, fibre, and starch in the potato juice and fibre extraction phase. The starch gets further refined in the classification and refinery phase, and as the last step, the water gets removed to ensure the starch is free of water.

Figure 7 summarizes these phases.

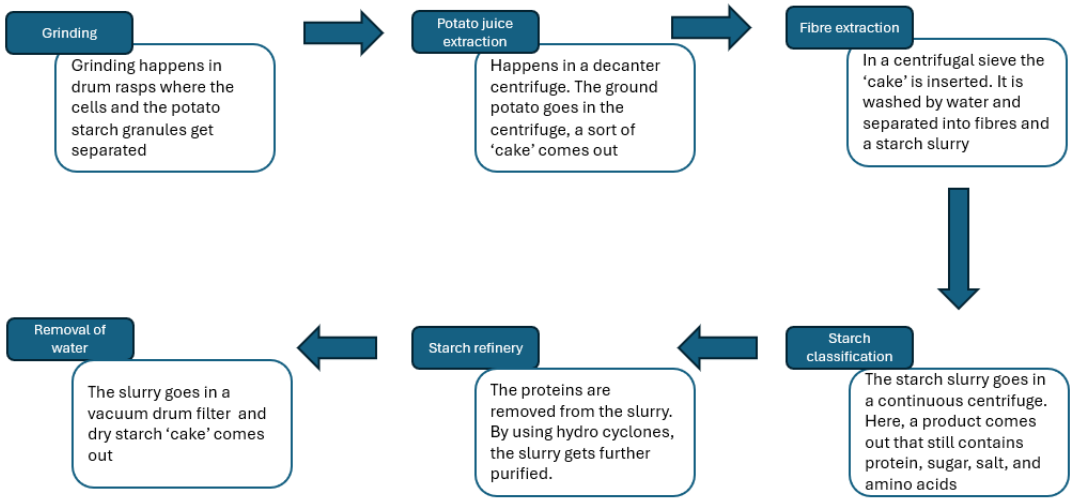

Figure 7 Different phases of the potato Starch Extraction

Cull potatoes—those that are unsuitable for sale due to their size or minor imperfections (Manthey, 2015)—are frequently utilized for starch extraction. By incorporating these otherwise discarded potatoes into the production process, it could be argued that the production of potato starch, using cull potatoes, is considered to be sustainable.
However, it is important to note that most likely not all cull potatoes are currently used for starch production, as there is still waste present at the production site (Tackling Root Causes of Food Loss in the Potato Supply Chain, 2024) (Willersinn et al., 2015). For further elaboration, see Chapter 5.2.3.

Typically, potato starch serves as a thickening or binding agent in various recipes (Dupuis & Liu, 2019). Additionally, online potato noodle recipes indicate that potato starch possesses appealing baking properties, allowing it to effectively replace wheat flour in certain applications.

5.1.2 Processing of potato flour

The production of potato flour typically involves several essential steps. Although the exact process may vary slightly depending on the method employed (Lingling et al., 2018), the general procedure is as follows:

1. **Cleaning:** The potatoes are thoroughly washed to remove dirt and impurities.
2. **Peeling:** Removal of the potato skin
3. **Conversion to Flour:** The peeled potatoes undergo a sequence of operations, including cooking, cooling, and drying, before being blended into a fine flour.

This structured approach ensures that the potatoes are transformed efficiently into high-quality flour while maintaining consistency throughout the process.

In 2018, Lingling et al. conducted a review of different preparation methods of products with potato flour, such as steamed/regular bread and noodles. In all these cases, potato flour was used to enhance the quality of the dough rather than to substitute for the other flour 1:1. Therefore, this would mean that potato flour does not have any baking properties and needs to be mixed with other flours to ensure a bakeable product.
Moreover, Preedy et al. (2011) suggest in their book 'Flour and Breads' that potato flour is used as a flavour, structure, or texture enhancer and that even gluten-free potato bread is not entirely made of only potato flour, but should be complemented by another flour, such as rice flour.
Next to that, the book stated that in 2011, the number of people in the world who have celiac (not being able to handle gluten) (Caio et al., 2019) would increase over the next years. Therefore, using potato flour might increase in popularity (Preedy, 2011), and therefore, using potato flour in different applications, is made more attractive.
The benefits of potato flour and potato starch are similar. Both of these products have proven health benefits, such as weight loss and blood sugar regulation (Preedy, 2011).

5.1.3 Difference between potato flour vs. potato starch

When purchasing potato flour in a Danish supermarket, no clear distinction between potato flour and potato starch is made, as the 'Kartoffelmel' (potato flour) in Figure 8 from NFP contains 100% 'kartoffelstivelse' (potato starch). Other Danish sources state that no distinction is made for the consumers when purchasing this product (Hansen, 2024). It is unclear why this is the case.

A distinction is made, however, in literature, and at the producers' side, between potato flour and starch, as these are two different products.

Figure 8 Store bought potato flour/starch

5.2 State of the art

Having explained the difference between potato flour and potato starch might help in understanding the usage of by-products of the potato value chain in Europe. This part of the research can be seen as part of the first diamond, see Chapter 2.1.

5.2.1 Pasta trends in Denmark and worldwide

Pasta has gained popularity over the years due to its convenience, price, and high fibre content (Bresciani, Pagani, et al., 2022). In Denmark, pasta is currently among the most consumed cereal products (Wendin et al., 2020).

In 2008, the Danish whole grain partnership was established, which focused on getting Danes to eat more Wholegrain products (Greve, 2014). This can be seen as a result of the rising health awareness amongst consumers (Chatham, 2015). Sustainability and the climate have also become a topic of growing interest for consumers.

An example of this increasing awareness can be seen in the production of pasta nowadays, using pulses (Bresciani, Erba, et al., 2022). Pulses are nutritious, as well as climate-resilient, as a crop, and they diversify the agri-food systems (Choo, 2025).

5.2.2 Potato production, waste, and consumption in Denmark

The potato value chain includes seed traders, who trade in seed potatoes (the potatoes that get planted in the ground), see Chapter 5.2.3.

Farmers farm the potato, distributors transport the potatoes to different factories. The potato gets distributed either to a processor or a wholesaler. The wholesaler sells the potato directly to the retailers, and the potato processor processes the potato before selling the product to the retailer. The retailers sell the product to the supermarkets and restaurants, and this is how the potato eventually ends up on the plate of the consumer (Devaux et al., 2021) (Smit et al., 2008) (Esbjerg, 2015).

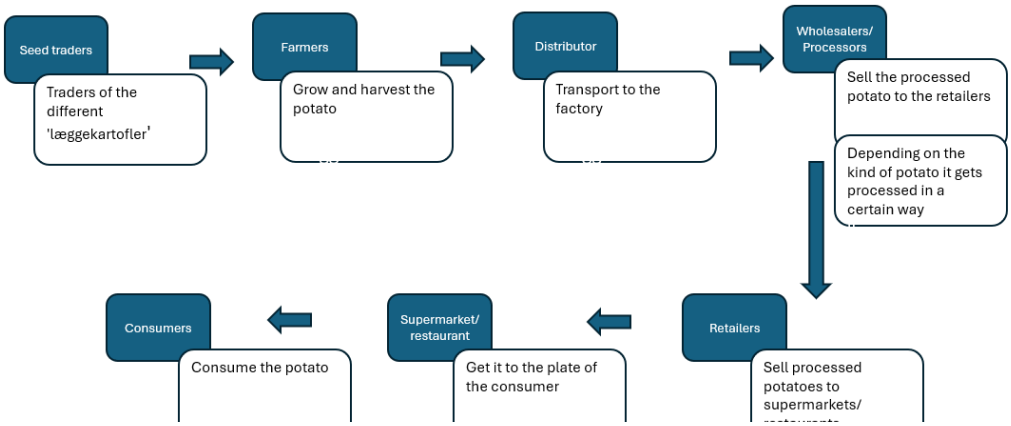

Figure 9 Potato value chain

5.2.3 Potato production, waste, and consumption in Denmark and Europe at the production side

Potatoes are an important crop worldwide. A distinction between the production and consumption of potatoes must be made, as not all potatoes that are produced are used for the same applications, as can be seen in the report from Danmarks Statistik (2024).

In 2024, agricultural land in Denmark was divided into three main categories for potato production: 'Læggekartofler' (seed potatoes), 'Industrikartofler' (industrial potatoes), and 'Spisekartofler' (potatoes for direct consumption). Only 7.69% of arable land was dedicated to the production of 'spisekartofler', with the majority being used for seed and industrial purposes."

According to the CSR report of KMC, which is a potato innovation centre in Jylland, for the year 2024/2025, the potato cultivation accounts for 2% of Danish agricultural land.

As more and more people have started to switch to a 'convenient' diet, a diet where consumers consume easy-to-prepare food, the demand for frozen French fries has increased. Thus, the potato production over the years has also increased in Denmark (Devaux et al., 2021).

Spillage occurs in the potato value chain due to several factors, which include improper storage conditions, incorrect labelling, damage during transportation, improper drying, and potatoes not fulfilling the quality standards (Schuler, 2017). The specific by-products that occur in this value chain can differ, depending on the way of processing, and these products can be edible, such as wasted potatoes, or inedible, such as stones that occur during the dumping process of the potatoes (Laus. Pers. Comm., 2025).

To make chips from potatoes, the potatoes need to fulfil specific requirements as the starch percentage of the potato cannot be too high (Laus, Pers. Comm., 2025). Therefore, there are often a lot of wasted potatoes in the chips production (Willersinn et al., 2015).

When producing fries, the potato gets cut into long vertical strips. During this cutting process, the potato naturally releases starch, along with other organic compounds (Chauhan et al., 2023) (Oei. Pers. Comm., 2025), which ends up in the processing water. This starch can be regained from the processing water as side-stream starch, whereafter it has the potential to be used as potato starch in pasta production. Because this thesis focuses on the ingredients potato flour and potato starch for pasta production, other organic compounds that end up in the processing water will not be discussed in further detail.

Currently, potato waste (PW) has different applications, such as the usage for biofuel or the usage as animal feed (Chauhan et al., 2023).

This thesis will, however, focus on the waste generated in the potato value chain at the producers' side that can be made suitable for upcycling for human consumption into pasta

products. This because it is logistically more feasible for a company to upcycle by-products of the potato value chain that occur at the producers' side, rather than the consumers' side.

5.2.3 Usage of potato by-products in Denmark and Europe

In Denmark, AKV and KMC, both potato innovation centres in Jylland, are currently extracting starch from potatoes. They use industrial potatoes to extract potato starch (Hashim, 2023). KMC modifies the potato starch and sells it to companies so they can use it in soup, for sauce, noodles, pasta, and for protein fortification.

Avebe is a Dutch company, similar to KMC, and modifies starch to be used for different applications, such as usage for human consumption, animal consumption, and industrial applications (*Avebe*, n.d.). This company collaborates with KMC on some projects, and Marc Laus, innovation manager at Avebe, stated in an interview that Avebe collaborates with other potato innovation centres as well (Laus, Pers. Comm., 2025). Therefore, it could be concluded that there is cross-border collaboration between the different countries in Europe regarding potato innovation.

A Belgian company, Agristo, makes potato flakes from leftover potato parts, after cutting fries, and sells these potato flakes to companies in Italy that make gnocchi out of these flakes, stated Kristof Wallays (Pers. Comm., 2025).

When making these fries, starch is naturally released in the processing water of Agristo. The company Duynie produces side-stream starch (Oei. Pers. Comm., 2025), that is extracted from the processing water of potato processors. It should be noted that side-stream starch has a lower yield (1.2-2%) compared to extracting starch from the whole potato (20%), stated Christiaan Oei (Pers. Comm., 2025), sales manager at Duynie, in an interview.

6. Production process differences between potato-based pasta and wheat pasta

EatWasted currently produces pasta from upcycled bread. A mixture of breadcrumbs and semolina flour (Tomarelli, Pers. Comm., 2025), is used for pasta production. This production method might differ from potato-based pasta production. Thus, if EatWasted wants to expand its practices into upcycling potato by-products, it is important to know if a change in the production process is needed to realize this. That is why the following chapter discusses *'To what extent can potato-based pasta be made from the same processing plant as wheat pasta?*

This chapter starts by describing the process of starch noodle production and the process of wheat-based pasta production. After this, it discusses the differences between these two production processes and describes the possibilities for waste valorisation. Potato flour and potato starch are two ingredients that could be used in this upcycling of potato by-products into pasta.

The Chapter ends with two recommended pathways that EatWasted can follow when expanding its practices.

6.1 Starch noodle production

Figure 12 applies to the production of starch noodles. Thus, this would be likely to be the production process that EatWasted needs to follow when producing potato starch pasta products.

However, if EatWasted decides to use potato starch for the production of pasta products, they can also research ways to produce this pasta according to another method.

The starch first gets isolated to form the dough. Dropping refers to mixing the dough in a sort of extruder. The dough ball that will be formed in the end is extracted from the extruder (Tan et al., 2009). After this, the noodles are hung, frozen, thawed, and dried, before they undergo the selection process and end up in the supermarket.

Starch noodles have been produced in East Asia according to the traditional method as depicted in Figure 10 (Tan et al., 2009).

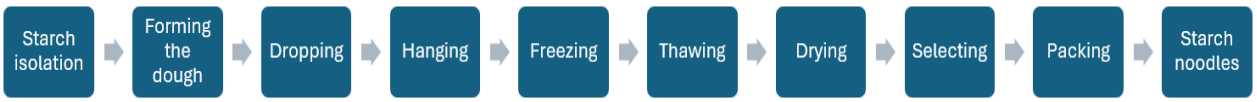

Figure 10 Starch noodles process Adapted from (Tan et al., 2009)

6.1.2 What should be taken into account regarding potato starch noodles?

Gluten acts as a binding agent in pasta production (Marti & Pagani, 2013). However, because of the large granule size of the potato starch and the water retention capacity of this starch, the gelatinization of this potato starch leads to a firm, elastic noodle structure (Bangar et al., 2023) . Nevertheless, overcooking and incorrect drying can impact the firmness and elasticity of the noodle (Kang et al., 2017).

Some studies suggest that heat treatment of the potato starch can make the production process easier. When heat treating the potato starch, it has the potential to be processed in the same way as wheat-based pasta (see Chapter 6.2) (Saini et al., 2023).

6.2 Wheat-based pasta processing

Pasta comes in many shapes (Tolentino, 2024). The traditional wheat that is used for pasta is durum wheat (Sissons, 2022). However, other (wheat) flours are also suitable for making pasta.

Figure 11 explains the traditional way of producing wheat pasta. First, the dough is formed by mixing and kneading. After, the pasta is pushed through the extruder to create different kinds of shapes. Then the pasta is hung on trays to dry (Tomarelli, Pers. comm., 2025). Depending on the factory, this drying can happen in drying chambers, where the pasta needs to be rotated once in a while (Gong, 2024).

Figure 11 Wheat pasta-making process adapted from (Chen, 2024)

6.2.2 What should be taken into account regarding potato flour production?

Since potato flour does not have any baking properties (Lingling et al., 2018), meaning that a mixture of another type of flour and potato flour needs to be used to produce pasta with, there would not be any difference in the production method of this type of pasta and wheat-based pasta, if semolina flour is added to the mixture with potato flour, to produce pasta with.

6.3 Possibilities for waste valorisation at the producers' side

Potato flour and potato starch form two potential ingredients for the upcycling of potato by-products into pasta. Now that this has been established, it is important to find out where in the

potato value chain there are options to create potato flour or potato starch from by-products of the value chain.

After the potato has been farmed, the potato can either end up at the wholesaler or at a potato-processing factory. This thesis will examine the waste that is produced at the production side (wholesaler/potato-processor), since this is more feasible, logistical-wise, for another company to upcycle the by-products from a producer than from a consumer.
According to a case study report by the Pacific Coast (2024) on Lamb Weston (a potato-processing company in the Netherlands), 21-38% of potatoes are discarded during the processing stage. Comparing this to a case study conducted in Switzerland, which states that the waste at the production site is between 9 and 35% (Willersinn et al., 2015). Based on the number from these countries in Europe, and because no literature can be found on the waste percentage at the Danish production site, it could be assumed that the waste at the Danish production site in the potato value chain is most likely between 9 and 38%.
Especially when looking at waste in specific production, such as chips production, it is known that the specific requirements potatoes have to fulfil are quite high, and therefore a lot of potatoes end up as waste (Willersinn et al., 2015).
At the wholesalers' side, there are also a lot of potatoes that go to waste, since these potatoes are directly sold to the supermarkets/restaurants, and therefore need to be perfect for consumption (Esbjerg, 2015).
Thus, wasted potatoes at the potato processor/wholesaler are one possibility for upcycling by-products.
Another part of the potato waste is the organic compounds that end up in the processing water of potato producers, such as the starch and other organic compounds, that are naturally released from the potato when cutting fries.
This thesis will focus on the starch that ends up in the processing water, as this is potato starch, and therefore, it has the potential to be used in potato starch pasta products. This starch, side stream starch can be removed from the process water using hydro cyclones (Oei, Pers. Comm.,2025). It should be noted that side stream starch has a lower yield (1.2-2%) than when extracting starch from a whole potato (20%) (Oei, Pers. Comm., 2025) (Laus, Pers. Comm., 2025). However, as Duynie has a collaboration with over 100 companies in Europe, and extracts the side stream starch from the processing water of all these companies, a collaboration with Duynie is a possibility to have enough potato starch for a base of a pasta product.

6.5 Possible pathways for EatWasted to follow and considerations

As this thesis started with the research question *'To what extent can potato-based pasta products be produced in Denmark?'* The pathway that was considered to be relevant to this research was:

Producing potato-based pasta products from potato starch

A collaboration with EatWasted led to pathways that focused more on waste valorisation of by-products of the potato value chain.

Considering the state-of-the-art, the opportunities for waste valorisation, and the variations in production methods—since these factors must be accounted for when evaluating the feasibility of pursuing a specific pathway—paths begin to emerge.

A pathway that was considered was producing starch from potato peels, literature supported that this was possible (Ahmad, 2024). However, Duynie, a company based in the Netherlands that extracts side-stream starch, states that it is difficult to extract starch from potato peels (Oei, Pers. Comm.,2025). This is because a potato contains soluble and insoluble starches and the starch that can be found in the peels is insoluble, which makes it harder to free the starch from the peel.
As Duynie is a company that extracts side-stream starch from a lot of companies their processing water, the total yield of these starches is high enough to use for EatWasted as a pasta product base (Oei, Pers. Comm. 2025).

The two proposed pathways that EatWasted could follow are

1. **Making potato flour from leftover potatoes. These potatoes can either be left over from the fresh potato production or the industrial production**
2. **Starting a collaboration with a company like Duynie that produces side stream starch. This side stream starch can then be used to produce pasta.**

7. What is needed for EatWasted to expand its practices to upcycling potato by-products?

This chapter will analyse the changes that are needed to realise the expansion of EatWasted their practices into upcycling potato by-products into pasta, according to the different pathways that are described in Chapter 6.5.

These two pathways will be analysed in Chapters 7.1 and 7.2, using the sustainable business model (SBM) canvas.
Using this SBM to analyse EatWasted their current practices, done in Chapter 2.2, and comparing it to the expansion of upcycling by-products from the potato value chain into potato-based pasta products, shows what EatWasted needs to expand their practices, contributing to the formulation of an action plan.

Furthermore, the current and 'future' actants and actors, the potato-processing, as well as the pasta market, will be analysed to identify opportunities for EatWasted, and this will be shown in Chapter 7.3. This actor network analysis shows EatWasted, which actors are important to take into account when expanding their practices.

Porter's five forces model will be used in Chapter 7.4 to analyse the potato processing and pasta market, and recognize potential barriers and opportunities on these markets.

All these analyses lead to recommendations/considerations that lead to an action plan for EatWasted. These will be discussed in Chapter 7.5. The action plan will be discussed in the discussion.

7.1 Proposed changes, pathway 1

In pathway 1, EatWasted would collect potatoes from potato-processors/ wholesalers that did not fulfil the selection requirements, and mill those into flour.

Potato flour does not have any baking properties (Lingling et al., 2018) (Preedy, 2011). Meaning that the semolina flour that EatWasted currently uses for the production of pasta would still need to be used for the production of potato flour pasta, as this needs to be combined with the potato flour to create a mixture to produce pasta with.
Potato-based pasta produced this way would contain about 20% potato flour and 80% semolina flour (Preedy, 2011). Thus, the product is not 100% made of gluten-containing flour. Therefore, EatWasted can advertise the product as gluten-reduced, attracting consumers who want to eat gluten-reduced products. However, there is no internationally recognized symbol for gluten-reduced products, only for gluten-free products (*GFCO.Org*, n.d.). Thus, the only way that EatWasted can market this as gluten-reduced is by explaining this on the back of the product. Nevertheless, this text might be less appealing than a symbol.

Discarded potatoes at the potato-processor/wholesaler currently go to the farmers to be used as animal feed, and these farmers pay a certain price for them. Therefore, it is most likely that EatWasted also has to pay a slightly higher price than the farmers, to make it attractive for the potato-processor/wholesaler to sell to EatWasted.

Logistically, EatWasted currently has a collaboration with an industrial bakery located in Copenhagen, and the pick-up is being done by an electric van. As found online, most of the potato processors and wholesalers are located in Jylland, and the radius of the electric van might not be sufficient to drive from Jylland to Copenhagen. Therefore, EatWasted might have to consider investing in a hybrid or a diesel truck, as these often have a higher range than electric. As this would mean there would be more emissions, switching to a different sort of vehicle might bring bigger eco-social costs with it.
As EatWasted currently outsources the milling of the bread into breadcrumbs, it is most likely that they would also outsource the milling of the potatoes into flour.

Figure 12 shows these proposed changes in red. The baseline scenario is being shown in black.

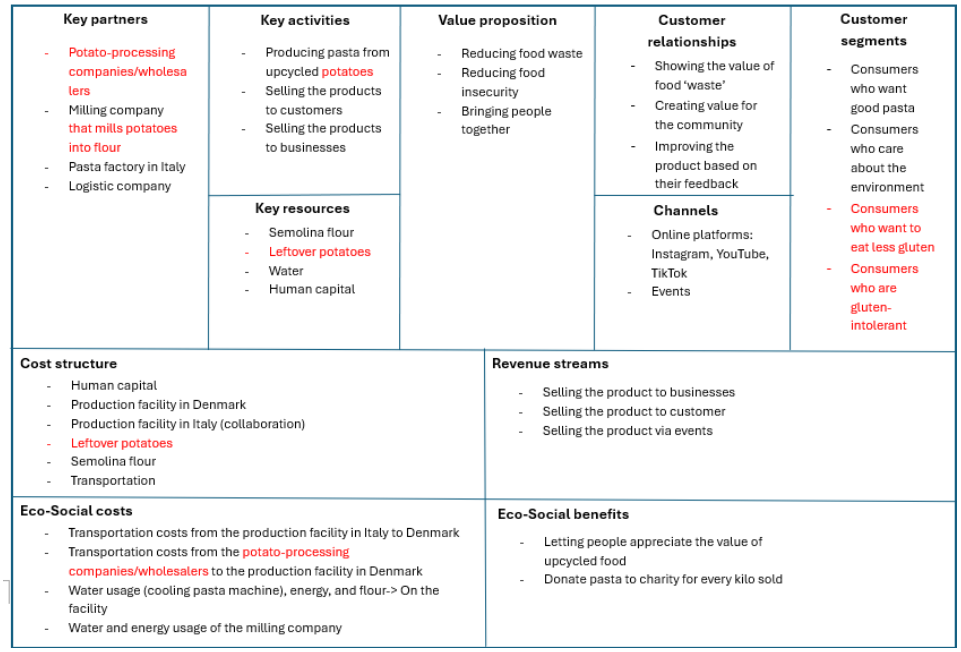

Figure 12 Proposed changes SBM, scenario 1

7.2 Proposed changes, pathway 2

In pathway 2, EatWasted would start a collaboration with a company that produces side stream starch, like Duynie, and upcycle this into potato pasta.

Potato starch has baking properties, and therefore, semolina flour would no longer be needed in this process (Meacham, 2023). Thus, gluten-intolerant and celiac consumers can be added to the customer segment.
However, if EatWasted wants to add celiac consumers or gluten-intolerant consumers to their customer segment, it is of paramount importance that they ensure that there is no cross-contamination (by either cleaning the production facility before producing the gluten-free pasta or setting up a separate production line). This is not of paramount importance for EatWasted (Tomarelli, Pers. Comm., 2025), but as the entry point of this thesis was to find an alternative to rice noodles, it is something to consider during the different pathways.

As side-stream starch is a by-product of the potato value chain, it has a lower yield than when the potato starch is extracted from the whole potato. When interviewing Duynie, which is a company that produces side stream starch, based in the Netherlands, Oei (Pers. Comm., 2025) stated that the yield of side-stream starch is 1,2-2%, compared to extracting starch from the whole potato, where the yield is around 20% (Laus, Pers. Comm.,2025).
Even though it might probably be possible to produce potato-based pasta products this way, Oei (Pers. Comm., 2025) stated in an interview that these pasta products cannot be produced according to the traditional starch noodle production, as discussed in Chapter 6.1, this is because the viscosity of this side stream starch is not high enough (Oei, Pers. Comm., 2025). Therefore, EatWasted needs to find a different way of producing potato-based pasta products using the side stream starch, rather than using the traditional starch noodle production method.

Figure 13 shows the changes needed for scenario 2, displayed in blue.

<table>
<tr>
<td>Key partners
- Potato-processing companies/wholesalers
- Starch extraction company, maybe Duynie
- ~~Milling company that mills potatoes into flour~~
- Pasta factory in Italy
- Logistic company</td>
<td>Key activities
- Producing pasta from upcycled potatoes
- Selling the products to customers
- Selling the products to businesses
Key resources
- ~~Semolina flour~~
- Water
- ~~Leftover potatoes~~
- Human capital</td>
<td>Value proposition
- Reducing food waste
- Reducing food insecurity
- Bringing people together</td>
<td>Customer relationships
- Showing the value of food ‘waste’
- Creating value for the community
- Improving the product based on their feedback
Channels
- Online platforms: Instagram, YouTube, TikTok
- Events</td>
<td>Customer segments
- Consumers who want good pasta
- Consumers who care about the environment
- Consumers who want to eat less gluten
- Consumers who are gluten-intolerant
- Consumers with celiacs</td>
</tr>
<tr>
<td colspan="3">Cost structure
- Human capital
- Production facility in Denmark
- Production facility in Italy (collaboration)
- Collaboration with Duynie
- ~~Leftover potatoes~~
- Transportation</td>
<td colspan="2">Revenue streams
- Selling the product to businesses
- Selling the product to customer
- Selling the product via events</td>
</tr>
<tr>
<td colspan="3">Eco-Social costs
- Transportation costs from the production facility in Italy to Denmark
- Transportation costs from the side stream starch company to the production facility in Denmark
- Water usage (cooling pasta machine), energy, and flour
- Water and energy usage of the potato starch extraction company, Duynie</td>
<td colspan="2">Eco-Social benefits
- Letting people appreciate the value of upcycled food
- Donate pasta to charity for every kilo sold</td>
</tr>
</table>

Figure 13 Proposed changes in SBM, scenario 2

7.3 Actor- network analysis

The Actor-network analysis shows the actors (humans) and actants (non-human actors) in the playing field. To understand power dynamics, predict outcomes, and engage in the field, it is important to know who the actors are in this field (Blasco-Arcas et al., 2020).

In the current field, the potato value chain starts at the seed traders (**actors**), who trade in seed potatoes (**actants**). These potatoes (**actants**) get planted by the farmers (**actors**). Some failed harvest (**actants**) go to the livestock farmers (**actors**), to be used as animal feed (**actants**).
The potatoes that were harvested well (**actants**) go to the potato-processor and wholesalers (**actors**). The processed products (**actants**), or the whole potatoes from the wholesaler (**actants**), will be sold to retailers (**actors**) who will sell these products (**actants**) to the food companies, such as restaurants or supermarkets (**actors**).
Moreover, consultant companies (**actors**) advise farmers (**actors**) on the best way to grow the potatoes, as well as the processing companies (**actors**) on ways to best process the potato and what technique(s) (**actants**) to use. R&D (**actors**) also researches in this field to see how to improve production methods.

When EatWasted (**actor**) expands their practice into upcycling by-products (**actants**) of the potato value chain, they have to establish a collaboration with a wholesaler or a potato processor (**actors**), if choosing pathway 1. As EatWasted (**actor**) will produce pasta, they have to compete with pasta producers (**actors**) in both pathways.
To process these potatoes into flour (**actant**), EatWasted (**actor**) needs to collaborate with a milling company (**actor**) that can mill the potatoes (**actant**) into flour, in pathway 1. If EatWasted (**actor**) were to go for pathway 2 where they would produce pasta products (**actant**) from side stream starch (**actant**), they need to establish a collaboration with a side stream starch extraction company (**actor**).
Furthermore, this expansion requires a collaboration with AAU (**actor**), for both pathways, as this thesis was written by a student from AAU about the expansion of EatWasted (**actor**).

Table 2 shows the actors and actants in the current field, these are shown in black, and the actors and actants needed to expand the practices, these are shown in green.

Actors	Actants
Consultant companies	(human) capital
Potato-processing companies	Potato waste, wasted potatoes, (human) capital, processed potato product
Wholesalers	(human) capital, potatoes, wasted potatoes
Agricultural farmers	(Failed) harvested potatoes, land, and farming equipment
Seed traders	Seed potatoes
Livestock farmers	Animal feed
Food safety authorities	Food safety law
R&D	(human) capital
Consumers	Cooking equipment, money
Retailers	(human) capital
Food companies	(human) capital
Pasta-processing companies	Pasta making equipment, (human) capital
EatWasted	Pasta-making equipment, wasted potatoes, (human) capital, pasta products
Side-stream starch extraction company/milling company	(human) capital, (wasted) potatoes
AAU	Laptop, phone
Distributors	Trucks, bikes

Table 3 ANT analysis of the current field

7.4 Porter's five forces

Porter's five forces model shows five competitive forces that balance competition and profitability in a market. This way, a company can determine whether it is attractive to enter a new market (Porter, 2008). In the case of EatWasted, this could be considered the last step for EatWasted to determine whether they want to enter the market or not, and start producing potato-based pasta products.

These 5 forces are (Hansen, 2013)

- Rivalry amongst existing firms-> Size of competitors, number of competitors, industry growth, and exit barriers play a role
- Threat of new entrants-> Economies of scale, customer loyalty, capital requirements, cumulative experience, government policy, and access to distribution channels make up the entry barriers
- Threat of substitute products-> number of substitutes, buyers' willingness to substitute, and price performance trade-offs determine the threat of these products
- Bargaining power of suppliers-> number of suppliers, supplier concentration, strength of distribution channels, and uniqueness of the product are all factors
- Bargaining power of buyers-> loyalty programme and product differentiation determine how well the suppliers can bind the buyers to their company

In a perfect competitive market, there is enough rivalry to secure prices that are not too high, it should be easy to enter, customers should easily be able to substitute one product for the other, there should be several suppliers to choose from, and there should be several buyers (Dobbs, 2014). The perfect market secures profit for companies and a price that is not too high for consumers. In practice, this means that there are multiple companies to choose a product from. The term perfect market could be seen as controversial, as the market does not need to be perfect for it to be a good market. For example, exit or entry barriers might secure invested players in the field.

Since Denmark does not produce potato-based pasta yet, but they do process potatoes and produce pasta, the potato-processing market and the pasta market will be analysed according to Porter's five forces. Even though there are starch noodle markets in Asia, these market characteristics might not be the same as in Denmark.

7.4.1 The Danish pasta market

When researching the internet, one can find around 10 players in the pasta-producing field in Denmark (Kompass, n.d.). The interview with EatWasted concluded that entering the pasta market as a big player can require large investments in a production facility, but entering the pasta market can also be done while having a small production facility. Making the threat of new entrants high.

By producing different types of pasta, using different flours, brands can differentiate. Since most pasta companies do not have loyalty programmes to bind their customers to them, it is easy for the consumer to switch brands, making the bargaining power of buyers low.

As there are many different distribution channels for pasta, and the pasta producers are spread out across Denmark, the bargaining power of suppliers is medium.

Pasta is considered to be a convenient food, as it is easy to prepare (Bogard et al., 2024), making it easy to substitute pasta with other ready-to-eat meals, making the threat of substitute products high.

According to Dobbs (2014), because the bargaining power of buyers is low, the rivalry is medium, the bargaining power of suppliers is medium, the threat of substitute products is high, and the threat of new entrants is high, the pasta market can almost be considered a market with perfect competition.

The Danish pasta market, according to Porter's five forces, is analysed in Figure 14.

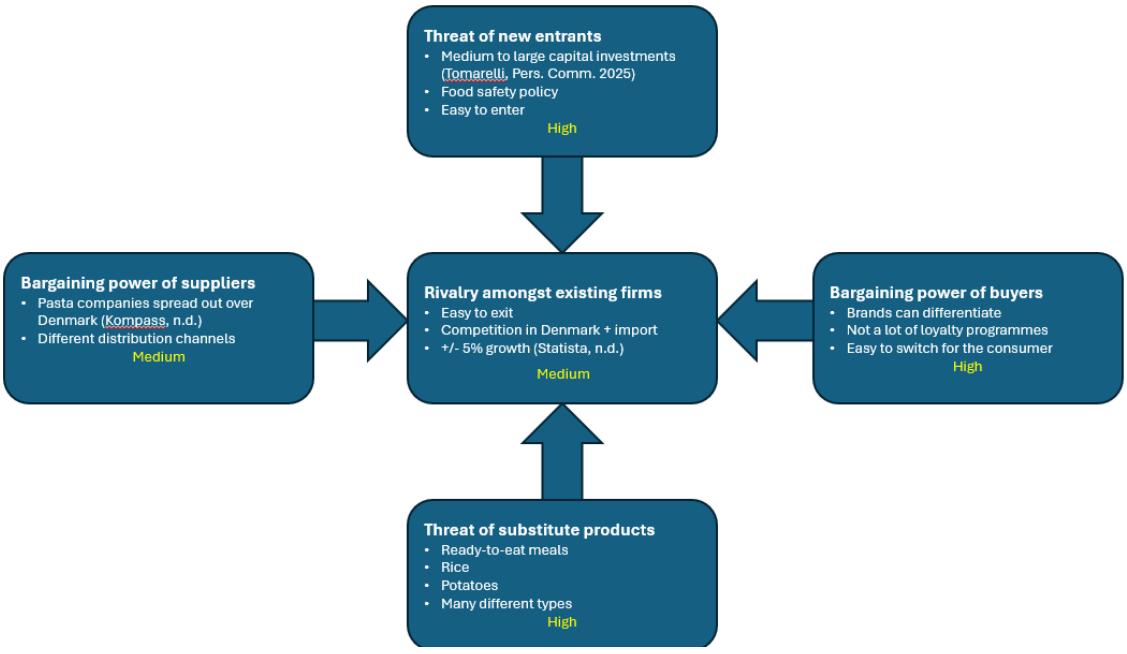

Figure 14 Porter's five forces of the Danish pasta market

7.4.2 The Danish potato-processing market

Danish consumers are moving towards a healthier diet (Choo, 2025). This often means that the consumers are consuming less processed food. However, consumers still want convenient meals, which are easy to prepare, such as French fries, which is why the Danish potato-processing market is still growing (Devaux et al., 2021).

Nevertheless, as consumers are also moving towards healthier diets (Choo, 2025)Investments need to be made by potato processors to improve their production method and make it healthier, such as by adding extra proteins. These big investments create a barrier to enter. Next to that, Smit et al. (2008) state in their paper that potato processors often have long-term contracts with their farmers, making it difficult to exit. Therefore, the threats of new entrants are medium.

As there are many different products to choose from on the potato-processing market, and there are also healthy alternatives to processed potato products widely available, the threat of substitute products is medium.

Analysing the Danish potato-processing market according to Porter's five forces model led to the following model.

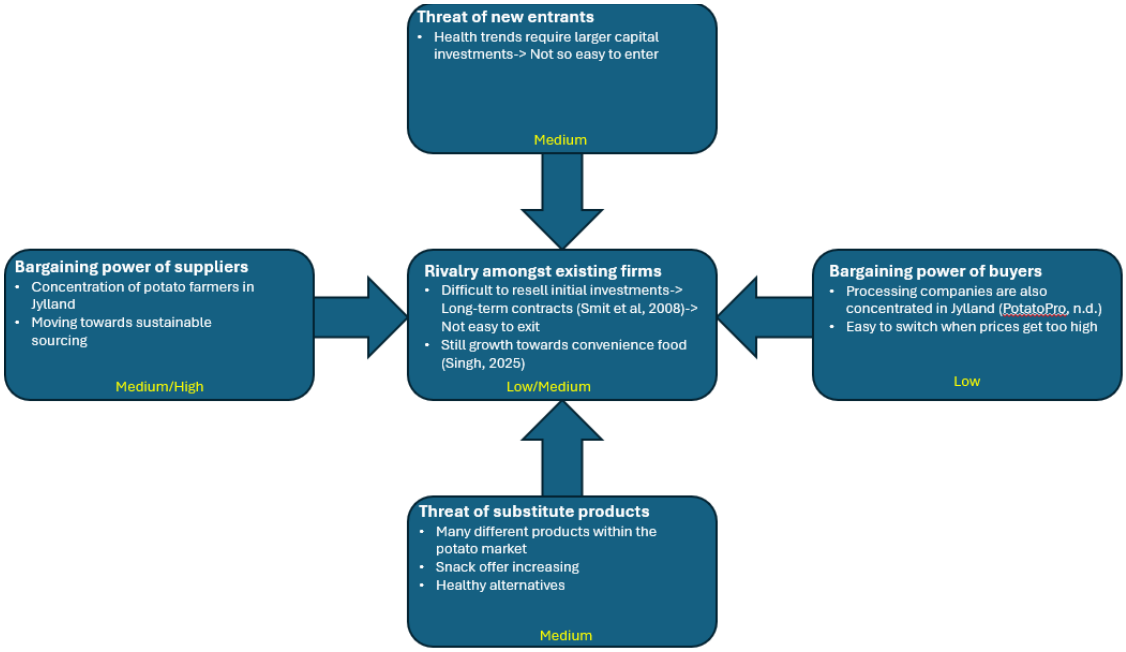

Figure 15 Porter's five forces of the Danish potato-processing market

7.5 Considerations

Currently, EatWasted is picking up the discarded bread from an industrial bakery in Copenhagen. After picking up the bread, they are bringing the bread to a mill in Copenhagen, where it gets milled into flour. From this flour, pasta is produced in their production facility in Copenhagen.

If they were to expand their practices into upcycling by-products of the potato value chain, they would have to collaborate with a potato processor or wholesaler to pick up the potato waste. These potato-processors or wholesalers are mostly located in Jylland (Google Maps, n.d.), meaning that the distance EatWasted has to cover to pick up the waste will be much longer than when the pick-up location would be in Copenhagen. The pick-up in Copenhagen is done by an electric van, and since electric vehicles usually have a lower radius than hybrid or diesel (Alanazi, 2023) EatWasted might have to consider investing in a hybrid or diesel van for the pick-up in Jylland.

In both pathways, EatWasted has to establish a collaboration with a player in the potato field. In pathway 1, EatWasted has to establish a collaboration with a potato-processor or wholesaler, and in pathway 2, they have to establish a collaboration with a producer of side-stream starch. Establishing a collaboration is not only important to collect usable by-products to upcycle into pasta products, but it is also considered to be important based on Porter's five forces model of the potato-processing market, because entering the potato processing market is difficult, collaborating with an established player in the field makes it easier to enter the market.

Choosing pathway 2 means that EatWasted has to establish a collaboration with a big producing company of side-stream starch as the yield of side-stream starch is much lower (1.2-2%) (Oei, Pers. Comm., 2025), compared to extracting starch from the whole potato (+/- 20%) (Laus, Pers. Comm., 2025). As far as can be found online, Duynie is currently the only company in Europe that produces side-stream starch. Therefore, EatWasted is bound to collaborate with them, or another big producer of side-stream starch in Europe, if they want to produce pasta from side-stream starch.

If EatWasted were to go for pathway 2, they would have to consider that if they want to market the pasta as gluten-free, they need to clean their production facility before producing, or set up another production line that only produces this gluten-free pasta to ensure there is no cross-contamination (Barbaro et al., 2018).

8. Discussion

The main research question for this thesis is

To what extent is it possible to produce potato-based pasta products with by-products of the potato value chain?

A collaboration with EatWasted made this research applicable in the Danish business context. The end product of this thesis was therefore an action plan that EatWasted can follow to expand their practices into upcycling potato by-products into pasta.

8.1 Action plan EatWasted

For EatWasted to expand its practices into upcycling by-products of the potato value chain into pasta, there are a few things that need to be taken into account. Logistically, the distance will become much longer, as the pick-up location moves from Copenhagen to Jylland. As the distance will get longer, EatWasted needs to look at the radius of the electrical van they currently have and decide if the radius is big enough to drive to Jylland or if they have to invest in a hybrid or diesel van. This will also have an impact on the eco-social costs of their new sustainable business model.
As they currently have a collaboration with a company in Italy, which produces pasta for them from upcycled bread, it needs to be discussed whether, and or how, EatWasted can still collaborate with this company once they expand their practices.

If EatWasted chooses pathway 2, and they want to put the gluten-free label on their product, they need to ensure there is no cross-contamination. Therefore, they need to either clean their production site before use, or start a production line that is dedicated to the production of gluten-free pasta.

Collaboration-wise, EatWasted needs to find a potato-processor or wholesaler to collaborate with, and they need to start a collaboration with a side-stream starch company. When searching the internet, it seems that Duynie is the only company in Europe that produces side-stream starch. Therefore, EatWasted is bound to collaborate with them if they choose this pathway.

Table 4 summarizes this action plan for EatWasted.

Category	Consideration	Possible Implications
Logistics	- Longer distance between Jylland and Copenhagen than between Copenhagen and Copenhagen. - The production company in Italy that EatWasted collaborates with currently produces pasta from discarded bread.	- Might need to switch from an electrical van to a hybrid or diesel van. - Could the company in Italy produce pasta from potato by-products as well? And could this be made gluten-free?
Production process	- If choosing pathway 2 and wanting to make the pasta gluten-free, there cannot be cross-contamination.	- Cleaning the production facility before producing gluten-free pasta or setting up a new production line might bring extra costs with it.
Collaboration	- Finding a potato processor or wholesaler to collaborate with. - Duynie seems to be the only side-stream starch extraction company in Europe.	- Are potato processors or wholesalers open for collaboration? - Does the monopoly of Duynie lead to an increase in price?

Table 4 Action plan EatWasted

8.2 Future steps

After the hand-in, the action plan will be discussed with EatWasted. This closing conversation is meant to create negotiation spaces, meaning that EatWasted can explore the different pathways that are discussed in this research, as well as come up with pathways on their own (Pedersen, 2020).

Bangar et al. (2022) conducted a review comparing different starches for noodle production. In this review, Bangar et al. (2022) suggest combining potato flour and starch into pasta products rather than only using potato starch. In this pasta product, a mixture of side-stream starch and potato flour would mean that two pathways are combined. It is also interesting to look into the production method of producing pasta products this way.

Another interesting pathway to further explore would be to extract starch from the whole potatoes that are picked up from the potato processor/wholesaler.

Future work will also look at the broader applicability of this action plan, to companies that also want to expand, or start, a new practice, upcycling by-products from the potato value chain into pasta.
My hypothesis is that if this company has been working with upcycling by-products before they decided to look at potato by-products, that the action plan, created for EatWasted, would be easier applicable to a company like this. Nevertheless, it would be interesting to research companies that transition from traditional pasta production, where by-products go to waste, to upcycling potato by-products.

However, it is assumed that the potatoes picked up from the potato processor/wholesaler lead to high enough yields when blending them into flour or extracting starch from these potatoes (as described in a potential pathway to further explore). Thus, this would be an interesting point to research in the future, as it is currently an assumption, as not all the potatoes are the same.

The focus of this research has been on the value chain of potatoes, and seeing to what extent it is possible to set up a value chain for upcycled potato-based pasta products.
Since this thesis solely focused on the value chain of upcycled potato-based pasta products, consumers' acceptance of this pasta has not been taken into account. It could be interesting to conduct surveys among different consumers to see what their acceptance rate for this kind of pasta is, and if we can increase the acceptance rate of potato-based pasta products.
One way that this could be done is by associating potato-based pasta products with food nostalgia. Food nostalgia refers to nostalgic associations people connect to a certain food (Espinoza-Ortega, 2021). It could be part of the reason why some consumers prefer one food over the other.

Upcycling food reduces food waste decreases the environmental impact of the specific food product. However, this might differ per product depending on multiple factors (Thorsen et al., 2024), such as the energy usage needed to upcycle this product.
One of these factors for EatWasted could be transportation. Because the potatoes need to be transported from Jylland to Copenhagen, the question is whether the extra emissions that this will cost in comparison to when the potatoes would be used as animal feed, still make upcycling beneficial.
It could also be interesting to research into other factors, and maybe conduct an LCA analysis to see what the real emissions of upcycling these potato by-products are.

8.3 Reflection on the process

The final report is organized according to the double diamond, making the process itself iterative.

As there was only one pasta-producing company in Denmark that wanted to collaborate with me, I had to reshape the research question. Since I wanted to keep Denmark as the scope of my research, I did not think of collaborating with companies in other countries. However, collaborating with companies in other countries might have made it easier, as it seemed to be relatively easy to schedule an appointment with companies in the Netherlands and Belgium. The scheduling of the meeting with the company in Denmark, EatWasted, was done in March, but a few weeks before, I was thinking of shifting the focus of my thesis to another country, like the Netherlands, as it seemed nearly impossible to schedule a meeting with a company in Denmark. However, as it turned out a few weeks later, the meeting with EatWasted was scheduled, and I still had the appointments with the companies in the Netherlands and Belgium, I decided to use the data from these interviews for the state of the art.

This process taught me the importance of sometimes looking beyond the scope of your research to find relevant data.

It also taught me that it is important to endure in a project and think outside the box, especially if there are very few companies that want to collaborate with you. Not thinking outside of the box in this thesis would have led to demotivation, as there were only a few companies that wanted to collaborate.

Overall, it might have helped me to have a more chronological order in some steps of the process, to define the exact focus of this project earlier in the process. However, because of the way the process went in practice, I did get a better understanding of the importance of iteration. Iteration did mean I had to go back and forth a lot of times, which turned out to be beneficial to my research, since this allowed me to compare previously gathered data better.

However, this iteration process did require a planning that left room for this iteration. During the thesis process, the need for iteration became more and more important, and therefore I acquired more precise planning skills, where I could make plans that allowed for iteration, during this thesis process.

8.3 Strengths and limitations

Since there is no market for potato-based pasta products yet, and a lot of different aspects can be researched to create a market for potato-based pasta production, it was difficult to find the scope and focus of this research.

Questions that could also have been asked are, for example, is there a demand for potato-based pasta in Denmark?
However, I had to scope my research down to value chain creation for potato-based pasta products from by-products of the potato value chain in Denmark.
Scoping this down can be considered a strength as well as a weakness of this study. The scoping down did lead to a more narrow focus, and therefore it allowed me to dive deeper into the subject. However, because I had to scope it down, I sometimes might not have looked at the bigger picture in the same way as if my research scope was broader.

Another limitation of this research is the use of the term by-products. By-products are products that are produced in the production line, next to the main products, and have the potential of becoming a waste product or a co-product. A by-product becomes a co-product when it starts to possess a positive market value, for example, when it can be sold to the consumer/retailer/businesses (Springer & Schmitt, 2018). According to this definition, upcycled potato flour/potato starch into pasta would turn the by-product into a co-product.
However, the term by-product was being used for literature review, as this term was included in the main research question. Nevertheless, using the term co-product might have given different perspectives on the topic discussed.

Collaborating with EatWasted on the topic allowed me to make the project more applicable to the Danish business context. However, because I collaborated with EatWasted and had a goal in mind of making an action plan for EatWasted, I focused on the action plan and changed the entry point of my research, not focusing on the production of a gluten-free alternative to rice noodles as much as I would have liked.

Since there are a lot of places in the potato value chain where waste occurs, there are a lot of possibilities for waste valorisation along the chain. Another strength of this research is that I decided very early in the process on what kind of waste I would focus on: whole potatoes that went to waste, and side-streams. However, this can also be considered a weakness, as there are a lot of options that remain unexplored.

9. Conclusion

The main research question for this thesis was

To what extent is it possible to produce potato-based pasta products with by-products of the potato value chain?

Using by-products of the potato value chain to produce pasta this way is already being done by some companies. In an interview, Kristof Wallays (Pers. Comm., 2025) stated that the side parts that are cut off from the potatoes, when making fries, are being used to make potato flakes, and these potato flakes are used in the production of gnocchi. Thus, it can be concluded that upcycled potato-based pasta products are already being made to some extent.

However, these potato flakes are being sold to companies in Italy, and is made into gnocchi. To make it more applicable to the Danish context, a collaboration with EatWasted was established. EatWasted wants to expand its practices into upcycling by-products of the potato value chain into pasta. By researching these two pathways, this thesis concluded that upcycling potato by-products for this company, would be possible in the following ways.

Pathway 1: Picking up potatoes from wholesalers/potato processors, milling this into flour, and using a mixture of semolina flour and potato flour to produce pasta with.
Pathway 1 would help to reduce the waste at the productions' site in the potato value chain, contributing to a more sustainable potato value chain with less waste.
Pathway 2: Starting a collaboration with a company that produces side-stream starch and produces pasta using this side-stream starch.
Following pathway 2 could result in a gluten-free pasta, transitioning from a system where consumers who eat gluten-free rice noodles, which emit 5,12 kg CO_2 per kilo, to potato noodles, which emit 1,68 kg CO_2 per kilo. Therefore, following pathway 2 would not only help with a reduction of potato waste at the processors' site, but also to a system for gluten-free noodle production that is more environmentally sustainable.

Since potato flour does not have any baking properties, and therefore cannot be used on its own to substitute wheat flour, a mixture of semolina flour and potato flour needs to be used for the production of pasta. Using this mixture would mean that the pasta can still be produced in a similar way to wheat-based pasta.
Using potato starch in pasta production might call for a different production method, as starch noodle production differs from wheat-based pasta production. Experimentation with heat treatment of potato starch, could however make it easier to produce pasta products with potato

starch, as some studies state that when heat treating the potato starch, it can be used in a similar way as wheat flour.

These two pathways resulted in an action plan for EatWasted to expand their practices into upcycling potato by-products into pasta. Elements that needed to be taken into account were: logistical, distance from Jylland to Copenhagen, and the production process in Italy. Production process, cleaning the production facility, before producing potato starch pasta, if wanting to advertise it as gluten-free (Caio et al., 2019), and collaboration, with which potato-processor/wholesaler are they going to collaborate? Is Duynie the only player in the field regarding side-stream starch?
These elements need to be discussed with EatWasted in the final conversation after the hand-in.

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