Food supply in times of crisis - the potential to utilise side streams from the Swedish food industry

A master's thesis by
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Lund University
Lund, 2024

Master of Science in Food Technology and Nutrition
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May 2024

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Abstract

This thesis investigates the potential to utilise six side streams/export streams from the Swedish food industry for human consumption in times of crisis. Side streams that are not the industry's main purpose but could still contribute to nutrition. Currently, these streams are going to biofuel production or production of animal feed. The aim of this master thesis is therefore to study the potential to utilise side and export streams from the Swedish food industry for human consumption, in the event of a shortage of food in a crisis.

The yield, characteristics, and nutritional composition of the streams were found in a literature study. To strengthen the results from the literature study, semi-structured interviews with Swedish food companies, research, and the Swedish Food Agency were conducted. From these interviews, problems, challenges, and opportunities could be identified. Economic obstacles, sensory challenges, antinutrients, and regulations were the four factors found to be the major obstacles of not being able to utilise the streams at present. Therefore, more research needs to be done in theory and practice. Calculations of the nutritional content in terms of calories and macronutrients were also done. The studies streams could contribute to *380 kcal/capita/day* which corresponds to 15.5% of the daily nutritional need in a potential crisis.

It is discussed about what potential applications there is with using some of the side streams. For instance, one of the applications is fortifying already existing food to increase the nutritional content, but also using them as growing substrate for other food items, or to make whole new products.

The food industry's role in a crisis was also investigated due to its importance in the food crisis supply management in Sweden. Their main purpose is to supply the population with food and nutrients. Therefore, it is of great importance that the production can resist disturbances in society. This could for example be if there were to be an import or export stop from other countries. Working with these issues could increase the use of food from Swedish sources and increase self-sufficiency in the food sector.

Keywords: Side stream, Crisis, Sweden, Food industry, Food supply management

Sammanfattning

Denna uppsats undersöker potentialen att utnyttja sex sidoströmmar/exportströmmar från den svenska livsmedelsindustrin till livsmedel för människor. Sidoströmmar som inte är industriens huvudsakliga syfte men skulle kunna bidra med näring. I dagsläget går majoriteten av strömmarna till produktion av biobränsle eller till djurfoder.

En litteraturstudie genomfördes där strömmarnas avkastning, egenskaper samt näringssammansättning identifierades. Resultatet från litteraturstudien stärktes genom semi-strukturerade intervjuer med företag från livsmedelsindustrin, forskare och Livsmedelsverket. Utifrån intervjuerna hittades problem, utmaningar och möjligheter kopplat till strömmarna. Ekonomiska hinder, sensoriska utmaningar, antinutrienter samt föreskrifter var de fyra faktorer som inte gör det möjligt att utnyttja strömmarna i dagsläget. Mer forskning inom detta område behövs göras, både på ett teoretiskt och praktiskt plan. Beräkningar av näringsinnehållet i form av kalorier och makronutrienter genomfördes också på de sex strömmarna. Det resulterade i *380 kcal/capita/dag vilket motsvarar 15,5%* av det dagliga näringsintaget i en eventuell kris.

Det diskuteras även potentiella användningsområden som dessa sidoströmmar kan användas till. Exempel på det skulle kunna vara, att berika redan existerande matprodukter som finns på marknaden för att öka näringsvärdet. Det skulle även gå att använda dessa strömmar som näringsmedel för andra livsmedelskategorier eller för att tillverka nya produkter.

Livsmedelsindustrins roll i en kris undersöktes också på grund av den stora roll i försörjningen utav livsmedel i Sverige de har. Det huvudsakliga syftet är att förmedla mat och näring till den svenska befolkningen. Därför är det av stor vikt att produktionen kan stå emot samhällsstörningar, i form av exempelvis import/export stopp till/från andra länder. Om detta görs, kan användandet av livsmedel från svenska råvaror, vilket i sin tur kan öka självförsörjningsgraden i livsmedelssektorn.

Acknowledgment

We would like to express appreciation to our two supervisors, Serina Ahlgren and Håkan Jönsson. Thank you, Serina, for believing in us and giving us the chance to write our master thesis with RISE under Formasproject 2022-02392: *Växtnäring i osäkra tider*. Thank you both, for giving us advice, guidance, and support throughout the journey of writing this thesis. But also giving us the experience, which will help us in the approaching working life. We would also like to give a special thank you to our examiner, Federico Gomez. Not only for being the examiner for this thesis but for also being the programme director for our program and always being there answering our questions. And thank you to all the people we have gotten to know thanks to the master's in food technology and nutrition, people we know always will be in our lives.

The biggest thank you to Nanna, for being an incredible thesis partner during this spring. You amaze me and I look up to you so much, both as a working partner, but also as a dear friend. Alex, thank you for the loving energy and enthusiasm you always have. All warm love and thanks to my mom, my dad and my brothers, for being the biggest supporters, always.

Sara

Thank you, Sara, for being the best thesis partner I could think of. Endless laughs and coffee breaks have made the four months going by quickly. Also, the biggest thank you to my boyfriend Johan, my mom, my dad, and my grandparents, for always supporting me in all my decisions and for believing in me. Both in good times and in bad times. I love you endlessly.

Nanna

Introduction

During the last 10 years, the geopolitical stability of the world has been largely tested. The occupation of Crimea in 2014, the Covid-19 pandemic, and the latest Russia's full-scale invasion of Ukraine. In June 2023, the Swedish Prime Minister, Ulf Kristersson, stated that Europe is experiencing the worst security policy situation since the Second World War. The crisis within the Swedish borders and war in the nearby area has resulted in a demand to upgrade the defence. The question of how resilient Sweden is has been more noticed, both in the media and on a governmental level. Entry into NATO (North Atlantic Treaty Organization) has come closer and in March 2024 Sweden was approved by all 32 member states which marked a new era in Swedish military history.

The Swedish Civil Contingencies Agency, MSB defines crisis as "An event in peacetime that threatens basic functions and values in society, for example, the electricity supply, people's health or freedom". To be more resilient against crisis is necessary for a nation in many aspects and how the resilience plan looks is different depending on which section of the society it is focused on, from the health care and infrastructure sections to the food section. The degree of self-sufficiency needs to increase, a statement that may sound easy in theory but is much more complex in practice. Factors are dependent on each other to work and if one is eliminated or disturbed, there will be disturbances in the whole chain.

Within Sweden's civil defence, the question regarding food and nutrition for the population has been more and more discussed. Sweden needs to prepare society for an eventual crisis, including the food system, from primary production to finalised products. Today, the Swedish food industry is producing only about half of the food consumed in Sweden, which is a potential threat to food security in terms of crisis (SLU, 2018). As a result of the production of food, the food industry will always produce different side streams that are not the company's focus. Side streams are defined as streams/products within the process that are not the company's main product. Currently, these types of streams go to animal feed, biofuel production or are exported. However, there is a hidden potential in the substantial side streams from the food industry, of which many are high in nutrients.

Aim

The aim of this master thesis is to study the potential to utilise side and export streams from the Swedish food industry for human consumption, in the event of a shortage of food in a crisis. The research questions are:

- What are the main side streams that can be utilised, their quantities, and their characteristics?
- How much nutritional content can the side streams provide to the Swedish population in terms of calories and macronutrients?
- What are the possibilities and challenges to optimise the use of side streams from the food industry in times of crisis?

This will be done with information gathered from the literature review and interviews with companies and researchers. In addition, the food industry's role in a crisis will also be investigated through interviews with companies. The literature review will provide the nutritional composition and the interviews will provide the different streams' quantities, characteristics, possibilities and challenges.

Background

Under the section background history and current work with crisis food supply management will be presented as well as European food supply management. The market share of food production in Sweden and food industries and their technologies will also be described. Lastly, a description of nutrition in terms of calories and macronutrients.

History of crisis food supply management in the Swedish food sector

Food supply management has for a long time been an important topic. After the First World War (1914-1918), the opportunity to supply food to the Swedish population began to be a rising problem. The Swedish government decided on a ration of certain food items. This system continued to be a part of Sweden's crisis food supply management during the Second World War (1939-1942) in combination with other factors connected to preparedness in the society (Schimanski, 2023).

Modern food supply management for crisis began during the Second World War. Sweden was dependent on food imports from other countries. Due to the insecure situation in Europe, the importance of making Sweden self-sufficient began to rise within the country. This resulted in the rearmament of preparedness, storage of food and other important factors needed for the society to work. The aim was to provide Sweden with vital necessities for up to six months and to be independent of the world around them (Schimanski, 2023). The storage was scattered all around Sweden, see *Figure 1 (Jordbruksverket, 2002)*. These vital necessities included food, animal feed, pesticides, fertilisers, and freshwater chemicals, see *Figure 2*. In addition, the first version of the brochure *Om kriget kommer- vägledning för Sveriges medborgare*, was released in 1943 with detailed instructions to the Swedish population regarding how to act in times of war (MSB, 2018).

Figure 1: Storage in Sweden 1994 (Jordbruksverket, 2002).

Lagringsvaror i ton vid tre tillfällen

Lagringsvara	1968	1978	Max. lagring efter 1988
Brödsäd	300 000	220 000	145 000
Gula ärter	4 000	3 800	5 000
Risgryn	2 400	3 000	8 000
Gröna linser	–	–	4 000
Bruna bönor	–	–	4 000
Socker	50 000	85 000	45 000
Margarinråvaror	20 200	20 000	15 000
Rapsolja	–	–	25 000
Kaffe (orostat och pulverkaffe)	6 000	6 000	6 000
Torrmjölk	3 000	4 200	5 400
Köttkonserv	–	2 000	4 000
Torrjäst	–	1 100	1 500
Koksalt	–	–	8 000
Insatsvaror för margarinindustrin	–	–	700
Fodermedel	65 000	82 000	146 000
Aminosyror	–	100	100
Gödselmedel	45 000	97 000	265 000
Bekämpningsmedel	260	260	900
Köksväxtfröer	–	–	15
Veterinära läkemedel	–	–	40
Vattenkemikalier	–	–	2 100

Figure 2: Amounts in the storage on three different occasions in Sweden (Jordbruksverket, 2002).

The authority responsible for the storage was the National Swedish Board of Economic Defence *(Sv: Överstyrelsen för ekonomiskt försvar, ÖEF).* In addition to the responsibility of the storage the implementation of W-businesses *(Sv: K-företag, krigs -och krisviktiga företag)* was also made. These companies had a central role in crisis food supply management during this time, the companies covered all sectors needed in society (Ingemansdotter et al., 2018).

The dismantling of the storage started in the middle of the 1990s and was a result of the decommissioning of the food security policy. This was done due to three factors; 1) the Cold War was over and the risk of an armed conflict against Sweden decreased drastically; 2) admission to the European Union in 1995 contributed to a more secure foreign trade due to a combined agriculture politics; 3) savings in the general budget and the defence budget (SJV, 1998). Due to this dismantling, the crisis of food supply management connected to the food industry has drastically changed during the last 30 years (Kullgren, 2023).

Current crisis food supply management in the Swedish food sector

The crisis food supply management in Sweden today originates from the responsibility principle (*Sv: ansvarsprincipen*). This means that the ones responsible for a certain type of task during peaceful times are also responsible for the same time in case of a crisis. In the food sector the Swedish Food Agency is the authority responsible for national coordination of fresh water and food supply in crisis- and preparedness planning after the primary production (MSB, 2023). Most companies work with crisis food supply management on a company level with no connection to the government. The law, 1982:1004 (Arbetsmarknadsdepartementet, 1982) described how authorities on demand can ask for information regarding the company or the industry in case of a crisis and in that way be a part of the planning regarding a crisis (Statens offentliga utredningar, 2024).

In 2016, the Swedish government presented a proposition for a food strategy that is aimed to be carried out until 2030 (Prop. 2016/17:104). One part of this strategy is to increase self-reliance in the food sector (which is currently at a level of 50%) in a situation of crisis, reinforced alert, and war (Prop. 2016/17:104, 14). Increased national production of food is also a part of the food strategy, which according to the government will help increase self-reliance. Due to the dismantling of the storage of food and agricultural inputs in the 1990s, Sweden has gone from a *just-in-case* preparation system to a *just-in-time* system (Bergkvist, 2020). This can be described from a business perspective where *just-in-case* is a business strategy that aims to have large quantities of this case food to minimise the risk of shortage, and *just-in-time* is the opposite business strategy, the production and delivery of food is done in exactly needed amount at a specific time and place (Lindgren, 2019).

The global trade system and global supply chains have therefore made the food sector dependent on the political and economic stability of the world. This was something that the world experienced during the Covid-19 pandemic, the trade between countries due to restrictions became more complicated and there was a shortage of certain food items (Jordbruksverket and Livsmedelsverket, 2021, Höök, 2023). The recommendation to individual households and private persons was renewed in 2018 with the brochure *Om krisen eller kriget kommer- viktig information till Sveriges invånare* (MSB, 2018).

Economic perspective of food production in Sweden today

Sweden is self-sufficient in the food sector at 50 %, and every other bite is said to be food imported from other countries, from an economic market share perspective (Sverige, 2022). Sweden has a system of exporting cheap food such as cereals and importing more expensive types of food such as cheese and fruits, resulting in a relatively low self-sufficient market share in terms of economic trade. Sweden is only self-sufficient in three types of foods, cereals, carrots, and sugar. From a nutritional perspective, these food items provide mostly carbohydrates. The cereals and carrots provide some fats, fibres, and vitamins as well, but not enough for the total population. In addition to the food items that are counted as self-sufficient today, there are food items that are closely to be able to provide nutrients to the whole population. This includes potatoes, milk, and eggs. See *Figure 3* for levels of market share, a value of 100 equals food counted as sufficient to provide food for the whole population. There is a constant increase in the market share of food such as fruits and vegetables, dairy, fish, and meat. The import groups with no domestic production due to the climate are for example citrus fruits, bananas, and coffee beans which only stand for 16 % of the total food import in Sweden, see *Figure 4* (Sverige, 2022).

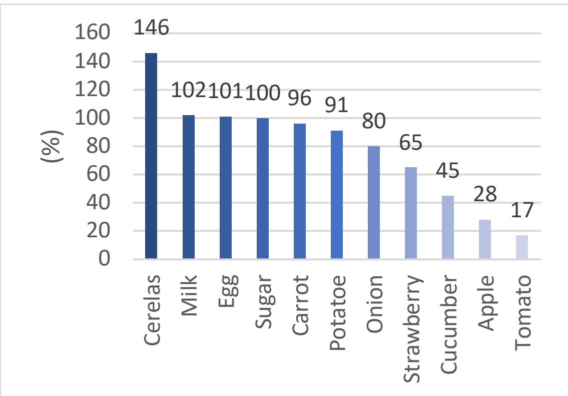

Figure 3: The market share of domestic production of food in Sweden 2022 (Sverige, 2022)

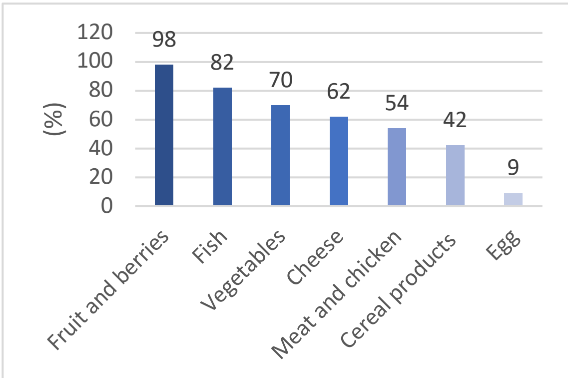

Figure 4: The market share of imported food in Sweden in 2022 (Sverige, 2022).

Food industries and their technologies

The food industry plays a key part in providing food in a country. The food industry have functional facilities within a country's borders that operate on a daily level to provide the national population with food and nutrition. Because of the major development and expansion within the industry over the last century, it is viable to produce enough food for a nation while microbiological safety is prioritised and improved. Heat treatment such as various types of drying techniques and pasteurization has both reduced the risk of growth of pathogenic organisms and lengthened the shelf-life of food items that are consumed. Food that had a short shelf-life and only lasted for a short amount of time, these industrial techniques have therefore been a crucial implementation that exists today (Sablani et al., 2024).

The food industries have a big role in times of crisis. They need to provide the needed nutrients for maintaining good health among the population. However, other than providing the nation with food, having an operating industry during a crisis will help the economy of the nation not halting (Upton, 1993). Another reason for keeping the stability of the industries is that it will contribute to the development of new products. An aspect of food industries adapting to a crisis is that they will need to be able to shift the production focus, due to the income of raw material that can increase or decrease in delivery to the facilities. The focus could also be shifted into making more products with increased shelf-life due to UHT treatment or pulverisation (Deeth, 2010). Qualified personnel or employees with knowledge will play an important role in times of crisis since they have a key role in making the production of food possible. (FAO/WHO, 2011).

Nutritional needs - Macronutrients and calories

The food sources from the different macronutrients within Sweden's borders often consist of cereal products, meat products, dairy products, different types of vegetables such as potatoes, carrots and onions (Ministers, 2023, Sverige, 2022). Carbohydrates are a vital source of energy, dense in starch and sugar and are vital for functions in the human body (Michael J. Gibney, 2009). Although, it is also beneficial to consume dietary fibre in a crisis since it increases the feeling of satiety (Salleh et al., 2019). Proteins are built of amino acids that are fundamental for functions in the human body (Michael J. Gibney, 2009). Therefore, it is preferable to consume food with an amino acid composition, such as animal- or fungi-based protein sources during a crisis since they have a complete amino acid profile (Michael J. Gibney, 2009, Mycorena, 2019). Fat is a compact energy source, and it requires a small amount to reach a high energy intake, which is beneficial in times of crises. However, the source of fat can still be of importance and an intake of mostly unsaturated fats is recommended to consume. Sources including essential fatty acids found in fish, flaxseeds and rapeseed oil if looking at food sources within Sweden's borders. (Ministers, 2023). The human body needs energy to be able to survive and perform. How much energy each individual needs depends on different factors such as gender, age, and level of physical activity. However, the average energy intake is required to normally be at 2350 calories per day (Ministers, 2023), and the Swedish food agency is recommending the average intake to increase to 2450 calories per day in times of war or crisis. The increase in the intake is motivated by maintaining the energy demand that will be needed due to the vital societal functions & critical infrastructure that must work properly during a crisis (Livsmedelsverket, 2021, Statens offentliga utredningar, 2024).

Food system strategies that could be relevant in a crisis

It is important to prevent malnutrition to the largest extent during a crisis. Hunger and even starvation can have major consequences for a population, especially for children who are in a growth and development phase in their life (Espinosa-Salas S). There are existing strategies to consider when planning to prevent these scenarios. Some agricultural production procedures could be implemented to increase the yield of a crop or make it more nutritious (Lazarte, 2023). This will not be brought up in this thesis. However, from a food industry perspective, some implementations may help prevent this issue.

Firstly, and the most achievable approach is fortifying the food that is being produced (Miller and Welch, 2013). This already happens in foods such as table salt which is fortified with iodine. In a time of crisis, it is therefore, advantageous to fortify the food with nutrients or ingredients with long shelf life. Depending on the solubility of the specific nutrient and the food matrix on the specific side stream that potentially could be food for human consumption, fortification can be a useful tool. Another approach the food industry could implement would be increasing the bioavailability with the help of technology and techniques to remove antinutrients. A component like this could be phytic acid for example, that inhibits the absorption of minerals such as iron or zinc. Examples of some techniques could be encapsulation, fermentation, or germination (Lazarte, 2023). In a plan to ensure that a population can receive the amount of nutrients that will be needed to avoid malnutrition, some alternatives could be adequately considered. It is advantageous to consume more food from multiple food sources that also are nutrient-rich to increase the chances of getting the best coverage, both from a macro- and micro-nutrition perspective. Since it is important to increase energy intake during a crisis (Livsmedelsverket, 2021).

Methodology

Here the methodology of the thesis will be presented. The foundation of selecting the different streams and the methodologies used are described and discussed.

Selection of studied streams

The focus is first to cover the macronutrient groups, to the most possible extent. Not every side stream covers all the macronutrient groups. However, it is assumed that if a combination of all the different side streams is consumed, the likelihood of covering the nutritional needs will increase for each citizen. The aim is to look at the macronutrients that will be relevant to consume during a crisis, such as protein, carbohydrates, fats, and dietary fibres. Therefore, side streams that contain very little to no content of just one macronutrient group are regarded as not valuable to include, for example, sugar. Even if glucose is essential for providing energy for the vital organs, carbohydrates and fibre as well is generally easy to access compared to proteins and fats, which could contain essential amino acids and fatty acids that could be difficult to access in times of crisis and food shortages. Secondly, the side stream also needs to be at an adequate amount of volume. This is to be able to cover the needs of food for a population. However, a lower limit is not specified, the selection is rather based on focusing on the larger food industries in Sweden with domestic raw material.

Some side streams have been eliminated in this thesis. To start with, import streams are not included. Streams before the raw material reaches the food industry production facilities will not be investigated, such as agricultural residues or similar. Food waste will not be looked upon since it is not a stream that is consistent in quality and over time, is difficult to track and it is hard to estimate how much of the food waste is fit for human consumption. Side streams from different production facilities often go as animal feed. Utilising animal feed for human consumption will have consequences for animal production. This is not included in the thesis due to time limitations, however, a reflection on what potentially could happen is included. Therefore, after investigating and evaluating, six domestic side streams/export streams were chosen to be included, see *Table 1* for a list of side streams/export streams.

Table 1: Chosen streams belonging to mainstream and raw material. The composition of the side/export stream represents what it consists of 100%, i.e. the original composition in the raw material is not included. The data are withdrawn from the result. *(Light green = carbohydrate, purple = fat, blue = protein, dark green = dietary fibre)*

Raw material	Mainstream	Side stream/ export stream included in this thesis	Est. composition of macronutrient in side streams / export stream
Cereals	Flour	Bran from cereals	64% 5% 18% 13%
Malt	Beer	Brewers spent grain	12% 34% 54%
Animals	Meat products	By-products from slaughter	5% 52% 43%
Wheat	Ethanol	Distillers grain	3% 4% 32% 61%
Rapeseed	Rapeseed oil	Rapeseed cake	15% 15% 34% 35%
Milk	Dairy products	Skim milk powder	58% 2% 40%

Characterization of side streams – a literature study

In the literature study, the method according to the literature review standards were followed (Snyder, 2019). Databases such as Google Scholar, ScienceDirect and Research Gate were used, and test searches were done to find search terms useful for the topic's terminology. After this, peer-reviewed articles on the topic were found. Information from authorities and the government has also been largely used to gather information connected to the Swedish crisis food supply management system, both in society and for companies. In addition, specific search words for each side stream were used to find relevant information. Some common and overall search words such as side stream, food industry and food preparedness were used. Search words connected to yield, quantities, nutrition composition, economics and chemical- and microbiological perspectives were used to gather information from each stream. Antinutrients, toxins, feed, Maillard reaction, bread, flour and food items are also used to gather information for some specific streams, such as plant-based streams. In addition, specific search words were used to gather more specific information regarding each stream, see *Table 2*.

This later formed the structure of the result from the literature review and could then be compared with information gathered from the interviews. The literature review was carried out to determine what has been written on the topic, find research gaps, and find what kind of questions were relevant to ask companies and researchers.

Table 2: Specific search words, total articles found, and total articles used for each stream in the study.

Side streams	Specific search words	Total articles found (approximately)	Total articles used
Bran from cereals	Millers' bran, Bran from cereals, Wheat bran	78 000	9
Brewers spent grain	Brewers spent grain, Spent grains	69 000	7
By-products from slaughter	Edible by-products, Offal, TSE-material slaughter	28 530	7
Distillers grain	Distillery, Wheat distillers' grain, Biorefinery	16 000	6
Rapeseed cake	Oilseed cake, Press cake, Canola	64 000	11
Skim milk powder	Skim milk powder, Dairy production, spray drier	241 000	9

Interviews with companies

Companies and researchers connected to the chosen side streams were contacted and recruited through email. Candidates for the interviews were identified by searching for relevant people online, and through contacts of supervisors at RISE and LTH. Responsible persons with different roles, sustainable manager and production manager were the two most dominant roles of the ones interviewed, see *Table 3* for the full list of people interviewed. Those were recruited due to their expertise and the possibility of answering the questions. Beyond the companies and researchers, one authority was also contacted. In total, seven companies with eleven participants, two researchers, and one authority participated in the interview. The interviews were processed from a semi-structured interview guide with room for follow-up questions suitable for the topic of discussion. The interviews are based on methods described by Bryman (Bryman and Nilsson, 2018). The interview questions were split into two themes, *Side Stream,* and *Crisis,* with the theme *Side Stream* as the main area of focus. The interviews provided information such as handling of side streams, quantities of the side streams, and crisis food supply management within the companies, information that were lacking in the literature review, or that confirmed information found in literature review. The interviews were set to last for a maximum of 30 minutes, which always were held. See *Appendix 1* for a complete interview guide with all questions asked.

The interviews were conducted between February and March 2024, online with a transcription tool from Microsoft Teams, which was afterwards manually controlled so the transcription was correct to use as results. The results from the interviews were analysed and synthesised through coding of the material. Through the coding could the four most recurrent themes be found, corresponding to the headings in the discussion, *Nutritional content, Problems and challenges, Food industries and their role in a crisis, and Potential development areas*. Summaries of all the interviews were also done, to get a better overview of the results.

Table 3: List of people interviewed with respective roles connected to each stream.

Stream	Interview	Role Person 1	Role Person 2
Bran from cereals	Company	Industrial PhD student	Responsible for innovation
Brewers spent grain	Company 1	Environmental manager	Procurement manager
	Company 2	Environmental manager	
By-products from slaughter	Researcher		
Distillers grain	Company 1	R&D manager	
	Company 2	Environmental manager	Sustainability and business policy consultant
Rapeseed cake	Company	Process Engineer	
	Researcher		
Skim milk powder	Company	Balance manager	Farm quality and sustainability manager

Calculation of calorie and nutrient content of the studied side streams

Calculations of the volume, caloric, and nutritional content of the macronutrients of the side streams that could be provided for the Swedish population during a crisis were done. The values were based on information that has been found (1) in the literature review in the form of the nutrient composition in percentage and (2) complemented with information provided by interviews with companies and/or researchers. Comparisons with the Nordic Nutritional Recommendations 2023 were also done. See *Appendix* 2 for the full calculation sheet in Excel.

A combination of the two methods

The two above-mentioned methods, literature review and semi-structured interviews were then combined to be relevant to the aim stated in the thesis. The literature study provided a general overview of the composition and characteristics of the side/export streams. The interviews contributed insight into specific conditions related to food preparedness in some of Sweden's most important food industries.

Author's contributions to the thesis

Since there are two authors to this thesis, the research behind the work, analysation and written titles has been divided between the participants. In *Table 4* it is presented how this has been done.

Table 4: A summarisation of the different authors contribution to the work of this thesis (LR = literature review, I = interview)

	Nanna Nilsson	Sara Johansson
Introduction	Abstract, Sammanfattning, Introduction, Aim	Aim, Abstract, Sammanfattning,
Background	History of crisis food supply management, Current, of crisis food supply management, Economic perspective of food production	Food system strategies that could be relevant in a crisis, Nutritional needs - Macronutrients and calories, Food industries and their technologies,
Methodology	Selection of studied streams, Characterization of side streams – a literature study, Interviews with companies, Calculation of calorie and nutrient content of the studied side streams	Selection of studied streams, Calculation of calorie and nutrient content of the studied side streams
Result	The nutritional potential of side streams/ export streams, Bran from cereals (LR), Brewers spent grains (I), by-products from slaughter (LR/I), skim milk powder (LR/I), Interview – The Swedish Food Agency	The nutritional potential of side streams/ export streams, Bran from cereals (I), Brewers spent grains (LR/I), Distillers grains (LR/I), Rapeseed cake (LR/I),
Discussion	Nutritional content, Food industries and its role in a crisis	Potential development areas, Food industries utilising own side streams in a crisis,
Conclusion	Conclusion	
Other	Future research, Diagrams, Tables	Diagrams, Tables

Results

Firstly, under section results will firstly calculations of the nutritional potential of side streams/export streams be presented. This is followed by the *Literature Review section and interviews on side streams and export streams.* All six streams are presented with information regarding raw material and industrial description, economy, nutritional composition, chemical -and microbial perspective and current use. A summary of interviews connected to each stream will also be included as a part of the results.

The nutritional potential of side streams/ export streams

Quantities per year of the side streams/ export streams from the interviewed companies, researchers, or from the literature will be presented in *Table 5.* Calculations of average values of the macronutrients Carbohydrates (C), Fats (F), Proteins (P), and Dietary fibres (DF) and the amounts of calories/capita that the streams will contribute per day will also be presented in *Table 5.*

Table 5: Calculations of nutritional content in the six streams, Carbohydrates (C), Fats (F), Proteins (P), and Dietary fibres (DF).

Stream	Quantity origin	Quantity [tons/year]	C [tons]	C [kcal]	F [tons]	F [kcal]	P [tons]	P [kcal]	DF [tons]	DF [kcal]	Total [kcal]
Bran from cereals	Company	70 000	39 760	$1.59 \cdot 10^{11}$	3010	$2.71 \cdot 10^{10}$	11 060	$4.42 \cdot 10^{10}$	7875	$1.58 \cdot 10^{10}$	$2.46 \cdot 10^{11}$
Brewer spent grain	Literature	26 667	0	0	2267	$2.04 \cdot 10^{10}$	6667	$2.67 \cdot 10^{10}$	10 667	$2.13 \cdot 10^{10}$	$6.84 \cdot 10^{10}$
By-products	Literature	37 000	1469	$5.88 \cdot 10^{9}$	16 550	$1.49 \cdot 10^{11}$	13 638	$5.46 \cdot 10^{10}$	0	0	$2.09 \cdot 10^{11}$
Distillers grain	Company	75 620	1966	$7.86 \cdot 10^{9}$	2571	$2.31 \cdot 10^{10}$	21 930	$8.77 \cdot 10^{10}$	42 196	$8.44 \cdot 10^{10}$	$2.03 \cdot 10^{11}$
Rapeseed cake	Literature	146 667	19067	$7.63 \cdot 10^{10}$	19 067	$1.71 \cdot 10^{11}$	42 533	$1.70 \cdot 10^{11}$	44 000	$8.80 \cdot 10^{10}$	$5.06 \cdot 10^{11}$
Skim milk powder	Literature	43 000	21 930	$8.77 \cdot 10^{10}$	645	$5.81 \cdot 10^{9}$	15 050	$6.02 \cdot 10^{10}$	0	0	$1.54 \cdot 10^{11}$
Calories/capita/day	*380 kcal*										
Omnivore diet	*15.5 %*										
Vegetarian diet	*13.2 %*										
Vegan diet	*11.4 %*										

Literature review and interviews on side streams and export streams

Bran from cereals

Literature review

Raw material and Industrial description

Bran or Miller's Bran is a side stream from the handling of cereals where the other hard shell surrounding the endosperms and germ of the cereal kern is removed. In Sweden, the biggest fraction originates from wheat. The cereals are harvested, dried, and go into production where the bran is carefully removed in the process of milling the wheat into flour. (Apprich et al., 2014).

Economy

In Sweden, roughly 6 million tons of cereals are produced each year, including wheat, oat, rye, and barley. 50% out of these 6 million tons are wheat, which is the most grown harvested cereal in Sweden. This fraction includes both autumn wheat and spring wheat, where autumn wheat is the most dominant one cultivated. 10-14% out of the wheat kernel is the bran, which results in a side stream of roughly 300 000 tons of wheat bran (Apprich et al., 2014).

Nutritional composition

The nutritional composition of wheat bran consists of mainly proteins and carbohydrates but also fats. A protein content of 13.2-18.4 % depending on the harvest (Harris et al., 2005), and a fat content of 4.7%. Starch is the most dominant with a range of 13.8-24.9 % of the total 56.8% carbohydrate content (Dornez et al., 2006). In addition to these macronutrients, the bran contains healthy components such as dietary fibres, phenolic acids, carotenoids, and phytochemicals. The wheat bran contains phytic acid which has a negative effect on the uptake of other necessary compounds in the human body. The product also contains vitamins and minerals, such as different types of vitamin B, iron, magnesium, and zinc. The stream is a good source of insoluble fibres or dietary fibres, which will increase bowel movement by binding water (Vithana Pathirannehelage and Joye, 2020). Brans are in pure form insoluble for human consumption and therefore a step of extraction or enzyme treatment needs to be implemented. This is necessary to be done if the bran is added to food applications to a larger extent than it already is.

Chemical – and microbiological perspective

Cereals and the bran of the cereals are both sensitive to a too-high water content upon drying. Too high of water content will affect the quality of the bran in a negative way and the risk of microbial growth increases. The biggest risk is the mycotoxins, which will be given a beneficial growing environment if the drying process is not handled correctly. Mycotoxins are found in the highest concentration in the wheat bran (Whitworth, 2019) and have a negative effect on human health (Harris et al., 2005). The risk of the mycotoxins drastically decreases if the bran is kept at 14°C and a water content of 14%. These parameters give a shelf life of one year, a lower water content will give an even longer shelf life. It has also been found that wheat bran can contain high levels of pesticide residues and heavy metals, with cadmium as the most dominant heavy metal (Randhawa et al., 2014). Up to 90 % of the wheat bran is contaminated in the post-harvest samples. Yeast and bacteria can also be found in the wheat bran (Santala, 2014).

Current use

Some wheat brans are used for human consumption and are available to buy in grocery stores. Most commonly, the wheat bran is added to bread or other baked products such as cereals, pasta, and snacks. Wheat bran is a good component in hard food structures since addition decreases the amount of gluten and starch. This will negatively affect the volume, softness, and taste of the product, due to the decreased structure-forming capability. An addition of 5-10 % or higher, of the wheat bran will increase the hardness, roughness, and brittleness of the food structure (Santala, 2014).

Interview

Grain company

The persons interviewed were the Innovation director and an industrial PhD student connected to the company. The PhD student mentioned that they work with all four big cereals with side streams from all of them, with wheat as the biggest fraction. Both mentioned that they perform research connected to how bran can be utilised in a more extended way, one specific project studies wheat bran and its opportunities in an innovation stage. Wheat is cultivated for mainly two different reasons, human consumption, and animal feed. The quality of the wheat is important when it comes to the fraction used in human consumption. Therefore, it is necessary to import some wheat to cover the quality demand, the quantity is unknown. As a result of this, 15% of all the wheat handled within the company is sorted into the side stream of wheat bran, which corresponds to 70,000 tons yearly. 5 - 10% of these 70 000 tons (3500 – 7000 tons) go directly to human consumption, it is used in the companies' products such as granola and other fibre-rich products. The person responsible for innovation also states how the quality works with the product and the importance of and high in Sweden if the product does not reach the right requirements, it becomes animal feed. This gives room for innovations and ideas connected to the side stream.

The PhD student mention one big question which is regarding the sustainable work with the wheat bran. How could wheat bran be used more directly for human consumption instead of going to animal feed? A possible problem connected to this is that the value of wheat bran among consumers is very low right now. It is more economical and profitable for the company to send the redundant bran to animal feed than to work with an industrial process for human consumption. From a nutritional point of view the wheat bran could contribute by reducing fibre deficiency among the population, which is a problem among approximately 70% of the Swedish population. Fibre and high fibre content are associated with bad sensory properties, it does not give bread the same appealing appearance or taste as bread with only white flour. Another thing she mentioned is that there are also big problems with toxins and heavy metals in the bran, with cadmium as the most dominant one. It is strongly connected to where in Sweden the wheat is grown, and which type of agriculture is used. The work with reducing the cadmium is an economical question for the company. If the value of the bran should increase, it would give more room for these types of innovation questions connected to reducing the heavy metals. Since there is no work with it now, the quality regulations for animal feed are lower and therefore the proportion that goes to animal feed is high.

The person responsible for innovation mentioned that the company works with crisis food supply management, but to what extent is unknown from her point of view. The side stream is fully eatable and exists in excess, and the production of the raw material would potentially be a source of nutrients. The company can produce and provide wheat bran for human consumption to a larger extent if there is an increased demand, for example, because of a crisis (Informant A and B, 2024).

Brewers spent grain

Literature review

Raw material & Industrial description

From the production of beer, the main side stream is Brewers' Spent Grain (BSG) which originates from malt. Depending on the amount of beer produced within Sweden's borders, it could potentially be a considerable amount that could be converted to food for human consumption. (Parchami, 2023). The side stream is created after the malt has been boiled together with the water and the milled malted barley. One challenge related to BSG is that the stream has a high temperature and moisture content coming when it is coming direct from the process. This increases the risk of having a material with a short shelf life and some sort of treatment will be needed to reduce the risk of getting the material spoiled. Examples of different treatments could be drying, treating it with preserving chemicals or storing it in a cold space (Parchami, 2023).

Economy

In Sweden, the brewing industry has grown in amounts of breweries over the last 30 years, from just 19 breweries in total 1995 to 436 breweries in 2023. In total, the breweries within Sweden's borders produced 505 million liters of beer in 2022 (Bryggerier, 2023). Over 400 of these breweries are so-called microbreweries or smaller breweries and they do not have an extensive side stream in their process. Considering that the side stream volumes in these processes are smaller compared to the bigger breweries, the volumes of these side streams of BSG will be neglected in this thesis. The three biggest breweries in Sweden have a capacity of producing about 400 million litre beer in one year (Bryggeri, 2021, Wiklund, 2016, Bryggeri, 2022). The average yield of how much of the initial malt that is turned into BSG is 31%. This represents approximately 20 kg of BSG on 100 litres of produced beer (Parchami, 2023). This results in that potentially about 26,700 tons of BSG produced within Sweden's borders could be converted to food or a food ingredient for human consumption based on the calculation in *Appendix 2*. The value is also calculated for its dry state, which approximately is equivalent to a third of the wet weight of BSG.

Nutritional composition

The nutritional composition of dry BSG consists of mostly fibre, between 30-50%, and for protein the amount could be between 20 - 30%, the remains consist of 7 - 10% lipids and some small amounts of carbohydrates and ash (Karlsen and Skov, 2022). However, dependent on the batch of BSG the amount of the macronutrients can vary, and this also applies to micronutrients. Therefore, BSG is also rich in minerals such as calcium, potassium, magnesium, iron, zinc, and water-soluble vitamins like the different B vitamins (Fărcaş et al., 2022).

Chemical/microbiological perspective

For humans to be able to BSG, it is important to treat it beforehand. Ideally, it should be milled into a flour, due to the high fibre content. It will then be easier to dilute and blend the flour food items, such as bread or similar (Mussatto et al., 2006). A recent innovation that has been made in Denmark is that a small company has transformed BSG into a paste that is similar to chocolate. Since it obtains characteristics of chocolate such as melting, setting, and snapping properties, it can act as a substitute in or on cookies or ice creams (Lorenzo, 2022). The fibre content in BSG consists of both soluble and insoluble fibres, different types of cellulose, and lignin (Mussatto et al., 2006). Phytate is an antinutrient that BSG contains, approx. 1.01g per 100g. In the case, BSG is used as an ingredient in breadmaking, fermentation would be an effective method of reducing phytates (Ktenioudaki et al., 2015).

Current use

Either in its wet or dry state, BSG is often used to feed cattle or other animals since it contains a large amount of protein (Nationalencyklopedin, 2023b). However, it can also be used for obtaining energy or as raw material for biofuel production (Wiklund, 2016, Westin, 2018). Research has also been made into utilizing BSG as a substrate for the production of mycoproteins (Stoffel et al., 2019).

Interviews

Two interviews with two different beer-producing companies were held. Both have a side stream of BSG, but they treat them in two different ways which will be described below.

Beer company 1

The first company that was interviewed is one of the largest beer producers in Sweden.
The persons interviewed were both managers, one of whom worked with the environment, and the other one with Procurement. Both mentioned that BSG is currently used as animal feed.

Recently, there has been an increased interest by the company to investigate if there is a potential to use the BSG for human consumption. The environmental manager mentioned that the company has initiated contact with a research organization. Hopefully, their collaboration will result in some products in the future.

The procurement manager mentioned that the main raw material, barley malt, comes from imported sources. She also estimated that 20% or less of the total grain they use comes from Swedish origin. The yearly volumes are around 20.000 tons of BSG in its wet state directly from the production, and the volume does not fluctuate in-between the years. At the moment, both of the managers agreed that the company is beverage-producing and does not have any plans of using BSG within their site. They argued that it would be crossing the line within another food category. Therefore, the BSG needs to be distributed to another company that will utilise the material. Also, another argument that was mentioned is that there needs to be large investments in a drying process to utilise and preserve the material. However, since no food invention makes this profitable, this is not prioritised.

Both managers mentioned that the company is working with preparation management to some extent. If there were to be a crisis within Sweden's borders the company could potentially provide some help to the population of Sweden. For instance, during the pandemic, they were able to, in collaboration with other breweries, collect the side stream of beer production into making hand sanitiser. The environmental manager also mentioned that they could provide clean water to larger groups, if needed. One example was during the summer fires in 2018, where there were working firefighters north in Sweden (Informant A and B, 2024).

Beer company 2

The second beer-producing company is also one of the largest in Sweden. The interviewed candidate was an environmental manager at the company. The majority of the raw material for their beer production comes from Sweden, which includes the main ingredient that makes beer, barley malt. Their solution of utilising their side stream of BSG is by drying it as pellets that will later be burned to generate energy for their process. If there is an amount of BSG that is too large for the company to handle now, the excess amount goes to an external plant where it becomes biogas. The amount of dry BSG that is generated per year is 5.000 tons, the excess amount of the side stream is usually going to biogas and could be between 10.000 to 15.000

tons of wet BSG yearly. Yearly the flow of the side steam has been stable. The environmental manager mentioned that they are using the side stream that they produce as an energy source and is therefore pleased with their prioritisation for now, due to the fluctuation in energy prices that has been experienced in the past years. But regarding food innovations, some tests have been made, such as collaborations with worm breeders where the BSG has been used for feed to the worms. This ended up becoming a protein-rich food source that would be served for human consumption. The BSG contains a lot of nutrients and other beneficial substances that make the worms grow rapidly in size. However, this has only been done on a smaller scale.

The environmental manager mentioned that one of the challenges with the side stream is that the BSG's shelf life is short, since it is warm and moist directly from the process. She mentioned that in the summer it will last for approximately 3 days before it goes bad, and up to a week during the winter. Therefore, the material needs to be treated or distributed quickly. Another food-related obstacle is that at the company's site, the process for handling the side stream into making pellets is not fitted for food safety, therefore it would be necessary to readjust the drying process to be safe for human consumption. There are also possible issues connected to the distribution of the BSG to other company partners or receivers. Because during the weeks and months of the production year, the flow can differ and fluctuate depending on the process. Therefore, no external company can receive the BSG continuously, like the worm company for example.

The company mentioned that they probably will never start utilising the side stream to make a finished product for human consumption at their site in peacetime. However, they are probably more willing to provide the excess BSG that will not be burned for energy purposes to a production that makes food for humans. However, if the company can make the process of making pellets safe for human consumption, then they would be able to shift and provide pellets for a human population in times of crisis if the process would be fitted to produce safe food. At the moment, there is nothing of the BSG that goes to animal feed (Informant C, 2024).

By-products from slaughter

Literature review

Raw material & Industrial description

By-products are defined as everything except the meat on the carcass, which includes for example the kidneys, liver, lungs, heart, blood, skin, and bones. By-products from slaughter can be divided into two categories, edible by-products, and non-edible by-products. Edible by-products are divided into two categories, suitable for human consumption and potentially suitable for human consumption. The non-edible by-products are categorised into three risk categories, high, medium, and low-risk material (1-, 2-, and 3-material). Regulation (EC) No 1774/2002 states that categorising 1-material is classified as a hazard for human consumption (FAO, 2002). The brain is an example of TSE-risk material and should be removed to reduce the risk of spreading diseases or toxins. The other two categories, risk 2 and 3-material also include parts that are not suitable for human consumption, but with no risk of spreading infections. See *Table 6* for an explanation and examples (FAO, 2002).

Table 6: Categorising of by-products from the slaughter industry.

Edible by-products		Non-edible by-products		
Suitable for human consumption	Potential suitable for human consumption	Category 1 (high risk)	Category 2 (medium risk)	Category 3 (low risk)
Offal such as blood, kidneys, liver, and other edible parts	Skin and bones for the production of collagen and gelatine	TSE-material Specified risk material	Digestive tract content. Animals deceased other than from slaughter	Suitable for consumption but not intended for consumption

The edible by-product yield from the slaughter industry varies depending on the type of animal, for cattle it is 12% and for pigs, it is 14%. This also depends on the gender and weight of the living animal for example. A small animal will give a lower yield than a big animal since the weight of the by-products is relatively constant between animals (Ockerman and L.Hansen, 2000).

Economy

Currently, a part of the offal and by-products from the slaughter industry are exported to other countries for human consumption. One reason for this is the weak Swedish market, both in an economic aspect but also a cultural aspect (Alsterberg, 2012). Almost half of the edible by-products did not become food in 2020 (Jordbruksverket, 2024). There is one exception, the sweetbread *(Sv: kalvbräss)*, which is seen as a delicacy and the market is therefore big and profitable.

Nutritional composition

The nutritional composition of by-products from slaughter varies depending on which part by-product that is looked at. In general, the by-products are high in desirable nutrients for human consumption, such as proteins and micronutrients including folate, iron, and vitamin A. The iron in meat sources is heme-iron which is highly bioavailable for the human body and is therefore easier for the body to absorb. Additionally, the offal contributes to keeping the body more satiated between meals (Coyle and Warwick, 2023). Consumption of offal could also have a negative impact if consumed in excess. Purines, an organic compound, increase the levels of uric acid which can cause hyperuricemia. As a result of an excess intake of purines the risk of developing gout increases (Arrutia et al., 2020). Offal also contains higher levels of heavy metals such as mercury and lead, that will have a negative effect on the human body if overconsumed (Livsmedelsverket, 2023).

Chemical/microbiological perspective

By-products and offal from the slaughter industry consist of living tissue, which makes it favourable for microbial growth. The offal and by-products naturally contain microorganisms and if handled the wrong way, such as a too high storage temperature, the microbial content will start to grow drastically. The microbial content can include pathogenic bacteria such as EHEC, Campylobacter, Salmonella, parasites, and toxins of different types (Livsmedelsverket, 2024b). The risks these could cause for human health if being consumed are being eliminated thanks to the classification, see *Table 6.* There is also an increased risk for heavy metals such as mercury and lead.

Current use

The current use depends on which type of the categories the material belongs to. The edible offal goes to food production and export to other countries. Non-edible by-products from category 1 go to disposal. Materials from categories 2 and 3 materials go to biogas production or production of animal feed for dogs and cats.

Interview

No responsible person from the slaughter industry was interviewed due to lack of resources within the company or no answers upon contacting. Instead, researchers with knowledge within the field were interviewed. The information gathered from the interview originated from a report open to the public with the title *Slutrapport av livsmedelsförluster* (Jordbruksverket, 2024) where slaughterhouses were interviewed in collaboration with the Swedish Board of Agriculture. Talking with one of the participating researchers gave a larger perspective and new insight into the already exciting information.

The report (Jordbruksverket, 2024) defined the products as "something some of the slaughterhouses were able to sell as food for human consumption, for example, the tongue but not the intestinal". Regarding the by-products, blood is seen as the biggest by-product in terms of volume, only very small amounts go to the food industry. Therefore, it is a bigger opportunity for the bigger slaughterhouses to handle and refine the by-products in comparison to the small slaughterhouses. It is an economical question; it does not pay off economically if the volumes are too small. Today the majority of the blood goes to the biofuel industry (HVO), hazardous waste is not included since it goes directly to disposal. For example, the brain of the cattle.

The lungs in addition to the blood are a very big by-product with 87 % of it not going to human consumption. The more common offal products such as kidney, liver and heart did have a good routine for taking care and utilising it for human consumption but could be better. 22 % of the liver did not go to human consumption, to note that those 22 % are not all able to go to human consumption. The liver can be attacked by parasites and will therefore directly go to disposal. It is the by-products and offal that are longer from acceptance and are harder to take care of. The pig cheek was one part that was mentioned as something that could be used for human consumption more effectively, with a weight of 1.2 kg per animal. One other by-product that is of interest is the fats, both tallow and lard. Some already go to the food industry, but a big part goes to biofuel. The researcher also mentions the trade-off, which parts of the industry need certain parts to maintain its current production. In times of crisis competition for this material could be happening.

The by-product of blood and how the industries would take care of the sensitive product with a quantity of 3400 tons is the biggest challenge within the slaughter industry. The source of nutrients such as iron and other minerals would be a good addition to a diet in times of crisis. To be able to provide this a freeze-drying facility in Sweden would be a good addition to the industry. In addition to the good nutritional profile, it would also create a product with a long shelf life due to the low water content.

Innovations connected to the slaughter industry are very regulated due to trade secrets and are not something the researchers investigated but could still conclude that bigger slaughterhouses had bigger opportunities due to better resources and a more stable economy (Informant A, 2024).

Distillers grain

Literature review

Raw material & Industrial description

Distillers' grains come from the production of ethanol or spirits such as, vodka, whisky or similar alcoholic beverages (Lantmännen, 2022). The distillers' grains come from the production step after the initial mass of water, optional starch and yeast has been fermented. The solid residue after that process is the distillers' grains. It is categorised into two different raw materials, firstly wet distillers' grain (WDG), which consists of 33% dry material with soluble substances included in the water. Secondly, dry distillers' grains with soluble (DDGS) and is the remains when the water is removed. This results in a dry material content of 96 %, including the initially soluble substances (Liu and Rosentrater, 2011). The side stream can come from two processes: manufacturing fuel ethanol and distilling alcoholic beverages. The industry of making ethanol fuel or biofuel, has been increasing in the last century considering the need for more resources of renewable energy (Lantmännen, 2022, Liu and Rosentrater, 2011). Hence, more distillers' grains can potentially be produced and utilised. Production for alcoholic beverages follows the regulations regarding food safety and will therefore be a safe side stream from the beginning. The biofuel process needs to follow food safety regulations first to consider the side stream safe to be used in food applications.

Economy

The alcoholic beverages industry in Sweden has been increasing for the last 30 years since the production of alcoholic beverages became deregulated and there was no longer any monopoly of the production within Sweden. However, many of the recently developed distilleries have a smaller production. One of the biggest alcoholic beverage producers in Sweden is The Absolut Company which is also Sweden's largest food exporter (SPAA, 2023). In 2023 they produced 114 million litres of vodka and 99 % of their product was exported (SPAA, 2023, Eriksson, 2023). Also, the bioethanol industry in Sweden has currently two production facilities currently, and only one of them is producing ethanol from grains. In 2022 when producing bioethanol, 200 000 tons of distillers' grain, in the form of feed, is produced (Lantmännen, 2022, Paulsson, 2007). Since DDGS obtains a high protein content it is often used for feeding both cattle and pigs (Sven Bernesson, 2011). The distillers' grains are mostly fed in a wet state, although they can also be dried and used as a concentrated complement to feed mixes (Nationalencyklopedin, 2023a, Roth et al., 2019).

Nutritional composition

The composition of wheat DDGS is made of mainly fibres and protein. The protein content is 29% and the fat and carbohydrate content consists of only 3.4% and 2.6%. The remaining consist of monosaccharides and fibre, lignin and ash. The fibre content includes both soluble and insoluble fibres such as cellulose, hemicellulose and beta-glucan. The monosaccharides consist mainly of xylose and arabinose (Chatzifragkou et al., 2016).

Chemical/microbiological perspective

In DDGS the xylose content consists of 16.7% of the total weight and for WGS it is 18.4%. Xylose can have a laxative effect if the consumed food contains more than 10% of the total weight (Livsmedelsverket, 2024a). However, the chances of it happening are minimal since the distiller grains are an incorporated ingredient in a food item. Wet distillers' grains are low in pH due to fermentation from both yeast and lactic acid bacteria. They will create an acidic environment in the distiller grains. Since the pH is low, it will inhibit the growth of pathogenic bacteria (Lyberg et al., 2013). The WGD is dried with a heat treatment to get DDGS. This could influence some amino acids that the distillers' grains contain, lysine and methionine for example, through a Maillard reaction, making the amino acids not available in a nutritional contest (Lyberg et al., 2013). Mycotoxins can occur in wheat and will be in a concentrated amount when turned into DDGS (Liu and Rosentrater, 2011).

Interviews

The interviews were held with two different companies that utilise wheat. One of them is a distillery that produces vodka, and the other is a biorefinery that produces biofuel made of ethanol. Both have a side stream of distillers' grains.

Distillery

The interviewed person was the R&D manager at the company. She first mentioned that the distillery is handling X % of all the wheat that is produced in Skåne. This means that their raw material for production is fully domestic. During the production, 4 litres of wet distillers' grains are generated from 1 litre of alcohol. At the moment, the wet distillers' grains go as animal feed. Roughly 250.000 cattle and pigs get it daily from the side stream. After the process, the farmer or receiver of the ones handling the wet distillers' grains can also dry the material (which turns it into DDGS) and can after that store the material as dry feed for animals. However, the drying process requires energy and leaves an additional side stream of water that is contaminated. Therefore, it is more valuable to transport the wet distillers' grains to local farms, to provide the animal with both feed and water.

The process is not continuous year-round, there is a longer stop during the summer due to less need of animal feed and a time to do service and maintenance on the factory. The manager also mentions that there is a well-established collaboration with the local farmers in providing feed to their animals. This will ultimately generate wheat for the company's production since the animals generate manure for growing wheat. Therefore, she mentioned that the organisation sees this system as a beneficial cycle. However, she also mentioned if there were a reason for ending up with access WGS due to less meat consumption or a bigger expansion in alcohol production, there would be a need to investigate alternatives to utilise the side stream in a good way.

The distillery does not do any research within the company on their side stream and if there are other ways of utilising the side stream for human consumption. However, they can provide material to external projects and partners. Some project has for example experimented with using the side stream as growing material for different mushroom cultivations. Both to make mushrooms for human consumption or for feed to fish for example. Additionally, there have been some occasions when thesis workers have tried to make bread from the WGS as well.

Historically the WGS or DDGS has not been used as food or a similar context for human consumption. Therefore, it is unclear whether it is allowed to use the side stream for human consumption. That is one of the obstacles to utilise the side stream according to the manager. The other obstacle that is brought up is that the side stream is very acidic, which makes the taste very acidic due to the lactic acid bacteria. Theoretically, it would not be unreasonable to fortify bread with either wet or dry distillers' grains to enhance the protein and fibre content. Now, the storage for the wet distillers' grains is not designed for a food safety perspective at the distillery, so that would implement if the end use of the distillers' grains would go to human consumption.

After both covid and the ongoing war in Ukraine the company has been working with crisis management and looking into what they can do to keep the company running since this food process is a continuous one. If there is an export stop for more than a week regarding the vodka, it would have consequences on the feed supply. This is due to that the production would need to be decreased (Informant A, 2024).

Biorefinery

The interviewed persons from the biofuel-producing company were an environmental manager and a consultant working with sustainability and business policy. The biofuel producer handles grains and starch-rich residual products from the food sector such as bread or similar. With this as raw material, it will generate ethanol that will be provided as biofuel. From the wheat input for the process, one-third of the raw material will become wet distillers' grains. Both the consultant and the manager mentioned that their company are continuously seeking smart solutions to utilise all the side streams in the best way possible. For instance, extracting gluten protein from incoming wheat before processing. By that act, the gluten can go to human consumption. The extraction line has been in use since spring 2023. Although the gluten is extracted from the raw material, the total content of the protein does not only consist of gluten. Therefore, the feed can still be considered as a protein-rich feed that will finish as a dried product.

The main obstacle to use the distillers' grains from the bioethanol producers is regarding food hygiene and since the process is not planned to utilise the distillers' grains as food for human consumption. Also, there is now no clear food innovation or similar idea to utilise the distillers' grains. Therefore, no more efforts have been made to use it for food. At the moment, there are no food research projects that are active, since the raw material does not have a purpose from the beginning to be utilised as food for humans. However, there have been some trials of using the distillers' grain as a substrate for growing mushroom protein, even called mycoprotein. But this is something that is not ongoing, at the moment, it has been put on hold for the last 5 years. At the factory, there are two factory lines in place. One only for grains and another for grains and starch-rich residual products from the food sector such as bread or similar. However, after both lines have been processed, both outputs come together as one side stream called distillers' grains.

Regarding preparation around crisis and in situations of war, according to both participants, there is an existing prerequisite that the company will continue to provide both biofuel and feed during a crisis. This is done by planning to have the raw material coming from domestic sources. In cases of a pandemic, they could also start producing hand disinfection. The consultant also mentioned that they can store raw materials if there is a need for that since they have previously done it, on behalf of the government (Informant B and C, 2024).

Rapeseed cake

Literature review

Raw material & Industrial description

The origin of rapeseed cake comes from rapeseed oil production and is a side stream product from when the raw material, passes through an expeller presser or an oil mill. The remaining product that will not become rapeseed oil consists of proteins, fats, carbohydrates ash and some water in the form of total moister content (Ahlström et al., 2022). The fats in the rapeseed cake will be exposed to oxygen and have a limited shelf life since the seeds have been processed and opened. Therefore, rapeseed cake will be considered as a perishable food item that can go rancid (Bernesson, 2007).

Economy

In 2022, the harvest of rapeseed in the autumn was estimated to be 387,600 tons. This can be seen in *Figure 5* where the amount of harvest also can be seen over time from 1965 (Jordbruksverket, 2023a). The graph also includes spring and autumn rapeseeds, and two other types of oil seeds that are closely related to the rapeseed plant *(Sv: höst- och vårrybs).* According to the graph, the major type of rapeseed is the autumn rapeseed. This is due to its higher growth rate, being more resilient to pests and have a higher yield (Wiklund, 2015, Erlandsson, 2023, Karlsson, 2011). The rapeseed generates approximate. 1 kg per rapeseed oil from 3 kg of seeds, which leads to 2 kg of the side stream (Östbring, 2020). Therefore, two-thirds from the harvest of 2022 could generate possibly 258 400 tons of rapeseed cake.

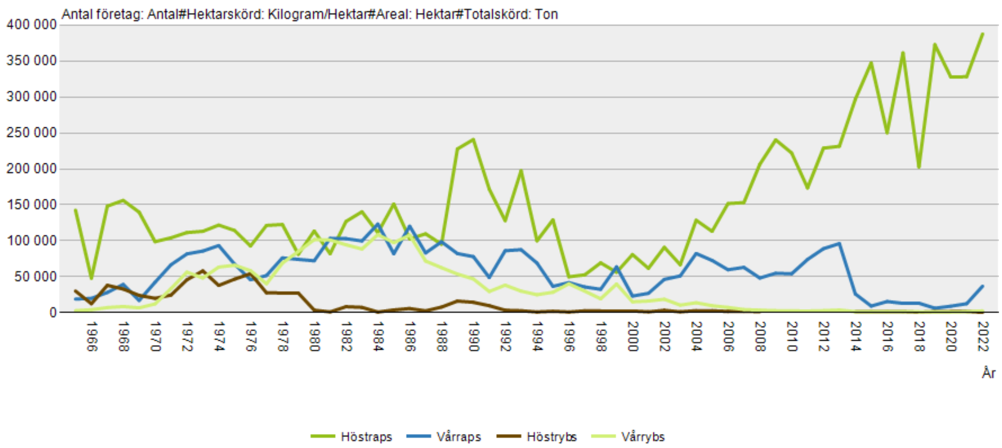

Figure 5: The total harvest of all sorts of rapeseed and rybs in Sweden between 1965-2022 (Jordbruksverket, 2023a).

Current use

The rapeseed cake is used for feed to animals, mainly cattle, pigs, chickens, and to some extent within the fish farming industry (Östbring, 2020). This is due to the beneficial nutritional profile and that rapeseed cake is a local alternative for protein instead of importing soybean meal as feed for example.

Nutritional composition of side stream

The nutritional composition of rapeseed cake is 43% carbohydrates, 13% fats, 29% protein. The remaining percent consists of 9% water and 6% ash. The carbohydrates consist mainly of fibres, about 30% of the total weight (Ahlström et al., 2022). The data regarding the micronutrient content of rapeseed cake is limited. However, rapeseed generally contains a higher amount of potassium and phosphors. The high levels of phosphorus could eventually be due to the exciting amount of phytates that is an antinutrient. Eventual lipid soluble vitamins would probably not be present in the rapeseed cake since it will likely get extracted together with the rapeseed oil (Wanasundara et al., 2017). It could be good to note that these numbers can change between different harvests and other factors. However, since data over larger amounts of rapeseed cake is hard to come by these are the values that will be used in this project, and therefore act as an assumption.

Chemical and microbiological perspective

The main issue regarding rapeseed cake from a nutritional and human-consuming perspective is that it contains antinutrients. Examples of this could be glucosinolate and phytate (Wanasundara et al., 2017). Glucosinolates are a group of compounds that are present in plants such as rapeseed plant, mustard and radish. These compounds can affect thyroid function and therefore have an impact on iodine metabolism (Hill, 2003). However, since the 1980s, the levels of glucosinolates have been reduced through selective breeding of the rapeseed plant (Arrutia et al., 2020). Phytate is a substance that decreases the bioavailability of minerals. In rapeseed cake, it is estimated that it contains 3.16g phytase in 100g dry product (Ahlström et al., 2022). Therefore, it is of importance and interest to end up with a product that has reduced phytate levels. There are methods of reducing the phytate levels such as fermentation or pH manipulation (Erdman, 1979).

Another issue with using rapeseed cake as a food source is that there are chemical aromas that negatively affect the taste. Examples of this is for instance phenolic compounds (Ahlström et al., 2022). Some methods have been successful in removing the unwanted compounds, like wet milling (Baker et al., 2022). Regarding microbiological concerns, the rapeseed cake is regarded as a stable food item, due to the low water content and activity. However, mycoflora can exist in rapeseed cakes and therefore mycotoxins can occur as well (Lanier et al., 2010).

Interview

For this side stream, two interviews were held, one with a company that produces multiple products that are connected to plant oils, where rapeseed oil is one of them. The other interview was with a researcher within the field of utilising press cakes from oilseeds.

Company

The contact at the rapeseed oil-producing company was a process engineer. He mentioned that the majority of the rapeseed that the company is handling is processed to rapeseed oil comes from Sweden. At an amount of around 220,000 tons and has a smaller import input that could fluctuate between 60,000 and 100,000 tons between the production years. Both autumn and spring rapeseed are handled equivalently. The amount is relatively constant in volumes in-between the years, but slowly and steadily increasing. In the process, there are two extraction steps. The first one is when pressing the seeds and the next one is extruding the oil. The press cake comes from the second extraction step and is today used as animal feed. From the extraction step, the rapeseed oil contains lecithin and phospholipids, this is seen as impurities. Therefore, those substances are removed from the oil and put back into the rapeseed cake. This is to enhance the feed with beneficial components and to reuse the substances that otherwise would go to waste. The seeds are going through a heat process to eliminate possible contamination from birds that could carry bacteria such as salmonella. Therefore, it will also denature the proteins in the raw material before the process. The yield from the company is 45% rapeseed oil and 55% rapeseed cake.

The engineer also mentioned that rapeseeds have a specific amino-acid composition that would be suitable in a plant protein-based alternative. Research is ongoing, but there has been no breakthrough yet to fully use it for human consumption. He also mentioned that the taste of rapeseed cake is the main obstacle at the moment, to be able to make rapeseed cake as food for human consumption.

Regarding crisis food supply management within the organisation, he mentioned that the company had shelf-stable oils that were contained in barrels for food preparedness purposes. However, this project was decommissioned in the 90s. The oils stored were rapeseed oil, coconut oil and tallow. The process of rapeseed oil would be possible to continue during a crisis if the infrastructure is working as it should. Nevertheless, to make it possible to make rapeseed cake for human consumption the engineer mentioned that it would be necessary to find a technology, process and product that is convenient and easy enough to produce. Only then it would be possible to make investors finance the process and make the idea a reality (Informant A, 2024).

Researcher

In the interview with the researcher, she agrees that it is a good idea to utilise rapeseed cake as a protein source. This is due to that rapeseed cake has good potential to be used in food applications, both regarding the nutritional and food technical aspect. However, the main problem with utilising rapeseed cake at the moment, is regarding antinutrient compounds. The compounds can inhibit mineral uptake when consuming certain foods. The antinutrients contribute to the sensorial aspect as well, which means that it does not taste good when consumed.

Using the rapeseed cake as a flour in food applications is an option depending on what type of applications the ingredient is aimed for, in the case where the antinutrient has been decreased. Apart from that, the flour would contain a lot of fibre, which would affect the functionality of a food application, from a food technical point of view. Although, the researcher mentioned that protein extraction from the rapeseed cake is the best method of utilising the proteins in the rapeseed cake. This is due to nutrition-wise; the protein contains all the essential amino acids which makes it a high-quality protein. The extracted content obtains good functional aspects regarding food technical aspects as well.

The process of making extracted rapeseed protein would be an inexpensive method to perform since it is based on the same method as when you extract soy protein for example. The

researcher could not give an amount of what the yield of extracting protein from the protein cake would be. It would be recommended that the protein is best suited for meat or dairy analogues if overcoming the obstacles.
In other oilseed cakes, like hemp for example, there is an existing method that extracts the unwanted substances, but the same method does not work for rapeseed. There is no universal method to work with to remove phytic acid. It is unknown why it is like this, but this is something that is being researched. However, the levels are not down to the desired amount yet.

Fermentation could eventually be a method of reducing antinutrients and substances that affect the bitter taste. However, it is difficult since microorganisms can outcompete each other and thereby inhibit the effect, and there is no single microorganism that can solve all the problems. She mentioned that it is also illegal to put phytase in food items that are aimed at human consumption within the EU, at the moment. The researcher did not know why and did not see how it would be dangerous to consume phytase for humans. This is due to that it is naturally occurring in sprouted beans for example, that humans normally consume. Soaking can potentially reduce the antinutrients that are water-soluble. Independent of what type of extrusion, the good fatty acids/fat will remain in the finished product. The existing fat can be seen as an impurity from a food technical and processing point of view since it depends on the application of the press cake material.

One point that the researcher mentioned that could be a good thing to note was that there is a difference between the raw material that the press cake consists of. i.e. if the rapeseed has been pressed at cold or warm temperatures. If the material has been pressed at higher temperatures, the proteins within the material have denaturised and will therefore have different characteristics from a food technical perspective compared to if the material has been exposed to colder temperatures. However, the denaturated proteins can still be consumed by humans. How difficult it is to extract the antinutrients from the press cake if it has been pressed at warm or cold temperatures is unknown (Informant B, 2024).

Skim milk powder

Literature review

Raw material and Industrial description

Skim milk powder is a result of the process where skim milk is separated from the high-fat cream. The skim milk is later treated in a drying process where the water is removed, often in a spray drier. In the spray drier, the skim milk is exposed to hot air in a drying chamber and some seconds in the air, it is transformed into solid particles before it hits the ground. This gives the product of skim milk powder with a low water content (Singh and Heldman, 2014).

The powder also goes through agglomeration technology, where the small particles are joined together into bigger particles associations. This makes it possible to dissolve the powder in for example water and therefore the dispersibility of the powder increases. In addition to the increased solubility, the technology also reduces the dust and therefore the risk of contamination upon handling, (Sharma et al., 2012).

Economy

The dairy production in Sweden is big and in 2022 the total amount of milk was 2 765 000 tons, which is equivalent to 7 500 tons each day (Jordbruksverket, 2023b). Of this amount, different types of dairy products were produced, such as heavy cream, cheese, and regular homogenised milk with different fat content. There was also a increase with 139% in the production of skim milk powder and between 2005 and 2014. The majority of the skim milk powder produced in Sweden is exported to countries all around the world, such as China, Oman, and parts of Africa (Jordbruksaktuellt, 2015). In Europe the skim milk powder is mostly exported to Germany, Poland, and the Netherlands.

Nutritional composition

Skim milk powder has all the nutritional components regular milk has but with a maximum fat content of 1.5% and no fat-soluble vitamins such as A and D. In addition to the low-fat content, it contains a mean composition of 51% carbohydrates and 35 % protein. The carbohydrates consist exclusively of the milk sugar lactose. The proteins include both casein (27%) and whey (6.6%), and the amino acid composition will provide all the essential amino acids needed for the body (Kim and Lee, 2021). The carbohydrate content of the side stream could be a limiting factor for people with lactose intolerance if not pre-treated with filters and enzymes (De Gregorio et al., 2023).

Chemical/microbiological perspective

As a result of a drying process, the water activity of the product is drastically reduced. At 25 °C, the water activity is 0.24-0.30 (Pugliese et al., 2017). Pure water has a water activity of 1. This low water activity inhibits the growth of both bacteria and fungi, which is preferable during long-time storage. Skim milk powder is seen as a stable food and has an average shelf life of 2 years. Due to the drying and exposure to heat, the skim milk may undergo non-enzymatic browning also called Maillard reactions. This happens in the presence of reducing sugars, lactose, and amino groups, with the essential amino acid lysine (Brands and van Boekel, 2003). This reaction can also happen during long-time storage in temperatures between 5-10 °C but at a slower rate (Porretta, 1992). As a result of this, the essential amino acid lysine is broken down, which could have a negative health effect if consumed in big quantities, since there would be a decrease of the intake of the essential amino acid.

Current use

Of the total amount of produced milk in Sweden, 23 % of the milk is used for different types of milk powder, including skim milk powder. Skim milk powder is currently not included in the Swedish food system to the extent that it can be found in stores. The biggest facility in Sweden produces each year 63,000 tons of milk powder, this includes both whole milk powder and skim milk powder. It is currently used as an ingredient in a lot of food applications, such as protein drinks, cheese, and the biggest market infant nutrition. It is used in both dairy and non-dairy products to improve flavour and/or colour. It can also be used to improve the formulation of a specific food product by changing the emulsifying, solubility, and water-binding ability of a specific food product (Sharma et al., 2012).

Interview

Company

The interviewed persons were first a balance manager, which includes everything from controlling all the incoming milk to the factory to the milk product that is going to be exported to other countries or different industry customers. The second person was a farm quality and environmental manager. They mentioned that the company only handles milk from Swedish farmers as their raw material. Some of the products from the mainstream go to export within Europe but the majority are kept in Sweden. Products are also sold within Sweden to other production facilities that will do further processes. Skim milk is produced as a side stream when the fat and protein are separated, and a lot goes back into the production and formulations of products. The balance manager mentioned that the company is only producing skim milk, which is further sold to companies that have the facility to dry it into skim milk powder. Approximately 10 % of the milk becomes skim milk and the value that goes into the production fluctuates from year to year. This is due to the quantities of what is milked at the farms and what is demanded from the dairy industry.

Even though skim milk powder is exported, the environmental manager mentioned that they are always looking for domestic companies that want to handle the stream. This is both due to the transport costs and since it is seen as a positive aspect to have Swedish ingredients in domestic products. Foreign companies do not take those aspects into account. The market in Sweden for skim milk is described as limited because of the few production facilities that can process skim milk into skim milk powder, only two are active today. The Swedish market is dominated by heavy cream and other products with higher fat content, creating an excess of skim milk that needs to be sold for economic reasons. Would the demand for regular milk or lean dairy products be bigger, it could be more than possible to keep the skim milk within the production. This could for example be a production of mozzarella cheese.

The balance manager mentioned that the company works with crisis food supply management, but to what extent is unknown for the ones interviewed, since the persons interviewed do not actively work with crisis management within their positions. The possibility of selling skim milk powder directly to the consumer is seen as something that is not likely in the bigger picture. Whole milk powder is a better alternative, and the production facility is set to handle a switch, where the production would be able to blend out the whole milk powder with water if there is a lack of milk (Informants A and B, 2024).

Interview - The Swedish Food Agency

The Swedish Food Agency was interviewed after the interviews with companies and researchers were finalised, to give clarity to questions that appeared in connection to the interviews.

Food always needs to be safe for consumption, this applies both in peacetimes and in crisis. To introduce a new food item on the market, there is no regulation in Sweden or in the EU that approves new food items. Instead, it must be a record of it being consumed in Europe before a certain date. If it is not, the food will be classified as a new food item. Still, the facility and industry need to be registered for producing a type of food or beverage. If the industries were to start to refine a side stream, a new registration needs to take place. After registration, the council has the responsibility to control the facility with the principle of HACCP (Hazard Analysis Critical Control Points). The councils have the responsibility to control all the food facilities except the slaughter industries, that is the Swedish Food Authorities responsible. The most important factor is that the raw material needs to be intended to be used as food for human consumption or as animal feed. For example, in wheat, there are controls in the primary production out on the fields to measure the levels of heavy metals. This is not done with wheat which is intended for biofuel production. There are controls for animal feed and for human consumption, so the animals do not get bad feed which in later stages could affect humans.

The aim is always that Sweden will function in the same way under peace as under crisis. The Swedish Food Authority in collaboration with the councils have a responsibility in the food sector to work with preparation in case of a crisis. The same applies to the limit of mycotoxins, heavy metals, and pesticides. The limit value is the same in peace as in war. Since this cannot be tested in a real-life scenario, these regulations could change. The war in Ukraine is an example of that, the EU has expedited and changed some regulations to make production easier, one specific case is connected to labelling on food packaging (Informant A, 2024).

Discussion

Under this section will the results be discussed under four sub-headings. Nutritional content and the calculations made, Problems and challenges connected to the streams, The food industry's role in a crisis followed by food industries utilising its side streams and lastly potential development areas.

Discussion of nutritional content

The nutritional calculations of the six side streams that can be seen in Table 3 show that it is possible to get sufficient nutrition from the streams. The biggest stream is the rapeseed cake with a quantity of 146 667 tons, which also contributes to the highest number calories of protein and dietary fibres. The highest levels of carbohydrates have their origin from the wheat bran and distiller grains contribute with the biggest fraction of fat. This is with the disclaimer that every molecule from the streams that can be used for consumption is considered in the nutritional calculations. This is impossible in a real-life scenario since there will always be losses.

The biggest fraction of nutrients is provided by protein, followed by fat, carbohydrates, and lastly dietary fibres. This shows that the macronutrients are all present in all the streams combined. Calculations of the energy percentage in comparison to the Nordic nutritional recommendations (NNR 2024) show that a fraction of calories will be covered by these side streams. In total the streams included in this thesis could provide 380 kcal per day per capita. resulting in a 15.5 % nutritional coverage of the total nutritional need every day in times of crises, 2450 kcal. This is assumed that people have an omnivore diet, in a vegetarian or vegan diet these numbers decrease to 13.2% respective 11.4%. This thesis only includes nutrients from a selection of specific side streams and companies, the actual potential could be much larger.

Discussion of problems and challenges

The interviewed companies presented challenges and/or problems for utilising side streams to human consumption. See *Table 7* for a summary of each stream's challenges and/or problems.

Table 7: Summary of challenges and/or problems connected to each side or export stream

Side streams	Challenges/Problems
Bran from cereals	economical, sensorics, toxins
Brewers spent grain	anti-nutrient, sensorics, economical
By-products from slaughter	economical, sensorics, cultural
Distillers' grains	anti-nutrient, sensorics, economical,
Rapeseed cake	anti-nutrient, sensorics, economical
Skim milk powder	economical

The different challenges varied between the side streams, but the recurrent problem was the economic obstacles. The products are of low value and the demand is low, this applies to both the wheat bran and slaughter by-products. Further, the process for handling the side streams is expensive and it is therefore, not feasible to continue the production line, even though the nutritional profile for the side stream is very good.

Antinutrients have been a big problem in some of the side streams according to researchers. The high levels of for example phytic acid reduce the bioavailability of nutrients, for instance, iron which could lead to deficiency. Therefore, technologies that reduce the levels of antinutrients on an industrial level need to be implemented before the actual consumption of some side streams would be possible. However, there is for example no known method to remove phytase in rapeseed cake. Hence, more research needs to be done before the possibility of a method removing antinutrients in the industry.

A recurrent problem was the sensory challenges. This was something the industries connected to wheat bran, BSG, DDGS, and rapeseed cake all mentioned. The main factors are taste and appearance, especially when these materials act as food ingredients. Wheat bran and distiller grains, with their high fibre content, change the taste and appearance if added in for instance, bread. Distiller grains also contain a high level of lactic acid bacteria which result in a very sour taste. A solution to the taste challenge could be to add smaller amounts of the side streams into the food items and therefore enrich the product by increasing the nutritional value. The sensory experience could also be connected to the antinutrient content, especially in rapeseed cake. Therefore, two problems would be solved if antinutrients were to be reduced.

As in all industries, there are regulations in the food industry that also need to be considered to keep food safe to consume. Therefore, it is easier for industries to cultivate cereals for biofuel production since the regulations regarding levels of heavy metals and toxins are much lower or even non-existent. This could cause difficulties if there would be a shortage of food. According to the interview with the Swedish Food Agency it is important to keep these regulations strict in times of crisis to minimise the risk of damaging the health of the population. They stated that the quality and safety work regarding food shall remain as it does during times of peace. Hence, it is not possible to have or plan on implementing new regulations just because of times of crisis emerging. In the long run, it could affect other sectors in the societies negatively and demand resources that would be needed in other places, this also applies to the slaughter industries. The regulations regarding what could be consumed or not are very strict and once again something that is not possible to change. Even though the nutritional values are good, and the quantities are big, the consequences of consuming contaminated material would be crucial and devastating. A scenario where these items would need to be consumed because of a food shortage is very unlikely to happen.

The challenges and problems connected to the side streams also come with opportunities and consequences when utilising the actual streams. Therefore, there needs to be an analysis before considering allocating the side or export streams. The opportunities of utilising the side streams produced within Sweden have some potential, depending on which of the side streams are being focused on. If obstacles are eliminated such as antinutrients, heavy metals and toxins and if the streams would be more economically profitable, it could be an opportunity to make use of a larger amount of food for a bigger population.

Food industries and its role in a crisis

At the moment, some of the raw materials of the side streams are being imported to the Swedish food industry. When comparing the two beer-producing companies, one of them imports their raw material and the other one uses domestic. This means that in times of crisis and if the import is coming to a halt, it would only be possible to use the BSG from one of the companies within Sweden. Which would reduce the total amount in *Table 3* presented in the results. The streams whose raw materials come from domestic sources are by-products from slaughter, wheat bran and skim milk powder. Since those streams are produced in a surplus, it could be beneficial to prioritise how to utilise them. However, rapeseed oil production generates the largest volumes of side stream, and if obstacles were solved it could generate large amounts of food. If there were an export stop, the vodka industry would be the most vulnerable since it would lead to a production stop. This is due to that vodka is Sweden's largest exported food product. Therefore, it could lead to having a large excess amount of unused wheat. Hence, a plan to produce the right amount, but also to shift the intended original use to something else, like disinfectant for example would be recommended.

Food industries utilising own side streams in a crisis

The last question during the interviews discussed how realistic it would be to utilise the side streams to human consumption as a preventative measure. To sum up, it seemed that it was not realistic now for the industries to utilise their side stream for human consumption. This is due to all the previously mentioned challenges as well as the orientation of the company itself. One example of this is with the beverage industries that were interviewed. Since they are a beverage-producing company, it is not within their process design to start handling solid material to produce milled flour of brewer spent grains or distiller grains to sell to other stakeholders.

Some of the interviewed companies would be able to convert their production line to human consumption. Although, to be able to implement it in their processing line, they would need to make sure that it is safe for human consumption and that it is approved by the commune that follows the safety regulations of the Swedish Food Agency. That could be a large investment for the company, as well as there would be new employers needed for that expansion, which would result in more costs. This scenario would eventually occur if the demand increased due to a crisis and with the help of additional resources and investment from, for instance, the government were implemented. However, many of the interviewed companies were willing to let their side stream go to external companies that would produce and utilise them. Although, then there would be additional things to consider, such as transportation and its cost. It needs to be considered if it would be feasible to transport the side stream and guarantee food safety. This is due to that many of the side streams have a short shelf-life. It would put a requirement on the external company not to be too far away from the industry where the side stream is produced. Another factor could be that the flow of the side stream is not continuous. This will then have consequences that will not be sustainable since their business idea would be highly dependent on another process, which would make both income and employment unstable.

Potential development areas

When it comes to the relocation of products made within Sweden's borders it is of advantage to be able to use the exported product within its borders as well. If there is a major import stop to a specific external country outside of Sweden, the industry can eventually encounter complications. Examples of complications could be having an excess amount of skim milk powder. If it is not possible to increase the skim milk content in products that already contain skim milk powder, it could be an alternative to investigate solutions that are applicable in a crisis. For instance, the possibility to instead utilise the milk by producing whole milk powder. The use would broaden, and more people would use it since more households are more willing to consume and utilise whole milk powder since it also contains fat and fat-soluble vitamins.

Apart from the implementation mentioned in both literature review and interviews, there have been some alternative usage areas that have appeared as suggestions during the period this thesis has been conducted. The first suggestion is utilising multiple of the grains side streams, such as BSG, DDGS, and wheat bran for example, as growing substrates for mycoprotein. Mycoprotein is a mushroom that has been presented as a vegetable protein alternative. Why this could be a potential food source in a preparation system is firstly because mycoprotein obtains a complete amino acid profile. However, it needs to be investigated about the storage possibilities of this protein alternative. The second suggestion is to combine the streams into a dough to form energy-dense cookies that have a long shelf life and contain all the macronutrients needed including a complete amino acid profile. The only side streams that would be excluded would be by-products of slaughter. However, it will contain a substantial amount of fibre, hence, the consumer would feel satiety. Moreover, to be able to consume it due to the sensorial aspect, domestic ingredients such as flour, sugar, and fat such as rapeseed oil should be added. To obtain more flavour, carrots could be an additional ingredient since Sweden is self-sufficient in them. Also, the chocolate alternative that is made of BSG is a great and suitable ingredient to add to this type of product.

Conclusion

There is a potential within the Swedish food industry to utilise side and export streams of big quantities for human consumption with a good nutritional profile. The good nutritional potential in the streams could contribute to Swedish crisis food supply management if handled correctly, *with up to 380 kcal/capita/day i.e. 15.5 % of the daily recommended* intake in terms of macronutrients. The biggest potential is with rapeseed cake, contributing with the largest quantities and highest content of protein.

Problems and challenges connected to the streams need to be solved before consumption can be made possible, some with a larger potential to be solved than others. *Economical aspects, antinutrients, sensory aspects, and regulations* were found as the biggest problems after the literature study and interviews with companies. Therefore, this is something that requires more investigation, both through research and innovation, which the results from this thesis could build the basis for.

An increase in the value of the different possible food items that originate from the side and export streams would be advantageous for the domestic food industry, taking Sweden one step closer to being more self-sufficient. Something that both the literature review and the interviews showed. The handling of large quantities is done by the food industries which includes being prepared with the right equipment and knowledge connected to the production line, so it is safe for processing food for human consumption.

Future research

For future research, it could be of interest to include more companies to get larger quantities of the streams. Including other streams that were not included in this thesis would also give a new perspective. Calculations of the micronutrients would also be a suggestion for future research on its importance for the human body. A more practical work is to do a real bar for crisis "kriskaka" with almost all investigated streams. The practical work could aim to include sensory tests with consumers to get a better knowledge of the acceptance among a group of people in society.

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Appendix

Appendix 1- Question guide for interviews

Introduction

1. Would you like to start and tell us which company you are and your primary function, both you and the company?

Theme 1: Side stream

1. From where does the company get the raw material from? Is there an eventual import of the raw material?
2. Is there an eventual export of the side stream?
3. Which side streams does the company have from the production?
4. What is currently happening with the side stream?
5. With the production of your mainstream, how big is the yield? In tons, litres, or percent.
6. Is the value of the side streams constant or is there a fluctuation between different years?
7. How does the company work with the side streams today? What types of ideas, innovation, or similar can be done with the side stream today?
8. What are currently the obstacles to being able to use the side streams as an ingredient in human consumption?

Theme 2: Crisis

1. Does the company work with crisis food supply management? If yes, in which way?
2. In what way could you as a food industry contribute to society in times of a crisis? For example, if there would be war in the nearby area or eventual import/export stop.
3. How would you motivate the realism to implement the production of human consumption of the side stream in the company's production line today?

Appendix 2- Complete nutritional calculations linked with Excel

		Quantaties in tons	number comes from:		Carbs (ton)	Calories C	Fat (ton)
	Bran	70 000	company		39760	1,59E+11	3010
	BSG (dry)	26 667	litterature		0	0	2266,695
	By-product (average)	37 000	litterature		1469	5,88E+09	16550
	Rapeseed cake	146 667	company		19067	7,63E+10	19067
	Distillers grains (dry)	75 620	litterature		1966	7,86E+09	2571
	Skim milk powder	43 000	litterature		21930	8,77E+10	645
	Total				84191,83	92,26501918	44109,485
	Calories/capita/day						
	% of the daily intake in times of crisis						
	Carbs	4					
	Fats	9					
	Protein	4					
	Dietary fibers	2					
	1ton=	1 000 000					
	Citizen	10 000 000					
	Days/year	365					