Food waste in bakeries- quantities, causes and treatment

Matsvinn i bagerier – mängder, orsaker och behandling

Maryna Iakovlieva

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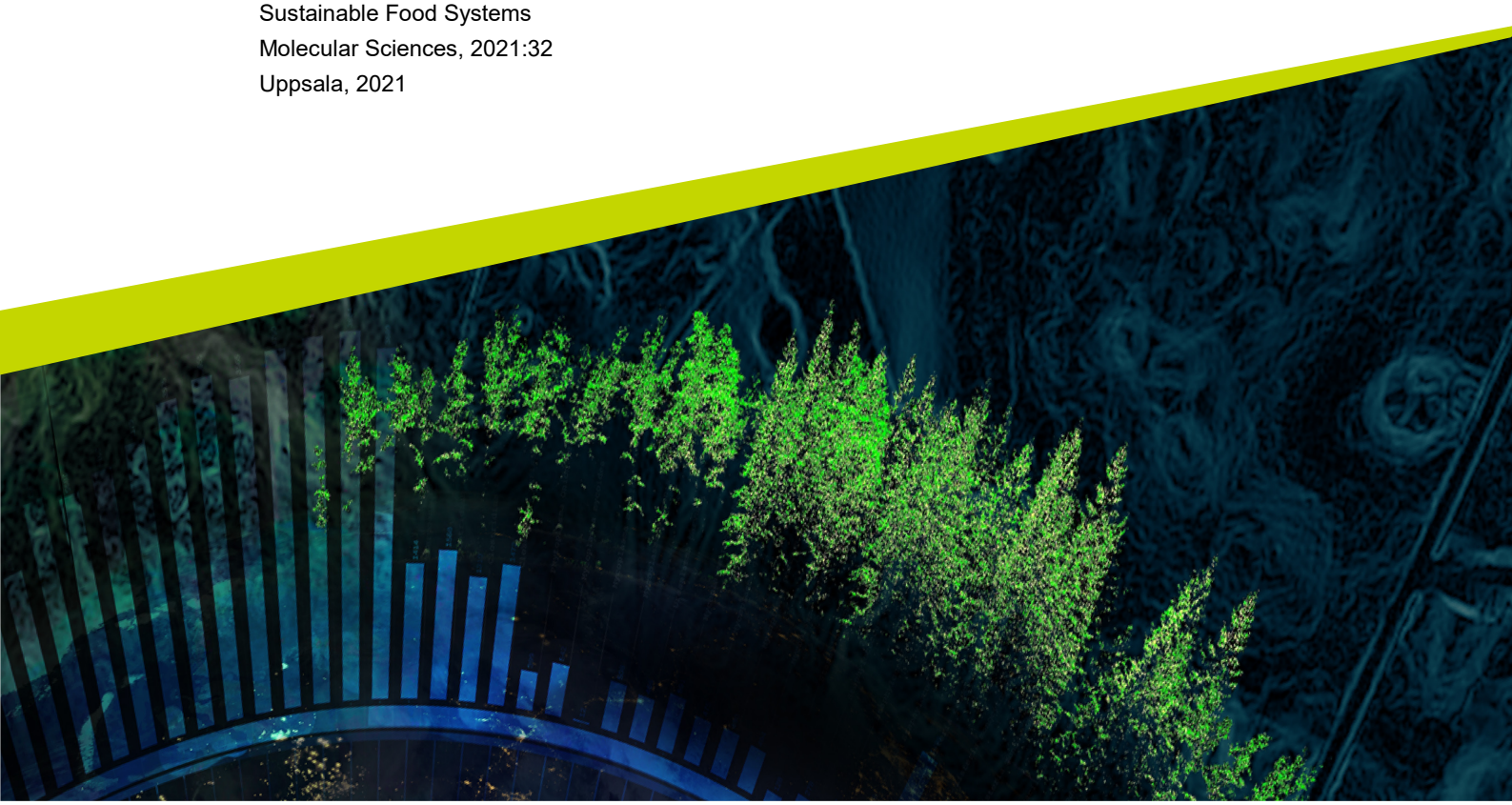

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Maryna Iakovlieva

Supervisor:	Mattias Eriksson, Swedish University of Agricultural Sciences, Department of Energy and Technology
Examiner:	Pernilla Tidåker, Swedish University of Agricultural Sciences, Department of Energy and Technology

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Swedish University of Agricultural Sciences
Faculty of Natural resources and Agricultural Sciences
Department of Molecular Science

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Abstract

Bread waste represents a considerable part of food waste in Sweden, and in general, food waste can have a significant impact on the environment. This study assesses the quantity of food waste in bakeries and identifies the main causes of waste during the production of baked products.

A sample was taken from the total number of bakeries in Sweden. In this study, 19 bakeries were analysed. Information for the analysis was obtained through telephone interviews and digital video calls with employees or bakery managers. For three bakeries, the study was also complemented by interviews conducted through face-to-face meetings.

Based on the collected data, this study concluded that bread losses in small bakeries accounted for about 1.5% of total production, and up to 20% of losses in large bakeries, including bread returned from supermarkets. The following reasons were identified as the seven main causes for the loss of bread and bakery products: technical difficulties, equipment failure, equipment repair, incorrect sizes of bread and bakery products during production (shape, low weight), expiration date, incorrect order and return of bread due to low demand. One major cause of the loss of bakery products was also the human factor. All used resources invested in the production of bakery products that are not sold such as water, fertilizers, land and energy, used in the production, transport and storage of food products are also lost.

Improvements to production processes in bakeries are of great importance, which can affect or reduce the amount of bread and bakery products not sold. It is likely that bakeries can adjust orders and forecasts for the amount of bread and baked products produced to minimize the proportion of losses.

Keywords: Bakery waste, bakeries, causes of losses, producers, Swedish bread industry, take-back agreement

Sammanfattning

I Sverige har brödsvinn, liksom matsvinn generellt, en betydande påverkan på miljön. I denna studie kvantifierades mängden svinn av bröd och bakverk i svenska bagerier för att hitta möjliga orsaker till svinn under olika skeden av tillverkningsprocessen. Totalt samlades data in från 19 bagerier genom telefonintervjuer och digitala videosamtal med medarbetare eller chefer på bagerierna. För tre av bagerier gjordes kompletterande intervjuer på plats på bagerierna.

Förlusterna av bröd hos små bagerier var cirka 1,5 % av den totala producerade mängden, samt upp till 20% hos stora bagerier inklusive det bröd som returnerades från livsmedelshandeln. Följande sju problemområden identifierades som huvudsakliga orsaker till att bröd och bakverk kasserades: tekniska svårigheter, fel på utrustning, reparation av utrustning, felaktiga storlekar av bröd och bakverk vid tillverkning, bäst före datum som gått ut, felaktig beställning samt bröd som lämnades tillbaka på grund av låg efterfrågan (returbröd). Ytterligare en viktig orsak till att bröd kasserades var den mänskliga faktorn. Bröd och bakverk som inte blir sålda i butik samlas in och återvinns till bioetanol, vilket medför en ekonomisk förlust för bagerierna. Alla använda resurser som investeras i produktion av bröd och bakverk som inte blir sålda, såsom vatten, gödsel, mark och energi, som används vid produktion, transport och lagring går också förlorade när brödet kasseras.

Förbättringar i distribution och tillverkningsprocesser hos bagerierna har stor betydelse och kan påverka eller minimera mängden bröd och bakverk som kasseras. Förmodligen kan bagerierna korrigera beställningar och prognosen för den producerade mängden av bröd och bakverk för att minimera andel förluster.

Nyckelord: Brödsvinn, bagerier, orsaker till förluster, producenter, svenska bagerier, returrätt

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Abbreviations

AFW	Avoidable Food Waste
BW	Bread Waste
EPR	Extended Producer Responsibility
FW	Food Waste
FSC	Food Supply Chain
GHG	Greenhouse Gas
SDG	Sustainable Development Goals
SCP	Sustainable Consumption and Production
SNFA	Swedish National Food Agency *(Livsmedelsverket*)
TBA	Take Back Agreement
UNEP	United Nations Environment Program

1. Introduction

Food waste is a complex phenomenon around the world that is gradually attracting international and national attention from the scientific and professional communities as well as national initiatives (Parfitt *et al*., 2010; European Commission, 2010; Mena *et al*., 2011; Katajajuuri *et al*., 2014; SIANI 2017; Naturvårdsverket, 2018). One-third of the food produced per year is lost or wasted worldwide (European Commission, 2014). According to Goryńska-Goldmann *et al*. (2021), food wastage contributes to environmental damage through emissions of greenhouse gases and other harmful substances released during the production of food. Each kilogram of food waste that is wasted generates approximately 1.6kg of CO_2e on average (Livsmedelsverket, 2020).

Bread waste makes up a significant portion of all food waste, along with fruit, vegetable, dairy, and meat products (Stensgård & Hanssen, 2016). According to Demirci *et al.* (2016) bread is the most commonly wasted product in Europe.

The production of bread and bakery products is widespread all over the world. Global bread production in 2016 was about 130 million tons, and the demand for bread is increasing (Bizcommunity, 2018). A large volume of bread and bakery products is also wasted around the world (Samray *et al.,* 2019), with losses on bakery products amounting to about 10 million tons worldwide (Demirci *et al.,* 2016).

In Sweden, the bakery industry is undergoing major changes. There is a growing interest in home-baked bread, which accounts for about 2% of the total bread volume, but about 98% of all bread consumed is produced by the country's active bakeries (Brödinstitutet, n.d.). The Swedish bakery industry has also seen continuous sales growth, and consumption of bread and confectionery products increased by 47% to 74kg per person between 1980 and 2018 (Jordbruksverket, 2019). In turn, Sweden has the largest range of bread and bakery products in the world (Landgren & Tjernström, 2007). Bread waste is also widespread in Sweden, but data on its quantity is difficult to determine in the supply chain, and the possibility of reducing it depends on the reason for the waste (Rytterstedt, 2008).

A previous study by Brancoli *et al*. (2019) found that bread waste is about 80,000 tons per year in Sweden, equal to 8.1 kg/person/year, and that most waste comes from households. However, another major part comes from retail stores and in

particular, the interface between bakeries and retailers. Brancoli *et al*. (2019) also found that the bread industry alone generates 12,040 tons of bread waste per year.

However, there is a lack of more precise knowledge about food waste in bakeries and its causes. Therefore, it is crucial to gain insight into this stage and to assess the scale of waste that occurs therein. This study will focus on the problem of bakery waste and losses. This is a quite narrow research field and expansion is desirable due to the potential of further research to reduce cost and environmental impact. According to Goryńska-Goldmann *et al.* (2021), the inaccuracy of the data is also related to the fact that the food processing sector is diverse; for this reason, the analysis of food waste requires a separate approach. Therefore, it is important to get a better understanding of this issue and investigate causes and waste prevention to reduce the environmental, social and economic impact related to food waste. Reducing the amount of bakery waste in bakeries will not only save resources and money needed to produce food but can also be used as an appropriate tool to form good habits and attitudes towards waste reduction for future generations.

1.1. Aim and research questions

This study aims to determine the magnitude of bakery waste, its causes and how the waste is managed. The specific research questions are as follows:

- How much bakery product waste occurs at different stages of production and distribution?
- Which are the main causes of bakery products waste generation?
- How is the waste generated in bakeries managed and treated?

1.2. Background

1.2.1. Why reducing food waste is an important aspect of sustainable development

It is necessary and important to reduce waste as part of sustainable development, which includes environmental, economic and social aspects (Loxbo, 2011). From the economic point of view, the value of all food produced in Europe is approximately 344 billion euros (Naturvårdsverket, 2011). The total value of waste is 103 billion euros, and bread has the largest share of this waste compared to other products such as meat, milk and vegetables (Naturvårdsverket, 2011). Food production requires a lot of resources and entails significant emissions (Eriksson, 2012).

In comparison with meat such as beef, bread that mostly consist of wheat has a relatively small environmental footprint (Eriksson & Strid, 2011; Sonesson *et al*.,). The main source of emissions from wheat is the use of commercial fertilizers and diesel fuel. The total estimated greenhouse gas emissions per kilogram of the finished product are 0.5kg CO_2e (Loxbo, 2011). Wheat also requires arable land and water, although significantly less than, for example, meat and dairy products. However, if the wasted mass is large enough, the relatively low costs and environmental footprint per kg will still add up to a large problem.

Less waste results in less use of the earth's resources and fewer emissions. Moreover, industrial processes and transportation contribute to the generation of CO_2 emissions, that together with other greenhouse gases, have the potential to impact the climate (Sonesson *et al.,* 2010). Thus, food industry actors need to be more aware that waste leads to inefficient use of resources and that reducing waste is economically beneficial.

1.2.2. Definition of food losses and food waste

To quantify food waste, we first need to understand what should be included in the quantification. The food itself consists of a large group of products, and it is very difficult to find a common definition that is suitable for all purposes. Furthermore, a process that turns food into waste involves a variety of situations and unforeseen actions. In the literature, food losses are defined in different ways. According to Dora *et al*. (2019), food loss is part of raw materials or products that is edible but somehow lost for human consumption. Moreover, food loss is then described as decreases in the quantity or quality of food (FAO, 2011).

Food loss and waste occur at various stages of the food supply chain, such as harvesting, post-harvest, processing and distribution (FAO, 2011). Therefore, there are a lot of terms for similar phenomena such as "food loss" (e.g., FAO, 2011; Dora *et al.*, 2019), "food waste" (e.g., USEPA, 2015), etc. However, numerous definitions are used to describe food waste (Eriksson *et al.,* 2017). A common definition of food waste is the one developed by the EU project FUSION (Östergren *et al*., 2014).

According to Östergren *et al.* (2014), "*food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including the following destinations: composting, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co- generation, incineration, disposal to sewer, landfill or discarded to sea)".*

As the definition indicates, even though the food waste may be used for bioenergy production or other purposes, it is still food waste as it was originally intended for human consumption. In the food industry, there is no commonly used definition of bakery waste, but the most common one refers to the loss of material (Lagerberg & Fogelberg, 2001). Waste can be regulated from different

perspectives, and there are several options for what should be included in the definition of waste (Loxbo, 2011). The definition of waste usually depends on which parts of the supply chain are being investigated. However, since the definition used by Östergren *et al.* (2014) is fully applicable to the bread industry, it is used in this study. Also, since food waste is often difficult to clearly distinguish from food losses (especially in later stages in the supply chain) these are used synonymously in this study.

1.2.3. Food waste and management

Over time, many researchers and companies have tried to find better alternatives to reduce waste. In practice, most of the bread that is not consumed is usually disposed of as food waste (Verni *et al.,* 2020). In addition, as stated by Lebersorger & Schneider (2014), "food losses are a total quantity of food items that have not been sold and were returned with different causes, such as packaging defects, the expiry date or the date of sales". Bread waste can be used for recovery–anaerobic digestion, animal feed, as a substrate for production of yeast for baking products, and biofuels (Pietrzak & Kawa-Rygielska, 2014; Östergren *et al*., 2014; Cerda *et al*., 2016; Pågen, 2017; Polarbröd, 2019). Yet while all practical alternatives could compensate for the environmental impact, none of them compensates for the economic losses.

Food waste prevention is an important issue to improve food security and resource management at the planning and implementation level (Zorpas & Lasaridi, 2013). The European Union has decided to focus sharply on reducing food waste (Eriksson *et al*., 2017; EPRS, 2017; Adessi *et al*., 2018; Partiha Caldeira *et al.,* 2019). Furthermore, according to Extended Producer Responsibility (EPR), "[the] *European waste management sector could be described as a 'collect and dispose of' operation, collecting mixed waste streams from municipal and commercial sources and disposing of the waste to landfill or through incineration*" (2017:15). The European priority is based on the 1999 EU Landfill Directive and the waste hierarchy.

The basic conceptual framework that lies behind the waste hierarchy with the Directive on Waste was introduced into European policy in the 1970s (Papargyropoulou *et al.,* 2014). Sometime later, the waste hierarchy was introduced into European law and has since been adopted worldwide. The waste hierarchy consists of five stages– prevention, reuse, recycling, energy recovery and disposal– which are shown in Figure 1 (ibid.). The aim is to reach the waste reduction stage at the top of the hierarchy. The hierarchy states that preventing food waste by reducing waste is the most beneficial alternative while the least useful option is disposal (Papargyropoulou *et al.,* 2014).

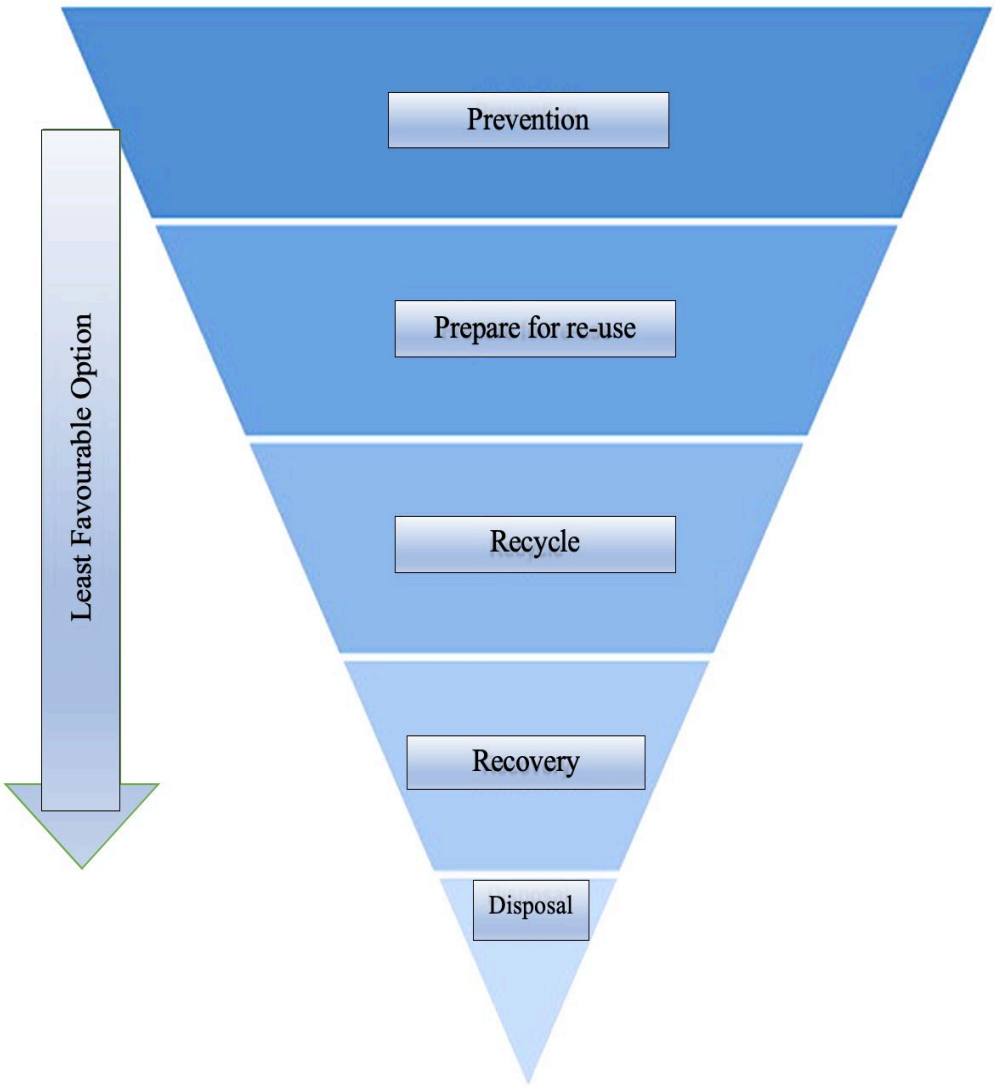

Figure 1. The waste hierarchy. (Adapted from Papargyropoulou et al., 2014).

In a broad context, preventive 'actions' may be of various types, and a waste hierarchy is a series of measures for the management of waste, through various degrees of renewal of the value of the product (Alexander *et al*., 2013).

Furthermore, the United Nations 2030 Agenda for Sustainable Development contains 17 Sustainable Development Goals (SDGs) (UNEP, 2015; UN, 2015a). Food waste is part of the Sustainable Development Goals 12.3 that state that, *"By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses".* This is not only considering a reduction in food waste and losses at the consumer and retail level but also a reduction in losses through the production and supply chain (UN, 2015b). The goal is to enhance sustainable consumption and production (SCP). Further, there are two ways to deal with bread waste. The first is to trim the flow of food production to avoid overproduction. The second is to treat

food waste (if it appears) optimally and rationally to recover as much as possible of the resources and value invested in the product.

Moreover, in many countries, food waste is sent to landfill, but in Sweden, this practice was abandoned after the implementation of Directive 1999/31/EC. In 2001, this led to the closure of a large number of landfills (Eriksson *et al.,* 2017; Andersson, 2015). The Swedish government's current goal is to reduce food waste across the entire food supply chain (Regeringskansliet, 2018). Reduction of food waste can bring both environmental, economic, and social benefits. It also reduces the burden on the climate, use of land and water and makes it possible to feed more people and increase profits due to the reduction in waste generation (Gjerris & Gaiani 2013; Brancoli *et al.,* 2019; Goryńska-Goldmann, *et al.,* 2021). Bread waste can be turned into biofuels, animal feed and yeast, for example, but doing so still causes a loss of economic means since it is downgrading resources (Brancoli *et al*., 2020). The waste hierarchy needs to be reviewed as it is not addressing inefficiencies in production (Papargyropoulou *et al*., 2014).

Food waste must be kept to a minimum to achieve a more sustainable supply chain (Eriksson *et al.,* 2017). This means that global efforts to combat hunger can focus on preventing production losses and waste in both low-and high-income countries. Therefore, by definition, it would be good to sell all of the goods produced (Papargyropoulou *et al*., 2014).

1.2.4. Who makes bakery products?

Different bakery companies usually produce and sell fresh bread and bakery products on the market (Rush, n.d.). In Sweden, there are three main bakery companies, Pågen, Fazer and Polarbröd, which represent 80% of the Swedish market as displayed in Table 1 (Nielsen, 2021).

Table 1. Market share in the Swedish food supply chain of bakery products

Company /Bakery	Market share (%)
Pågen	38.4
Fazer	18.4
Polarbröd	23.1
Private labels	8.5
Others	11.6

Often private label products are produced by one bakery industry but are sold under the label of the retailer (Brancoli *et.al.,* 2019). The local bakeries sell most of the bread via retailers ICA, COOP, etc. (Brödinstitutet, n.d.). Local bakeries account for about 10%, while traditional bakeries (that bake and sell their bread in their own stores) have approximately 2-3% of the market share. Also, some retail stores bake their own bread within the store and such businesses account for about 5% of the Swedish bakery market (Brödinstitutet, n.d.).

1.2.5. Take-back agreement

There is one specific business model that is commonly used in the Swedish bread market to distribute bread from bakeries to retailers (Ghosh & Eriksson, 2019). A take-back agreement (TBA) is a trade practice in which the supplier takes full responsibility for unsold bread at the retailer (Lebersorger & Scheider, 2014). In other words, the manufacturer must pick up leftover bread products, such as unsold bread, even before the expiration date (Ghosh & Eriksson, 2019). In addition, the manufacturer is responsible for the placement of bread on the store shelves within the supermarkets as well as ordering and forecasting the future demand for bread. Bakeries also take care of the logistical issue of removing unsold bread from the store shelves and transporting this bread for waste management (Brancoli *et al*., 2019). Approximately half of the bread and bakery products sold in Swedish supermarkets are subjected to TBAs (Brancoli *et al.,* 2019). The bread products that are delivered in large quantities to the shops have the largest impact on the total waste in terms of mass, even though the relative waste of these products can be fairly small due to the large volumes sold (ibid.).

Since the TBA gives no incentive or power to the supermarket to handle the bread waste, this is normally something that is handled solely by the bakery. This means that bread that is subject to a TBA is not donated to charity or sold for a reduced price by the retailer, since the retailer does not own the bread (Ghosh & Eriksson, 2019). Due to this practice, the relationship between the supplier and the retail chain is also not very transparent since the cost of waste management is often seen as a trade secret, making it difficult for researchers–as well as retailers that could be a key actor to fight this waste–to estimate the actual amounts of bread wasted.

However, not all bakeries have this type of agreement with retailers, so the form of contracts may differ (Eriksson *et al*., 2017). Private label products are usually produced without TBAs since they are produced exclusively for a retailer (Brancoli *et al.,* 2019). Bread or bakery products that have been ordered by retailers or made by private bakeries are usually sold to retailers, who have full financial responsibility for the bread and bakery products. In this contract, bread without a TBA can be reused, donated or sold for a reduced price by the supermarket to reduce waste (ibid.).

1.2.6. Classification of bakeries and organization of the production process

All bakeries from small to large scale are challenged by the same issues according to Erasmus plus (2018):

- To achieve higher standards (quality, nutrition values and safety/health)

- Extended shelf life for bread
- Lack of knowledge within the working staff
- Difficulty finding responsible persons (staff training).

Consumers prefer to buy fresh, high-quality and safe bakery products that are produced by the traditional baking method and have an even longer shelf life (Erasmus plus, 2018). This practice includes a fermentation process of the dough that takes place over a longer period. This allows carbohydrates to be converted into alcohol and carbon dioxide, which in turn causes the dough to rise (Perishable news, 2012). In this way, bakery products also become more aromatic tasting, and the shelf life of the final product increases. Therefore, for bread producers, there is always the question of a balance between old and new technologies by providing a better way to satisfy consumer demand (Erasmus plus, 2018). Employees and employers in bakeries usually have the skills and knowledge to engage in the baking process and to work with issues that meet quality and safety standards (*ibid.*).

Bread production is classified in different ways, depending on the capacity of production such as the productivity of the oven (Goryńska-Goldmann *et al*., 2010; Erasmus plus, 2018; Statista, 2021). At the industrial level of bread production, the bakery industry becomes more productive and can contribute to the employment of more than 100 people. The medium-sized bakery companies usually have 15-25 employees and produce and sell their products locally or regionally (Brödinstitutet, n.d.).

There are different stages of bread processing for bakeries, and waste can vary greatly depending on production capacity (Melikoglu & Webb, 2013). For example, large producers usually include many production lines and can be divided into different production zones. In the first stage of bread production, the raw materials are loaded and then the raw materials are mixed. Then the dough is produced, the bread is processed, the bread is baked (depending on the type of industrial furnace), the product is cooled, as well as packaging and final transportation of products. Therefore, the causes of bread waste and production losses can be identified at every stage of the bread-making process. Moreover, for small and medium-sized bakeries, the baking process does not necessarily have to involve a large production process or production lines, making it more difficult to clearly identify the waste from different steps and processes.

1.2.7. Food waste quantities in bakeries

Bread waste and losses have been quantified in a few previous studies (Table 2). In all these studies, different system boundaries, methods and bases of comparison were used in the bread waste quantifications. Moreover, different publications have focused on bread waste in different sectors such as retail, household, restaurants

and school service. Brancoli *et al.* (2019) and Ghosh & Eriksson (2019) present a percentage of bread waste from the manufacturing and retail sectors.

Table 2. Brief review of published data of the percentage of bakery waste in the presented literature

	Reference	Country	Relative bread waste (%)	Basis
Bakery	Brancoli *et al.* (2019)	Sweden	5.2%	of total production
	Goryńska- Goldmann *et al.* (2021)	Poland	2.6%	of total production
	Stensgård & Hanssen (2016)	Norway	1.2%[1]	of total production
	Beretta *et al.* (2013)	Switzerland	5.1%	of total production
	Katajajuuri *et al.* (2014)	Finland	6.5 - 8.5%	of total production
Bake-off	Brancoli *et al*. (2019)	Sweden	8.5%	of total mass delivered
TBA	Brancoli *et al.* (2019)	Sweden	8.8%	of total mass delivered
	Ghosh & Eriksson (2019)	Sweden	30%	of supplied bread loaves

The waste of fresh baked goods was small, only 1.2% of the total bread production in Norway (Stengård & Hansen, 2016). A large percentage of bread waste was found in Sweden (Brancoli *et al*., 2019; Ghosh & Eriksson, 2019). In addition, the percentage of bread waste and loss is 2.6% for Poland (Goryńska-Goldmann *et al*., 2021) and Norway (Stengård & Hansen, 2016). In Finland and Switzerland, losses are reported to be slightly higher (Beretta *et al*., 2013; Katajajuuri *et al.*, 2014). This shows that bakery products are produced and sold with various percentages of waste in different countries. Thus, the quantification of bakery waste in the supply chain showed the importance of taking actions in the production sector to prevent bakery waste.

1.2.8. Causes of bakery waste

Bakery products are food products, the most common of which is bread; however, many other types of baked goods are baked as well. Moreover, food can be wasted for a variety of reasons such as the lack of knowledge about the handling of materials or improper storage where losses may occur as a result of pest infestation (Loxbo, 2011). In the production of bread, the reasons are mainly related to non-

[1] Fresh bakery products

compliance with the quality standard for technical reasons (Rytterstedt, 2008). For example, a common technical reason for waste is that the bread does not have the right weight and shape. Other technical causes of waste are that the bread falls off the production line, problems with packaging or that the bread is not baked properly in the oven. Waste is also caused by an incorrect assessment of consumer demand; if the delivery of bakery products exceeds the demand, it will subsequently lead to the wastage of products (Modin, 2011).

In this study, the waste of baked goods meets the FUSION definition and is counted as food wasted. The common denominator for defining food waste in bakeries is that waste is a material loss that does not reach the end consumer, for example, due to recycling or a process such as recovery.

2. Material and Methods

This section describes the methods used for collecting primary data, as well as a description of the validity and generality of the thesis.

2.1. Data collection and analysis

Information regarding the quantities, causes and treatment of food waste were gathered through interviews. The interviews were conducted in the period from 22 January to 4 March 2021. The semi-structured interviews with bakery manufacturers took from 15 to 50 minutes and were provided at a convenient time for the respondent. All information and data collection was the result of dialogue with bakery representatives. Three physical interviews with producers of bread were conducted, while all others were done through telephone or video conferences.

In total, 48 bakeries were approached with questions regarding bread waste quantities and causes, but only 25 of these provided any type of reply. Of the 25 that replied, another 6 bakeries were excluded due to large data gaps. All respondents were situated in Sweden except for one representative from Ukraine. The selection of the interviewed companies was made through a convenience sample where all bakeries of reasonable size that could be found through a simple search on Google search engine were approached. Cafés, convenience stores, supermarkets or other organizations that possibly produce bread as part of their business were not included in the sample.

The interview questions were open-ended, and the wording of the questions was prepared beforehand (Appendix I). During all interviews, notes were made, as well as audio recordings, which allowed more focus on the interview process. Transcription of the interviews was done manually.

Some bakeries preferred to stay anonymous; therefore, it was decided to make all the respondents anonymous. All participating companies were informed of the purpose of the study and that participation was voluntary. The names of the companies are coded with letters, and if several respondents came from the same organization, the number indicates the different representatives, as outlined in Appendix II. Some citations were also confirmed with respondents to validate that they had been correctly interpreted.

2.2. Data processing and quality

2.2.1. Data of food waste quantities

Data about food waste in bakeries was collected from 19 bakeries, the majority of which were small bakeries followed by medium-sized bakeries (Table 3). The study involved 3 large bakeries, 10 small and 6 medium-sized in this study. Of these, only three companies use the TBA business model (Appendix II).

2.2.2. Bread categories in the studied bakeries

The studied companies produce a wide range of bakery products. Their products have a variable shelf-life (up to 7 days) with an average weight from 0.450 to 1.7kg. Fresh bread and packed bread were the main products. Moreover, the quantification of bakery waste considered other breads such as burger buns, pastries, hot dog bread and partial baked bread and rolls. Primary packaging for baked products was often plastic or paper bags. Primary data on bakery waste also contained data on returned bread from the retail sector of the larger bread producers included in the study. To estimate the total mass of bakery waste in the surveyed bakeries, their losses were calculated in relation to the total amount of bakery products produced, and not to the number of bakery products sold. The result was presented as a percentage of the total number of bakery products produced.

3. Results

3.1. Bakery waste quantities

For small and medium-sized bakeries, the reported production waste ranged from 1% to 1.5% (Table 3). In production, the amount of waste varies between different types of bread. In the surveyed bakeries, the bakery products wasted were mostly loaves (fresh bread). Those products that were subjected to TBA in small- and medium-sized bakeries were no more than 1.5%.

Table 3. Declared level and volume of bakery wastes and losses in the examined bakeries.

Bakery (company)	Products under the take-back agreement (TBA)	Declared level of waste generation (%)	
Small		0.3	
Small		0.2	
Small		1.5	
Small		1.3	
Small		0.12	
Small		0.12	
Small		0.1	
Small	x	0.1	
Small	x	1	
Small		1	
Medium	x	0.1	
Medium		2- 5	
Medium	x	1- 1.5	
Medium		No losses (except feed use)	
Medium		1- 1.5	
Medium		2- 5	
Large[2]; Large[3]	x	3- 5	3- 20
Large		1.5	
Large	x	8- 10	

[2] [3] - different representatives but the same company

Not all large bakeries reported production capacity–i.e., the mass of baked goods produced every day or month–instead only revealing the relative waste of bread and bakery products in total was reviled, since bakeries do not want to disclose company secrets. Moreover, one bakery declared that there was no waste at all and everything was reused in the production of new bread. In addition, the share of raw material waste was not declared by any of the large and small bread producers. Companies S, P and K noted that the share of raw material losses from the was 0.04% of the total weight of bakery products produced. These raw material losses include failure to calculate the right amounts, re-sorting of flour with mixtures, cleaning of trays, losses in storage and preparation of dough, flour dust after preparation of the tests, on the production line, flour dust after cleaning in the bakery and using flour on the conveyor.

In addition, there is bakery wastes due to the deformation of bread in an irregular shape, the wrong weight of baked goods, poorly formed bread (minimal defects), burnt loaves of bread and bread damaged by equipment. Waste in large bakeries was for these reasons higher than in small bakeries, between 2% and 5%. However, the reported amount of waste in the manufacturing sector for all bakeries was also declared to be relatively low concerning the proportion of returned bread (TBA). The largest group of bakery waste was unsold bread that was returned from supermarkets. This was declared to be the process with the largest share of waste, but only among the large bakeries, where it ranged from 3% to 20% of the number of loaves sold.

3.1.1. Causes of bakery waste

The study identified the causes of bakery waste and production losses. These causes of losses of bakery products can be classified into different categories: those resulting from problems with the mechanisms in the production process (due to machine error/faults) and irregular causes (human errors). Systematical causes occur over a long time but are in many cases insignificant in the bread production process. The causes of irregular bakery waste are related to what happens as a result of mistakes and events.

The most common reason for bread waste generation, according to bakery respondents, is human error. This includes errors when adding raw material according to the formulation, bread that is burned during baking and unsold bread. Technological problems due to poor quality and failure to meet quality requirements for finished products, mechanical damage and production waste (excess flour), damaged packaging, low weight, poor condition of bread and bakery products (shape, colour, the structure of bakery products, incorrect size of package), and bakery products with defects were noted by large bakeries. Wastes due to the sub-optimal ways of processing the bread, changes in the formulation on the

production line and damage during transportation were negligible, according to bakery respondents.

The representatives for small- and medium-sized bakeries also stated that other reasons were of high importance. The causes were the prediction and reassessment of order quantities. This was a common reason for wasting of bakery products, and this type of the cause may be easy to identify due to various factors such as weather conditions, seasonality, the habits, consumer demand and special events such as holidays. All of these causes can create a change in demand for bakery products and it is difficult for bakeries to accurately forecast this variation. According to the company respondent J1's estimations, wastes due to technical failures with power outages was found but were of minor importance for bakeries.

Moreover, the frequency and values of other potential causes of waste, for example, incorrect delivery of flour or other raw materials, were not noted. Furthermore, another cause of bakery waste of large bakeries is overproduction. Overproduction is used as a simple means of avoiding "stock out" at the retail outlet. In addition, the return of bread from the retailers was highlighted for large producers and the common cause of this waste was unsold bread (TBA products). Therefore, losses of bakery products depend to a large extent on how specific actions and processes are managed in the bakery sectors.

3.1.2. Bakery waste management

With regard to bakery waste management, there is first a need to note that waste management depends on where the bakery products occur and who owns them. Several ways of collecting bakery products have been identified, such as bakery products from the store that becomes biogas or a local donation, and bakery goods that are taken back (TBA) and converted to ethanol, animal feed, or donation. According to the collected data, the focus was on the most commonly used methods of bakery waste management, as presented in Table 4.

One of the differences between the bakeries considered in this study is that bakery products traded with TBA that are not sold to the consumer are instead collected and redirected to the bakeries or go directly to the production of biofuels (biogas and bioethanol). In other words, in the case of such bakeries, feedstocks are collected from supermarkets and bakeries then taken to the logistics hub during the return journeys. From the logistics hub, the feedstock is then transported to the production facility (e.g. for ethanol) thus allowing for larger deliveries.

Bakery waste such as dough is processed in another way, namely, raw materials and ingredients are processed into bread in a continuous production process. Moreover, wasted bakery products are transported directly from various bakeries within the framework of regulated waste management activities.

A small amount of the waste in large production sections can be used as animal feed or repurposed for producing other doughs for other products or testing

purposes. The bakery products can be donated (if still within the sell-by date) to food banks or for other research purposes.

The bread waste from small- and medium-sized bakeries that was donated to charity was sometimes used as animal feed, but mostly used to produce biogas through anaerobic digestion. The use of bakery products as food donations could also be viewed positively as this has a beneficial social effect for disadvantaged people, but this was still less common than using the bread for biogas production.

Table 4. Waste management options used by the bakeries

Bakery size	Biofuel (ethanol, biogas etc.)	Donation	Reuse of waste of bread	Animal feed	Composting	Disposal in landfill
Small			x	x		
Small					x	
Small		x			x	
Small		x			x	
Small		x			x	
Small					x	
Small[4]						x
Small		x			x	
Small		x				
Small				x	x	
Medium		x		x		
Medium					x	
Medium	x		x	x	x	
Medium	x			x		
Medium	x	x		x	x	
Medium	x				x	
Large	x	x		x	x	
Large	x			x		
Large	x	x	x	x		
Total	7	9	3	9	12	1

One difference was noted with the surveyed bakery located in Ukraine. Bakery products that were not sold before the expiration date were usually collected with other waste and disposed of in landfills. As mentioned earlier, this method of waste treatment is illegal in Sweden. In addition, other ways of organic waste treatment were not specified for the particular bakery in Ukraine. However, the reuse of surpluses or breadcrumbs to produce new bakery products has not been a widespread method of handling bakery waste. At the same time, it was also noted that bakeries do not always manage to get high-quality products by adding surpluses of bread to the recipe, as this requires skills and experience.

[4]One of bakery represents from Ukraine

3.1.3. Factors and implications of bakery products turning into waste

All producers are interested in producing high quality, fresh and safe bakery products that meet consumer preferences in sufficient quantities to satisfy consumer demand. Company A (2021) stated: "*we provide daily training of employees, general control of the baking process from raw material to the finished bread. We control all bakery losses and don't want to waste it. 'Zero' waste from bread production is still an ambitious goal in production and difficult to achieve. We are responsible for our products, but there is still a significant role for the consumer. If bakery products are not available ... in turn it can lead to the loss of more than 300 jobs*". According to Representative J2 (2021), "*we sell for the whole of Sweden and do not want to make bakery products in vain, but we try to sell enough and sell most of what we produce*". Thus, the start-up release of dough for fresh quality bakery products has to start very early in the morning or the big producers usually work double or more shifts all night. There are usually stops in the run to allow for switching to a different type of product, and for processing and cleaning lines and other manufacturing equipment (A, H, I, J, J1, J2, L, O, 2021).

Work plans, schemes and strategies are among the most important tools for planning and optimizing bakery processes for companies (Goryńska-Goldmann *et al*., 2010). It is also interesting to note that in bakery production, bakery waste exists in various volumetric forms in the manufacturing sector (Polarbröd, 2019) and can vary throughout the day and between days (Representative A, J1, O, 2021). For example, Company J1 (2021) stated: "*We are not the only bakery working to optimize production. It is happening that errors are caused by a human factor, an automatically improperly dosed raw material or a solution, an error in production, breakdown of electricity for the furnaces (ovens) are happening less often. Bread making is a complex process. We have different goals for each production line to reduce bakery waste and production losses. Moreover, we mostly reuse the sourdough, but it is difficult to trace all of the products, some of the bakery waste goes to animal feed, and most of all waste goes for ethanol production, we would not define this as 'bakery waste'*".

For example, the data from interviews shows that small bakeries are more cautious when dealing with food waste, and bakeries can manage and easily prevent it by donating bakery products (Representative D, H, L, R, 2021). A very small part of the bakery products (a few loaves) can still be thrown out and found a place in organic waste containers.

On the other hand, the analysis also showed that there are unclear management structures at the production level. Representative I (2021) states: "*Our production volumes are large, about 29.5 tons per day, and all baked bread gets sliced, but in order to ensure the cutting process on the machines, the equipment must use vegetable oil because otherwise our bread cannot be cut. This process creates*

bread shavings that are blended with that vegetable oil, we can't change our equipment to optimize... All bread waste volumes of 1.5 tons per week are going into the production of biogas. All bakeries use roughly the same machine or at production levels, the bread must be cut". Thus, the problems of bakery waste are noted in different ways.

In large bakeries, where high levels of production and reliance on well-quantified daily marketing remain their highest priority, company J1 (2021) states: "*bakery waste, that means simply baking a lot of bread, that is, overproduction, it will not be sold and then discarded ...we could reduce waste, for example by minimizing the assortment, it would be possible...but we try to find the right bread for consumers, the bread they want...consumers are inconsistent but spoiled...*". The retail aspects (placement in supermarkets, etc.) generate wastes due to unsold products and this leads to higher wastes. Moreover, bakeries often face pressure from retailers, such as filling the shelves with bakery products, which mainly affects the accumulation of large amounts of bread waste.

All participants are aware of the waste treatment and have clear strategies for their use. Half of the companies seemed to be concerned about bakery waste and losses of returned bread. Interviews also included questions about whether bakery losses were a problem and most bakeries agreed. However, several of the bakery's respondents (D, F, J, 2012) did not perceive that they generated enough waste that it was a problem because, as D, F, J says, "*We must produce more bakery products, we have a good level of bakery waste today. The company's policy is to always have fresh-baked bread every day, if our shelves are empty, the consumer goes to another place to buy bread. Bakery waste is not a problem for us, but it is still difficult to optimize for 'zero waste' or 'a few loaves of bread wasted'*". This may imply that there is a denial regarding people's own role in food waste issues at several levels in society.

Bakeries try to influence the situation by optimizing the entire automation of production. Since more than 10% of baked goods are unacceptable for manufacturers, according to Representative B (2021), they have to accept losses as they not only compete for the seasonality of purchase but also with retailers who insist on filling the shelves with more orders and the competition level is high. Otherwise, they have no chance of being competitive in the food supply chain, and they cannot reduce waste below 5% because then they will lose in sales (Representative B, 2021).

4. Discussion

4.1. Delimitation

This project is mainly geographically limited to Sweden, but the study provided primary data from a bakery in southern Ukraine. It was difficult to accurately identify bakery waste quantities and production capacity data through interviews and not all large producers were open to sharing and discussing data. The project did not include two of the major bakeries in the Swedish market because they did not respond.

In addition, a limitation that makes it difficult to accurately quantify bakery waste is that there was no direct weighing or records provided by the bakeries of retailers for the TBA. Therefore, it is difficult to determine the accuracy of interview answers and the calculations based on these answers. Moreover, given the approach and the chosen course of the research, it would be possible to conduct an extensive statistical analysis (first of all, by reaching a large number of respondents). However, this approach of quantitative research is complex, time-consuming and resource-intensive.

4.2. Trustworthiness and validity

Questions about the number of bakery products and the reasons for loss management were open, while questions about the causes of bakery waste, and waste management had a list of predefined alternatives in questions answered by respondents in the semi-structured interviews (Appendix I). This makes the results comparable between bakeries, even though the answers from the respondents might not be perfectly accurate. In addition, it is likely that the selection of bakeries is biased towards the most sustainable ones and/or the ones with the least food waste. There is therefore a risk that the actual bread waste in Swedish bakeries is higher than what was found food in this study.

4.3. Bakery waste

There is little research on the estimation of bakery waste in bakeries. This study showed that bakery waste in small and medium-sized bakeries amounted to 1% - 1.5% of the produced mass of bakery products, and for larger producers, this increased to the range of 3% - 5% (not including bread that is returned under a TBA). These figures are relatively close to those reported previously for the bakery sector, which was found to be 5.1% in Switzerland, 6.5% in Finland, 2.6% in Poland, 3.9% in Belgium, 2.1% in Norway and 5.2% in Sweden, relative to the total production of bakery products in each study, respectively (Table 2).

In comparison with the production waste, this study shows a higher percentage of waste for bread that was returned to the bakeries under a TBA, with this waste varying between 3% - 20%. Even if this waste was on a similar level to other studies, there was considerable variation found both in this and other studies. First, the findings on the magnitude of food waste in bakeries indicate that the losses are variable, depending on bakery size, location, strategy and variety of products. The waste in the small and medium production environment is relatively limited for bakery products compared to the waste found in returned bakery products from retail. This result supports Brancoli *et al.'s* (2019) claim that the common cause of bakery waste is unsold bread that is returned under a TAB. This amount of waste is probably economically justified for bakeries, as the market for bread has increased in recent years. On the other hand, from an environmental point of view, it cannot be justified to waste natural resources on this scale even though this waste comes at a low economical cost.

The analysis also showed that most bakery waste occurs because of reasons such as the human factor, cancelling of orders, technical breakdowns, etc., which are usually not taken into account in the data system of small and medium-sized enterprises. This might suggest that the company does not have information to declare the exact amount of bakery wastes. Further, there might be a lack of transparency that hides information regarding problems such as waste and therefore, prevents collaboration between actors to make joint efforts in addressing these issues. Bakeries do not offer technical or business information since these are considered "trade secrets" of the company. Moreover, in the baking environment, the development of a solution to the problem of waste is not immediately apparent, since accurate forecasting has to be done before production to avoid overproduction that later on generates waste. However, food production companies still have a need to use a sustainable management system that strives to eliminate all types of losses because not doing so indirectly leads to unregulated use of natural resources, which leads to environmental impoverishment (Akdogan & Coskun, 2012). Thereby, all of these factors that lead to bakery waste, even if they are not significant, can be addressed by using lean manufacturing (lean production) tools and techniques. According to Dora *et al.,* (2014) the concept of lean manufacturing is a new way

for the food industry to reduce waste. It can be implemented in various food companies from small to large businesses to assist companies to gain efficiencies and become more competitive and effective.

Moreover, consumer demands are constantly changing but are becoming more stringent in terms of environmental and health protection. For example, consumers tend to be interested in the products they want to buy, not only because of "health" and "safety" issues but also because of how the food is produced and how it arrives on supermarket shelves. This trend creates a wide range of products on the market with various packaging sizes and so increases the possibilities of waste. These results should be taken into account when considering how to achieve the Sustainable Development Goals (SDGs). The bakery industry is one important actor and, through further development management, they can emphasize responsiveness, and efficiency in the supply chain. The potential certainly exists to minimize the waste of bread production (Akdogan & Coskun, 2012) and ensure a sustainable work process (Schrettle *et al.,* 2014).

It can be assumed that overproduction is a common reason for food waste in most bakeries, as they want to produce baked goods and offer their products in sufficient quantities for the needs of customers, rather than have empty shelves in retail outlets. The analysis presented here estimates that bakery waste can be managed more accurately and optimally in bakeries. For example, selling unsold bakery products for feed can save costs for bakeries and reduce the cost that goes to waste treatment (Brancoli *et.al,* 2020). However, today, the use of unsold bread for the production of yeast, feeding livestock, and as donations for vulnerable segments of the population are not the main types of destination for surplus bread. A more frequent method to handle this resource is waste management through anaerobic digestion and incineration, which are common waste treatment methods in Sweden. Bakery waste is a good source material in the production of biofuel (Brancoli *et al.,* 2019). Moreover, waste management companies or other actors can take care of routing waste, which illustrates that all of these methods of improved and convenient transportation with integrated solutions that are adopted by bakeries works for today, however the operation of such methods usually leads to long transports. The study assumes that even if bakeries do not want to discard bakery products, there seems to be a system in which food waste in bakeries becomes the consequence due to circumstances. In this case, individual and collaborative efforts across the entire supply chain are important.

Further, the data suggests that there is a need to develop an active policy on how to avoid the overflow of bakery products (TBA products) in a way that is acceptable for bakeries such as opportunities from a long-term perspective. It can be assumed that changing the existing business model for bakeries may be difficult for flexible and fast restructuring in the bakery business, so policy changes may be required to encourage several participants in the food chain to take measures to prevent food

waste or change their commercial practices. Thereby, further steps are needed to establish and monitor the effective strategies used, creating more optimal measures to deter food losses.

Priority should be given to measures aimed at preventing the generation of waste from unsold bakery products, because of the potential to achieve greater overall waste reduction. Consumers also play an important role in reducing the number of unsold bakery products because their pressure on producers and retailers will cause a reaction and stimulate those responsible to take steps to reduce food losses. Further, it is always important to consider individual cases, as these could provide an important key for change.

In conclusion, it is apparent that the problem with bakery waste is framed and defined in numerous different ways. Several of the respondents (A, F, J, H, O, 2021) brought up the importance of well-filled shelves in shops and also mentioned that abundance and oversaturation of food choices of bakery products can contribute to significant food waste.

This research to identify even the minimal causes of waste reduction in bakeries is of great practical importance. The perceived need for an abundance of bakery products is a major driver of this issue. Against this background, there is also the waste of food in general to consider. This fact means that entrenched habits of affordability and abundance of products are not an obstacle to reducing waste. The unlimited access to food, together with a perceived disconnection and lack of knowledge, could then be seen as contributing to the growth of wasteful attitudes.

5. Conclusions

This study found a high percentage of bread waste during the return of bakery products (TBA), estimated to be 3 - 20%. Waste and loss of bread in small- and medium-sized bakeries accounted for 1% - 1.5% of the total of bakery products, and in large-scale production it was estimated to be 3% - 5% (excluding returned bread from retail trade). This study confirms that the waste of bread in bakeries can be associated not only with production and management errors but also with natural causes (human error) and market trends in the profitability of producers and retailers.

The bakery waste and losses results of this study aligned with the range reported in the results of other studies. Although the number of small and medium bakeries in the Swedish bakery industry is not high, they play a role and there is a need to limit the number of losses.

Moreover, it was noted that bread producers can exert control on the production, but despite the dialogue about waste, they focus more on the role of the consumer, stating that, “The producer must meet customer needs”.

Several of the respondents also acknowledge bakery waste to be a problem, probably as they were aware that their business wastes money, time and even food.

The study assumes that even if bakeries do not want to discard bakery products, there seems to be a system in which food waste in bakeries occurs regardless due to circumstances. Therefore, it is vital that both individual and collaborative efforts across the entire supply chain are taken to address this. Measures, such as reducing the product range, can work effectively by minimizing unsold bread (TBA), reducing food waste in bakeries, and thereby reducing economic, environmental, and social costs.

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Appendix I. Questions to bread producers (bakeries companies)

How many employees are working at the bakery/bakeries?
How large are your bakeries?
Which sort (type) of bread and baked products do you produce at the bakeries?
How much bread is usually produced per day/ week/ month/ year?
How do you characterize (define) the bread waste and losses?
Do you know which bread and bread products are subject to the greatest losses?
How does bread waste and losses look at the bakeries?
How many bread and baking products are usually thrown away / disposed of?
How much waste and losses do you have per day/week/month/ year?

Which are the causes for the bread, and baking products wasted?
What are the main causes of bread and baking products thrown away?
Who is responsible for forecasting and ordering baking products as bread?
What are the ordering routines?
Do you have a take-back agreement with your retailers?

If you have taken action to reduce food waste? How did you evaluate this action?
Are there behaviors among other actors in the food supply chain that cause bread waste for you?

What does a sustainable food system mean for you?
Is bread waste and losses an environmental problem for your company?
Why or why not? Is bread waste and loss an economical problem for your bakeries?
Do you know what happens with your bread goods and baking products which have not been sold in the retail sector?
How do you look at donating goods to a charity?
Would it be possible to reduce your bread waste and losses to zero in bakery, at bakery production?

Appendix II. Collected data from the examined bakeries

Table A1. Categorizing of interviewees with collected data losses and wastage

Bakery (company)	**Losses and bread waste amount during production per day/month/year** (including amount of bread returned)	**Causes**	**Character of Losses**	**Method of prevention/done**
Respondent A	A wide bread assortment and bakery products, bread wastes depending on which type of bread or bakery goods produced and consists about 2% to 5% bread waste.	Quality sorting Human factors. Technical breakdowns and machinery, equipment.	A short stop in the production. Production of bread with a diverse of components and ingredients affects the outcome of a finished bread or bakery products (not baked in from the unwanted differences among the baking products). Due to this factor bread may fail to satisfy the specified quality criteria (high quality standards for baking). Sorting out products due to high-quality standards, although the bread would be edible and healthy. Strict rules due to consumer demand. Technical problems or changes in the production process (equipment's), failure to observe the process parameters, oven defect, incorrect dosage of raw materials, salt solution etc., deformation of the bread: improper net, weight of the bread and bakery products (deformed, minimal defects, poorly shaped). Sales due to seasonality of bread (COVID-19, holidays, etc.) Not enough control in the	**No TBA** Daily training for employees. Overall control of baking process from raw material to finished bread (including the time and temperature of baking process etc.). Strict observance of work position instructions. Control over machinery and equipment—inspections and maintenance documentation. Supervision over the process of packing and control before releasing the goods for sale. Optimizing production volume with retail. Allowing for seasonality of production. All returned bread, surpluses of bread, as defected form or different size of bread products used for recirculation like production of ethanol and can be used for animal feeds or donated in COVID- 19 pandemic.

			retail chain. Overproduction due to consumer satisfaction.	
Respondent B	There is a different assortment of bread and bakery products. It is assumed as returned bread averaged 0.25% per month.	Unsold bread/returned bread, difficult to follow forecasting. (Overestimation of orders)	It is difficult to predict orders and give forecasts due to consumer demand. Sales allowing for seasonality of products.	**No TBA** Reused in any form, most. Sale at reduced price—lower quality. Use for charity and becomes animal feed, tiny part of dry dough, flour for composting.
Respondent C	It can produce more per day depends on day of week 60.5kg 50 loaves x 0.6= 30kg 100 pastry x 0.125=12.5kg 200 buns x0.09= 18kg (60.5) Wasted all fresh bread 1/5 or 12.1kg or 0.2%	Unsold bread/ difficult following of forecasting (overestimation of orders)	The company policy is based on consumer satisfaction, final unsold bread (there should be bread on the shelves). Production losses, short shelf-life expiration (not fresh bread next day)	**No TBA** Daily training for employees better follows previous orders or prediction of orders. Packaging of bakery products and composting.
Respondent D	Different sorts of bread waste per day 1.5%	Unsold bread. Overproduced/ overestimation of orders.	The company policy is based on a consumer satisfaction. Short shelf-life expiration (not fresh bread next day)	**No TBA** Daily training for employees better follows to previous orders or prediction of orders. Composting, donation, use of social needs.
Respondent F	A wide assortment of bread produced about 1.5 tons per month and 1.2% bread wasted per month other small bakery products 0.1%.	Unsold bread. Overestimation of orders.	Shelf-life expectation. Difficult to predict orders due to demands. Consumer attitude and behavior, lack of knowledge, a consumer is in priority. Losses of customers there is a policy. Policy of company is based on a consumer satisfaction. Low raw materials for produce high margins.	**No TBA** Optimizing production volumes with retailers / costumers. Calculation better "forecasting", control, and daily observation / inspection. Organic waste is a common occurrence if baked goods are not sold by the end of the working day.
Respondent J	There is different bread and bakery products, produced average 7200kg/month, it is wasted average 0.10% per/day.	Overestimation of orders. Less human factor.	The surplus of bread comes from the one retail trade in the form of returned bread. Difficult to change order and more ordered than sold. Sales allowing for seasonality of products (holidays etc.). Hardly ever stop or disruption of the baking process (equipment) there is not much amount of used flour, dirty dough come from the production. Policy	**TBA & No TBA** Most of the portion bread and other bakery products produced are not kept for the next day, but they can be frozen. Company J (2021) states: "*Fresh means fresh, and then it's cheating to freeze bread*." Thus, it is not entirely clear, that is, all the surplus goes to organic waste composting from retail. There is a separation of bread from the retailer

			of company is based on a consumer satisfaction.	and the leftovers of different bread and sometimes there is waste flour, dry part of the dough, etc. All this excess goes to animal feed, but it can still end up in organic waste.
Respondent H	2.4 tons of different sort of bread and bakery products produced per month. Wasted bread is average 1% month.	Less overproduction and Overestimation of orders	Difficult to follow based on previous orders; Better prediction of orders (COVID pandemic period, fewer or more sold (exactly day to day), weather or seasonality, less system interference, etc.) It is unlikely that it will ever happen that flour will be composted, but this is only in case of damage to the bags of flour from the suppliers of raw materials (it is assumed that several kilograms were scattered on the floor).	**No TBA** Sale at reduced price (KARMA) 25 loaves of bread and the rest of the remaining bread is usually sold to consumers at the end of the day. Although, not sold bread is sent to containers for organic waste. Use for social needs, internal sales (donated for charity organization, poor people).
Respondent I	There is different sort of bread and bakery products. Produced average 29.5 tons. 250 kg/day 7250 tones/month of this amount form spoiled "crumbs of bread" 1.5% bread waste.	Improper conditions of bread and bakery products. Technical breakdown. Human factors	Knives may deform or damage the sliced products, large volumes of crumbs (drops of cooking oil on slices of bread. Damage and deformation of the goods (sometimes forcing, disposal of the final bread to waste) Strict rules due to safety reasons, damage, and deformation of the bread. Releasing safe, but reduced quality bread for sale (deformed, minimal defects, poorly shaped)	**No TBA** Controlling of baking process, daily inspection, and instruction of working stuff. All the bread of unsuitable forms or surplus from production and that is, also crumbs and slices of bread spoiled by food oil from equipment is mixed with other production surpluses is sent to the production of biogas. Portion of the excess bread or waste in the form of dough, rejected bread can be used for livestock feed or composting.
Respondent J1	Produces a large volume of bread and buns every month, or on one production line about 1500- 2000 bread 18000- 20000 bread roll (dinner roll) per/hours not large volumes of production losses and bread waste but most returned bread for one sort of around	Returned bread Overproduction/ Overestimation of orders (Consumers demands) Improper conditions of bread and bakery products. Technical breakdown. Change in the	Production of bread with diverse of components, ingredients affect the outcome of a finished product. Strict rules due to safety reasons, damage, and deformation of the bread. Improper net weight of the weighed dough portions. When switching from one product to other in a production line, it is essential that allergens are not transferred e.g., gluten	**TBA** Transported to the production of ethanol, less animal feed and may reused returned bread or dough, research project, donation. Daily controlling and supervision. Control of baking process: find distribution channels for bread dough which contains allergens. Daily training and studying for employees. Control over machinery and

	3% to 5% per day and depends on type of bread.	production line. Human factors.	into gluten- free bread. unpureed bread can result. Releasing safe, but reduced quality bread and rolls for sale (deformed, minimal defects, poorly shaped). Failure to observe the process parameters, oven defect incorrect dosage of raw materials. Technical problems or changes in the production process (ovens, etc.). Sales allowing for seasonality of products (holidays etc.)	equipment—inspections and maintenance documentation. Supervision over the process of packing and control before releasing the goods for sale. Optimizing production volume with retail/customers. Allowing for seasonality of production.
Respondent J2	There are production losses not response, but most volumes of losses returned bread one type of bread can be from 3% to 5% and in average up to 20%.	Returned bread Overproduction/ (Consumers demands) Improper conditions of bread and bakery products. Technical breakdown. Change in the production line. Human factors.	Large amounts of returned bread from retails. Technical problems or changes in the production process (testing new sorts of baking products etc.). Sales allowing for seasonality of products (holidays etc.), Damage and deformation of the bread. Improper net weight of the weighed of bread, defected forms.	**TBA** Daily training and studying for employees. Control over machinery and equipment—inspections and maintenance documentation. Supervision over the process of packing and control before releasing the goods for sale. Some part can be donated and collaborate with research all returned bread goes to production biofuels.
Respondent K	Produced 2320kg/ month different sorts of bread (between 0.35- 1.7kg) 281kg waste per month 0.12% About 250kg flour per month	Human factors. Improper conditions of bread and bakery products. Technical breakdown.	Improper quality of finished products. Unsold before its expiration shelf-life date. Sales allowing for seasonality of products (higher holidays etc.) Damage and deformation of the bread or bakeries products (burned in ovens). Improper net weight of the weighed dough portions. Releasing safe, but reduced quality bread and bakeries products for sale (deformed, minimal defects, poorly shaped). Less errors during the preparation of mixtures of raw materials. Policy of company is based on a consumer satisfaction.	**No TBA** Daily controlling and supervision. Control of baking process. Daily training for employees. Moving to landfills.
Respondent L	Produced different sorts of bread and baking products bread waste up to 1%	Human factors, technical reason. Less returned bread and quality of sorting	Damage and deformation of the bread or bakeries products (for ex. burned in ovens) flour dust after kneading the dough or	**TBA & No TBA** The returned bread or the rest is taken by the staff, goes to feed the animals, can be donated, and minimally

			preparing the dough, cutting on the line during processing.	disposed of because it was burned in the oven as the first one at the beginning of work.
Respondent M	There are different sorts of bread and bakery products 163kg per day (it can produce more it´s depends on day of week) Wasted bread approximately 20kg 0.12% per day	Unsold bread. Overestimation of orders Less human factors	Shelf-life expectation. Difficult to predict orders due to purchaser demand. Consumer attitude a consumer is in priority. Policy of the company is based on a consumer satisfaction.	**No TBA** Only one sort of bread is frizzed. Sometimes use for social needs (all bread donates for charity organization, poor people) and the bread that was not sold goes to the container for composting. Daily controlling and supervision. Control of baking process.
Respondent N	Produced 600 000 tones of different sort of bread. No responses	Human factors. Hardly ever improper conditions of bread and bakery products and technical breakdown	Errors during the preparation of mixtures of raw materials (for example overdosing of salt solution etc.)	**No TBA** Control of baking process. All defects as dough or surpluses of bread, surpluses that usually occurs reused in a sourdough at the production.
Respondent O	Produces from 3000 to 5000 tones bread products per year. From 300 000-400 000 bread. Most of returned bread as waste 100 000 tones per year – 8- 10% If it´s frozen bread, returned bread 6- 7%	Quality sorting. Technical breakdown. Human factors. Returned bread overproduced	Errors during the preparation of dough as a mixture of raw materials (for example overdosing of salt solution, and other components). Technical problems or changes in the production process (daily equipment's efforts). Sales allowing for seasonality of products (weekend, public holidays etc.). High quality standards for baking. Less failure to observe the process parameters, oven defect. Not enough control on the retail chain. Strict rules due to consumers satisfaction.	**TBA** Control of baking process**.** Strict observance of work position instructions. Weekly discussions with retail chain as supplier and retail. Control over machinery and equipment—inspections and maintenance documentation. All defects as dough or surpluses of bread, returned bread that usually occurs and used to production of ethanol (two times per week) There is form of compensation for recycle bread.

Respondent P	Produces from 30000- 40000 bread and bakery products per/day 22weight 0.135kg = 4050kg losses with flour and waste bread 50kg per day = 0.012%.	Quality sorting. Losses due to suboptimal method of processing. Improper conditions of bread and bakery products.	Less errors during the preparation of dough as a mixture of raw materials. Selling under orders, strict rules due to consumer satisfaction.	**No TBA** All bread with defects, such as dough or excess bread, flour from the flow of damaged bread, usually ends up in composting tanks.
Respondent Q	Different type of bread (200 different articles) and losses and bread waste failure dough, estimated dough 1%-1.5%	Quality sorting. Human factors, Improper conditions of bread and bakery products.	Sorting out products due to of high-quality standards, although the bread would be edible and healthy (high quality standards for baking) Errors during the preparation of mixtures of raw materials (for example overdosing of salt solution etc.)	**No TBA** Control of baking process. All defects as dough or surpluses of bread that usually goes at the production ethanol.
Respondent R	Different type of bread and bakery products 2%- 5%	Unsold bread. Overestimation of orders due to consumers demands.	Improper quality of finished products. Unsold before its expiration shelf-life date. Sales allowing for seasonality of products (higher holidays etc.) Damage and deformation of the bread or bakeries products.	**No TBA** Controlling of selling process, optimizing production volume with retail/customers, allowing for seasonality of production. Unsold bread is sold for half prices amounting to 2%-5% and after can be donated if it is not sold then will be composted.
Respondent S	Average 1296kg 40kg 0.030% per day	Quality sorting. Human factors.	Improper quality of finished products. Damage and deformation of the bread or bakeries products.	**TBA** Controlling of baking process selling process, optimizing production. All defects as dough or surpluses of bread that usually occurs at the composting.

Appendix III. Popular science summary

Bread waste makes up a significant part of food waste, along with fruit, vegetable, dairy and meat products. Bakery product waste is usually used as animal feed and disposed of in landfills or incinerated. All participants in the supply chain are responsible for efficiently handling food products to minimise the risk of food losses. Hence, reducing bakery waste can bring tangible financial benefits. Resource efficiency and waste reduction in the food sector are a priority for business optimisation.

This study analysed 19 bakeries and identified the amount of bakery waste, its causes and methods of waste management. All the data collected was based on interviews with representatives of bakeries. All respondents were situated in Sweden except for one representative from Ukraine. Three physical interviews with producers of bread were conducted, while all others were done through telephone calls or video conferences. The results revealed that bread losses in small bakeries accounted for about 1.5% of total production and up to 20% of losses in large bakeries. The results also indicated the seven main causes for the loss of bread and bakery products: technical difficulties, equipment failure, equipment repair, incorrect sizes of bread and bakery products during production (shape, colour or low weight), expiration date, incorrect order and return of bread due to low demand. One of the main reasons for the loss of bakery products was also the human factor. The study of the amount of bakery waste, its causes and methods of waste management also showed that the most common factor is the change in consumer demands. This trend creates a wide range of products on the market.

Furthermore, this study covers a brief review of bakery waste percentage data from other literature based on Sweden, Norway, Poland, Finland and Switzerland. The results revealed the bakery waste rates found in this study fell within the range reported in this literature. Moreover, the findings on the magnitude of food waste in bakeries indicated that the losses are variable, depending on bakery size, location, strategy and variety of products.

In addition, this thesis provided a brief overview of one specific business model that is commonly used in the Swedish bread market. The results of this project indicated that a take-back agreement is a risk factor for high waste generation. This thesis proposed suggestions that aim to reduce food waste in bakeries. The first suggestion is to make a change to the current business model to achieve a more

sustainable supply chain with less waste. Second, there is a need to optimise ordering and forecasting, and to implement waste-reducing actions, such as price reductions.

Determination of the causes and calculation of bakery waste allows us not only to determine where it is necessary to strengthen control concerning the bakery industry but also to take appropriate measures to reduce them. If bakeries would produce the amount of the range according to what they sell, it would lead to less waste, which requires less energy and utilising fewer resources.