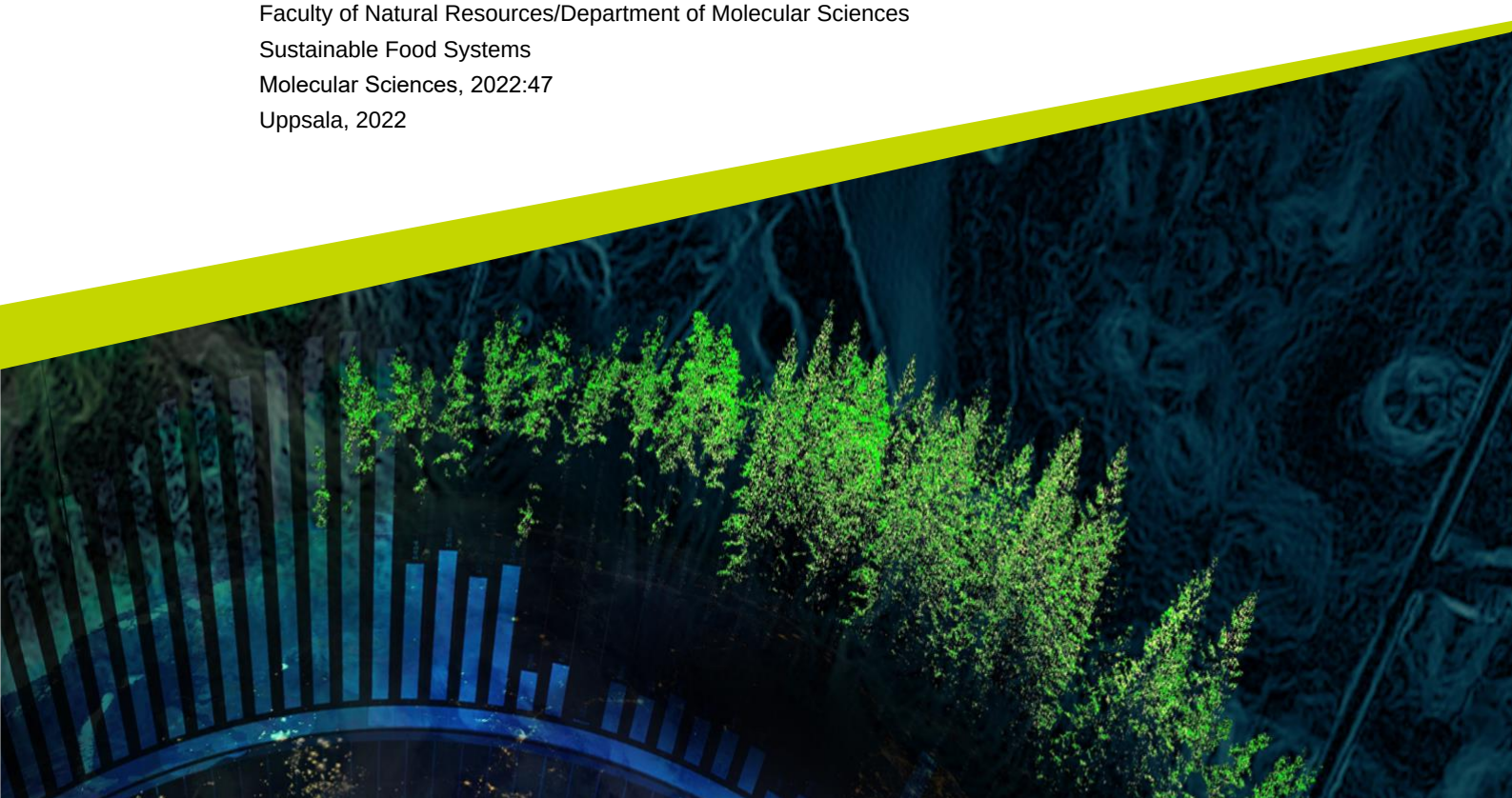
Food losses and Waste at Bakeries, Retail and Household Levels

– A Case of Sweden

Indrachapa D. Balasooriya

Degree project, 30 hp
Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources/Department of Molecular Sciences
Sustainable Food Systems
Molecular Sciences, 2022:47
Uppsala, 2022



Food losses and Waste at Bakeries, Retail and Household Levels-A Case of Sweden

Indrachapa D. Balasooriya

Supervisor: **Techane Bosona, Swedish university of agricultural sciences, department of energy & technology**

Examiner: Girma Gebresenbet, Swedish university of agricultural sciences, department of energy & technology

Credits: 30 hp
Level: Advanced level, A2E
Course title: Master thesis in Food Science
Course code: Programme/ education: Course coordinating dept: EX0875 Sustainable Food Systems Department of Molecular Sciences

Place of publication: Uppsala
Year of publication: 2022
Title of series: Molecular Sciences
Part number: 2022:47

Keywords: Bread value chain, Food loss, bread waste, causes of bread waste

Swedish University of Agricultural Sciences
Faculty of Natural Resources
Department of Molecular Sciences

Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file.

If you are more than one author you all need to agree on a decision. Read about SLU's publishing agreement here: https://www.slu.se/en/subweb/library/publish-and-analyse/register-and-publish/agreement-for-publishing/.

☒ YES, I/we hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

☐ NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.

Abstract

Reducing food waste is necessary to assure food security and overcome environmental issues. This study was aimed to assess food losses and waste (FLW) along bakery, retail, food service and household stages of bread value chain in Sweden, causes and identify potential measures to reduce losses and waste. Both quantitative and qualitative analyses were carried out. Both primary and secondary data were used in the study. The FLW was 80450tonnes per year in the entire Swedish bread supply chain. Household contributed to the highest waste fraction (37.2%) of bread waste in entire value chain among the bakery, retail, restaurant and canteen stages followed by the retail (34.9%), bakery (14.9%) and restaurants (8.9%), Canteens (3.3%). The major causes of FLW in household were forgetting to consume after purchase and over purchase of bread. Th most frequent cause for bread waste in bakeries were over production, TBA and poor production planning. Overstocking and passing expiry dates were identified as the most frequent causes of bread waste at retails and food services. More causes such as lack of knowledge regarding the issue, lack of attention, lack of collaborative effort among the actors, demand-driven food system, consumer demands for more types of bread products, etc. were identified. Strategies and actions identified to reduce waste and losses were proper sales and order planning, increasing awareness of FLW, reducing over purchase, freeze storage after purchase, prepare different products from left-over bread which have more shelf life, serve only sufficient amounts at food services, prepare different recipes at restaurants and canteens to motivate the consumers to finish what is served, donate to feed people in need and for animal feed, recycle food rather than wasting.

Keywords: Bread value chain; Food loss; bread waste; causes of bread waste

Preface

If you have a preface, you can write it here.

Table of contents

Note! Do not delete the table of contents before you are done, instead go the **References** tab to update it. Don't forget to erase these instructions.

List of tables

List of figures

Abbreviations

FAO	Food and Agriculture Organization of United Nations
FLI	Food Loss Index
FLW	Food Losses and Waste
SDG	Sustainable Development Goals
UNEP	United Nations Environment Programme

1. Introduction (should start on an odd page number)

Food is wasted in larger amounts every day. Those food could have been utilized if they were been handled differently (Åhlander, 2016). Food loss and food waste (FLW) is a widespread problem in Sweden as well as around the world which leads to unnecessary environmental and economic impacts and moreover, it can eventually weaken the ability to feed the growing world population with sufficient food (Swedish Food Agency, et al., 2020).

Around one third of the world's food was lost or wasted every year (FAO, 2011) and it has changed the global perception of the food waste problem. FAO identifies food loss and waste as an issue which has taken great public concern. The 2030 Agenda for Sustainable Development also reviews that there is an increased global awareness of the issue. Sustainable Development Goal (SDG) target 12.3 aims for halving per capita global food waste at the retail and consumer levels by 2030 and reducing food losses along production and supply chains (SDG 12.3). As estimates suggest, food for a value of USD 1,200 billion is wasted annually while moving through the food supply Chain (Royal Swedish Academy of Engineering Sciences, 2020). Estimates reflect that 8-10% of global greenhouse gas emissions are related to the unconsumed food (United Nations Environment Programme, 2021) and consumes one quarter of all fresh water which is used in agriculture which would have been utilized to produce food to feed people who are starving without having enough food to eat (Royal Swedish Academy of Engineering Sciences, 2020).

Since the substantial amounts of food which are produced but not consumed by humans cause considerable negative environmental, social and economic impacts (United Nations Environment Programme, 2021), reducing food waste and losses has become a necessary concern. Lowered food loss and reduced food waste can lead to efficient land use and improved management of water resources which may lead to positive impacts on climate change and livelihoods of living beings (FAO, 2011). Food waste and losses carry a large amount of economic and environmental values along the food supply chain (Åhlander, 2016). Reduction of food waste can lead to a more productive supply chain, less competition for the natural resources as well as it can save money for the actors in the supply chain. Therefore, reducing food waste at retail level, food service as well as household level can provide benefits for both the planet and people live on it.

Food is wasted in Europe and North America largely during retail and consumption levels (Mattsson, et al., 2018). According to the estimation of European food waste levels by (Stenmarck, et al., 2016). 70% of the EU food waste occurs at the retail, food service and retail levels and those actors have been identified as parts of the food supply chain. An average Swede is estimated to throw away around 19 kilograms of perfectly edible food and about 26 kilograms of food and drink down the drain (Swedish Food Agency , 2021) causing both financial and environmental costs. The carbon footprint associated with the annual food wasted by Swedish households is equivalent to the annual greenhouse gases released from 360,000 cars (Swedish Food Agency , 2021) . Swedish retail is responsible for 8% of the total waste occur along the supply chain which is relatively a small number. But since Swedish retail is an important actor in food waste reduction as they gather a large amount of food products and connect them between producers and consumers within a limited and specific number of locations (Ejnarsson & Bengtsson Ekström, 2020).Therefore, implementation of food waste reduction in Sweden is important. However, understanding the true scales of food waste and losses as well as its impacts is necessary. So, the opportunities provided by reducing food waste can be exploited and trapped. In order to take serious actions to tackle food waste, we need to put increased efforts on measuring food waste and assessing actions taken for reduction at retail, food service and consumer level and also food losses along the value chain at country level (United Nations Environment Programme, 2021). Using reliable information and data, will enable us tracking the progress on Sustainable Development Goal (SDG) target 12.3, in order to reduce food losses along the production process and supply chain as well as to halve per capita global food waste at retail and consumer levels (United Nations Environment Programme, 2021).

1.1. Problem Statement

Since food production requires larger amounts of resources such as water, land, energy and nutrients, food losses and waste cause negative environmental impacts such as climate change, global warming, freshwater resource depletion and biodiversity loss, and also unnecessary social and economic costs and consequences, there is an increased necessity to address food waste (Brancoli, 2021) ; (FAO, 2011); (Eriksson, 2015); (Swedish Food Agency , 2021). Different measures are needed along the different steps of the food supply chain in order to reach the goal of reducing food waste (Swedish Food Agency , 2021). Food waste levels in Sweden reflect that many efforts are taken to reduce food waste, but much more is remaining to be done. Research and studies on food losses and waste still remains emerging, and there are much more to be assessed and studied about the functions of the food supply chains, the food waste quantities (Swedish Food

Agency, et al., 2020). As there are many intermediate actors in supply chain which makes it less transparent due to the loss of information along the way, global food supply chains become challenging to improve (Swedish Food Agency, et al., 2020).

When we consider specific food products in terms of waste and losses, bread in particular can be considered as a neglected food item in the research literature that were reviewed during the literature survey of this project. The doctoral project (Brancoli, 2021). has been the first quantitative study conducted of bread waste in Sweden. However, larger amounts of bread products are wasted every year as well as some are used for animal feed and anaerobic digestion (Brancoli, et al., 2020). Bread waste has become a large portion of the global food waste. According to (Brancoli, 2021), it is estimated that 80,410 tons of bread is wasted in Sweden every year and it is equivalent to 8.1 kg per capita/year. According to (Brancoli, 2021), bread waste causes a significant impact on the environment even though bread waste has not been considered for any significant waste flows at retail levels earlier. Pedro Brancoli, who had recently received his doctorate in resource recovery at the University of Borås has found that if bread waste was transformed into new or other products, it would have provided many environmental and economic benefits. Therefore, I consider that more assessments and studies are needed on bread value chain and bread losses and waste reduction. Swedish stakeholders can contribute in this issue in many ways through practical solutions to reduce food waste particularly bread waste and losses with collective knowledge and experience held by different actors across the value chain as well as researchers. University students like us can contribute to address this problem by developing systematic data collection as well as reporting to assess the practices and their effectiveness and potential to reduce bread waste and losses as well as by finding suggestions for targeting for further improvements and environmental and economic cost savings.

1.2. Research questions

1.What is the value chain map and the main actors involved in the bread value chain?
2.What is the estimated quantity of bread FLW (e.g., %) ?
3.What are the main causes of FLW in bread value chain?
4.What are the technologies and practices used to reduce FLW in bread value chain?
5.What are the implications of FLW in bread value chain in relation to sustainable food systems?
By answering these questions, this study aims to assess the effectiveness and possibilities of the practices along the bread value chain of bread to reduce estimated FLW in Sweden and provide recommendations for future actions and

practices to be taken by the actors to manage and reduce food waste better throughout the chain specifically for bread products.

1.3. Objectives

The overall goal of this project was to analyze the value chain, Food Losses and Waste (FLW) and related GHG emissions of a selected food commodity (bread products) to assess the possibilities and effectiveness of technologies and practices and measures to reduce bread losses in early stages of the chain and bread waste especially on large grocery stores and bakeries in Sweden specifically in Uppsala region.

The specific objectives are to:

map the bread value chain

assess the FLW at different stages of bread value chain

identify the main causes of FLW along the bread value chain

identify the technologies and practices to reduce FLW along the bread value chain

2. Literature review

2.1. Definition for value chain, value chain analysis and approach

(Porter, 1985) introduced the concept of "value chain" to discuss the full range of activities, that are required to develop a product or service from the conception stage, across several stages of production of the product or service, distribution to consumers, and disposal stage after consumption (Omoleye, 2020). When a product or service moves from one stage to another, it is presumed be value added (Omoleye, 2020). Value Chain Analysis (VCA) is a method which is used in identification of the stages where the food loss and waste is most crucial across the supply chain (Omoleye, 2020) Level of food losses and waste differs across the different stages of food supply chain and depends on various actors such as the type of food product, country or region as well as social and cultural aspects (Omoleye, 2020).

2.2. Definitions for food loss, food waste and bread waste

To quantify food losses and waste, understanding what should be considered and included in quantification is very important. However, according to literature and studies, different definitions are adapted to different organizations and studies.
The report (HLPE, 2014)defines food losses and waste (FLW) as

> "a decrease, at all stages of the food chain from harvest to consumption, in mass, of food that was originally intended for human consumption, regardless of the cause" (HLPE, 2014).

This definition was adopted with a food security and nutrition perspective. However, when considering terminological purpose, this study will make a distinction between food losses and waste based on the definitions used in literature. Even though, food waste is usually difficult to be clearly distinguished from food

losses especially at later levels of the supply chain, there are some definitions that distinguish them into two different terms.

According to (FAO, 2022), Food loss is defined as

> "the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers" (FAO, 2022).

So, according to this definition, food loss refers to any kind of food that is discarded, incinerated or disposed across the food supply chain from post- harvest stage but excluding the retail level and it does not re-enter in another form of utilization, such as feed or seed. However, according to (UNEP, 2022) food loss refers to "food that gets spilled, spoilt or otherwise lost, or incurs reduction of quality and value during its process in the food supply chain before it reaches its final product stage. Food loss typically takes place at production, post-harvest, processing, and distribution stages in the food supply chain" (UNEP, 2022).

Food waste is defined as the

> "decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers" (FAO, 2022).

And (UNEP, 2022) defines food waste as

> "food that completes the food supply chain up to a final product, of good quality and fit for consumption, but still doesn't get consumed because it is discarded, whether or not after it is left to spoil or expire. Food waste typically (but not exclusively) takes place at retail and consumption stages in the food supply chain" (UNEP, 2022).

Comparatively, (FUSIONS, 2016) define food waste as

> "any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)" (FUSIONS, 2016).

This definition includes drink and liquid waste, fish which are discarded to sea as well as any material waste that are ready to be harvested, but have not been harvested. It also includes the inedible parts of food such as bones and skin in food waste. This FUSIONS definition does not consider products which are converted to animal feed or bio-based materials and products that are used in biochemical processing as food waste.

According to the literature, there is no common, single definition of food loss and waste (FLW) and different actors as well as stakeholders in food industry use various definitions and terminologies (FAO, 2022). And, there is no common definition for bakery waste in the food industry (Iakovlieva, 2021). The definition of food waste depends on which stage of the supply chain is being considered and investigated.

In contrast to the other definitions, according to (UNEP, 2022) food that was originally meant to be consumed by human but removed from food chain due to various reasons even if they are taken for non-food use such as animal feed or bio-energy, are considered as food loss or waste. Therefore, even though the food waste is used for bioenergy production or other purposes, it is still considered as food

waste since it was originally intended to be consumed by human. As the definitions of food losses and waste by (UNEP, 2022) are more applicable to the bread industry, they are the main definitions used in this study.

Therefore, according to the definition considered in this study, all bread which is produced with the intention for human consumption and has completed the food supply chain up to the final bread product which is suitable for human consumption but is not consumed by humans due to being discarded, whether or not after it is left to expire, or spoil will be considered as bread waste in this study regardless of its final disposal route or non-food use. Donated bread will not be defined as food waste in this study. Bread used for animal food and bioenergy will also be considered as bread waste. Referring to UN environment program definition, wheat, raw material or other food materials that are spilled, spoilt or lost or subjected to quality or value reduction during the process along the bread supply chain before it reaches its final product stage will be considered as bread loss. Bread loss will be considered to take place at production/post-harvest stage, processing, baking and distribution stages of the bread supply chain".

2.3. Food Losses and Waste (FLW) at a global perspective

Several studies are aimed in estimating the food losses and waste and consequences associated with it at a global level. The Food Loss Index (FLI) (FAO, 2018) and the Food Waste Index (FWI) (UNEP, 2021) are some latest studies that have estimated the food waste amounts at a global level where FLI quantified food losses from post-harvest level to retail level (excluding retail level) and FWI covering the retail and consumption levels. According to FLI (FAO, 2018), approximately 14 percent of the world's food is lost at global level annually between harvest stage and the retail market. And according to FWI (UNEP, 2021), the food waste at the retail and consumer level is estimated to be 17 % of world's food. (UNEP, 2021) estimates that around 931 million tonnes of food were wasted in 2019 where 61 per cent of it is generated from households, 26 per cent comes from food service and 13 per cent is generated from retail.

According to the figure 01, per capita food waste generation at household level is approximately similar across country income groups which means that actions to reduce food waste is relevant in an equal level for high, upper middle and lower middle income countries. However, (UNEP, 2021) highlights that, even though the data on the edible fraction of food waste is insufficient to analyze comparatively across country income groups, the estimated amount of total food waste in these areas is sufficient to consider circular approaches or else the other strategies of food waste diversion to be important.

When substantial amounts of food are produced and not consumed by humans cause a significant negative impact on the environment, society and economy (UNEP, 2021). According to the estimates, it is suggested that 8-10% of global greenhouse gas emissions are related to unconsumed food (UNEP, 2021). According to (FAO, 2022), Greenhouse gas (GHG) emissions associated with the food that is lost is around 1.5 gigatons of CO2 equivalent every year. (FAO, 2022)mentions that, Food and Agriculture Organization of United Nations (FAO) and UN Environment Program (UNEP) together with their partners impulses everyone to work more on reducing food loss and waste in order to reduce the great drop in food security and natural resources associated with this global issue.

2.4. Waste and losses in the food supply chain

Food loss is a problem along the whole food supply chain. However, more value is added in terms of resources and money at every step along the food supply chain. Therefore, waste constitutes more loss of value at the late stage of the chain as more subprocesses are carried out. Thus, the potential economic benefits associated with waste reduction per unit mass are higher at later stages of the food value chain (Eriksson, 2015). In contrast, some food products such as of animal origin, more life cycle emissions are generated at farm stage and food waste reduction may have the same reduction effect across the whole supply chain followed by the farm level (Eriksson, 2015). In a global perspective, the levels of food losses and waste shows a great spread between the different stages of the food supply chain. However, the main area of food loss is primary production (earlier stages) in the food supply chain (IVA, 2020). However, (IVA, 2020)concludes that, according to its result, there are major data gaps in the food waste flows along all parts of the food supply chain and it is difficult to estimate the total amount of food loss and waste occurred across the food supply chain. Currently, we throw away large amounts of food, which with different handling could have been consumed as intended. If the unnecessarily waste food is consumed instead, it can result a reduction in human impact on the ecosystems which will reduce the environmental impact associated with the entire food supply chain including production stage, distribution, consumption level and waste management (Swedish National Food Agency, 2016). Thus, food which has been produced could have been used to fulfil the needs of more people without increasing the environmental impact.

2.5. Importance of reducing food losses and waste for a sustainable food system

Reducing food loss and waste is considered as a necessity to improve our food system broadly toward improved food safety and security, quality, increased efficiency as well as sustainability (FAO, 2022). Since food loss and waste has become a complex issue which causes economic, environmental and social impacts, it is linked with the sustainable development (Eriksson, 2015). Despite the fact that reducing food waste might not lead to sustainable development automatically, it has the potential to place an important contribution to sustainable development and posse a symbolic value (Eriksson, 2015). A significant reduction of food waste has been suggested to be a main systemic change that has the potential in significantly reducing the unsustainable use of ecosystem services as well as natural resources and a significant reduction in GHG emissions related to the food system (Bajželj, et al., 2020). Moreover, as there is a significant water, land and fertilizer footprint from global food loss and waste in a global level, a low-waste food system would require significantly less water, land, water and would reduce GHG emissions related to food systems in future (Bajželj, et al., 2020). As (FAO, 2022) emphasizes, due to increasing resource constraints and the need of increasing global agricultural production by 60 percent by the year 2050, reduction of losses and waste is considered as a key element in sustainable development. For increasing the food availability, reducing food loss and waste is an important principle which is more efficient compared to expansion of food production. Therefore, there is a global community agreement with the Sustainable Development Goal:12 (SDG 12), and agreed on a specific target (12.3) with the aim of halving per capita global food losses and waste by 2030 (FAO, 2022). Hence, tackling food losses and waste along the whole food supply chain is a necessity in order to create a sustainable food system.

2.6. FLW in Sweden

According to statistics from Swedish Environmental Protection Agency, almost 1.3 million tonnes of food was wasted in 2016 in Sweden (IVL, 2020), which represents an average of 129 kg per person including both inedible parts of food (peel, bones or coffee grounds) and avoidable food waste (IVA, 2020). There are significant differences between at which stage of the food supply chain food is wasted. According to statistical data from Swedish Environmental Protection Agency, almost 75 percent of food is lost and wasted at consumer level in the Swedish food supply chain. According to (IVL, 2020), average discarded food waste was 133 kilograms of food waste per person in 2018 in Sweden and more than 1.3 million tonnes of food was wasted across the country which was about 4 per cent more than

in 2016. The main reason for this difference has been revealed by a new calculation method which is that grocery stores discard more food than previously. Comparatively, households are responsible for the most food waste generation, 70 per cent of the total food waste (IVL, 2020) while grocery stores represent 8 percent, agriculture is responsible for 7 per cent and industrial kitchens, restaurants and the food industry generate even less food waste. Food loss and waste in Sweden in 2018 includes 37,000 tonnes (4 kg per person) from food industry,100,000 tonnes (10 kg per person) from grocery retail sectors, 148,000 tonnes whci is 14 kg per person from restaurants and food services, 6,100 tonnes of serving waste and 5,000 tonnes of plate waste (60-70 gr/lunch/person) from school and pre-school canteens and 917,000 tonnes (excluding 693,000 tonnes of food wasted via sewage) which is 95 kg per person from households (European Commission, 2022). (IVL, 2020) reveals that despite the fact that some fractions of food waste such as shells and fish bones cannot be avoided, almost half of household food waste is avoidable which includes leftovers such as "shrivelled fruit and mouldy bread" (IVL, 2020) and those food could have been consumed is they were properly managed (Brancoli, et al., 2020) (IVL, 2020).Thus, (IVL, 2020)emphasizes that while one third of the world's food is discarded, Sweden has become a major culprit regards the issue. Therefore, in order to tackle this issue and move towards a positive change, there is a need for a collaboration along the entire food chain. As a response to this problem, the Swedish Government has adopted two national targets aiming to reduce the total food loss and waste which is generated across the entire food supply chain, in compliance with the Sustainable Development Goal Target 12.3 (SDG 12.3) (European Commission, 2022). The targets are to reduce food waste by 20 weight per cent per person from 2020 to 2025 and to increase the share of the food production which reaches retailers and consumers by 2025. Theses targets are parts of the "revised Swedish waste management plan and waste prevention program 2018-2023" (European Commission, 2022).However, according to 2019 statistics, the residual waste has decreased by four percent and food waste collection has increased by seven percent in Sweden in 2019. Total of food and residual waste has decreased by three percent, from 216 kg to 209 kg per person (The Swedish Waste Management Association, 2019). Therefore, it is considered as a positive step towards reaching the two Swedish national goal of goals of reducing food waste. But it is clear that much more is needed to be done as a nation to reach the goals by 2025.

2.7. The waste hierarchy

According to European commission, the five-step "waste hierarchy" is considered the "The foundation of EU waste management" and it is formulated in the Waste Framework Directive (WFD) (European Commission, 2022).The waste hierarchy

ranks the preference of the waste management, prevention and disposal options. WFD encourages options which offers the best environmental outcome with a life cycle perspective despite the fact that it is different from the waste hierarchy (Eriksson, 2015). The fundamental conceptual framework associated with waste hierarchy became a part of European policy in the 1970s (Iakovlieva, 2021). Later, the waste hierarchy has since been adopted and developed. However, it still introduces the general guidelines for all types of waste. Th EU waste hierarchy consists of five stages prioritizing prevention, followed by re-use and preparation for re-use, recycling, energy recovery and lastly, disposal (dumping in landfill) globally (Brancoli, 2021) which aims to reach the top- most waste reduction stage of the waste hierarchy. Waste hierarchy declares that waste reduction is the most beneficial alternative to prevent food waste and disposal is the least useful action in preventing food waste (Brancoli, 2021). However, the US Food Recovery Hierarchy, adopted in Figure 7 with reference to (USEPA, 2021), basically agrees with the EU waste hierarchy (European Commission, 2008). However, it divides the food waste prevention stages into two sublevels. Among those two sublevels, source reduction is the most preferred action and feeding hungry people is less preferred comparatively (Eriksson, 2015) which This implies that despite the fact that food is eaten as an option to prevent food waste relating to the intentional use of food, the best option is to become proactive and minimizing food production.

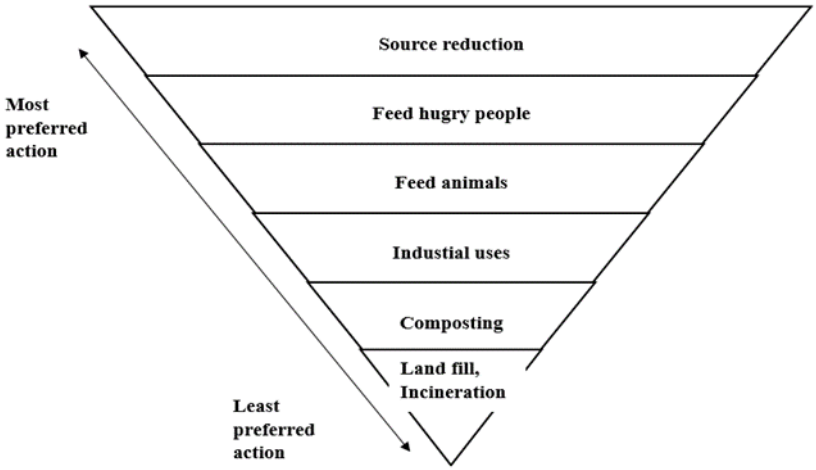


Figure 1:The food recovery hierarchy adopted by the author referring to (USEPA, 2021)

2.8. Food waste management in Sweden

According to (Eriksson, et al., 2015) among different waste management options, landfill is the least favorable option followed by composting and thermal treatment while anaerobic digestion was most favorable which doesn't fit in all the studies (

Eriksson, et al., 2015). Sweden ‘s aim is to reduce food waste along the whole food supply chain.

As assigned by the Swedish government, the Swedish National Food Agency, the Swedish Board of Agriculture and the Swedish Environmental Protection Agency continued to work together to reduce food loss and food waste in Sweden between 2017 and 2019 (Swedish Food Agency, 2018). As the first stage, a collaboration with relevant players and developing an action plan about Sweden taking long-term measures in reducing food loss and food waste was initiated aiming to contribute to achieving global sustainability goal 12.3. Several players such as primary producers, processes, retailers, restaurants and public catering services, procurement, consumers, education, regional work, municipal work and research are already working to reduce food loss and food waste. However, more players need to be actively involved and actions are required for more measures (Swedish Food Agency, 2018). The action plan has identified prerequisites for a successful effort to reduce food loss and waste in Sweden. According to the work on the action plan, a clear national goal is necessary from the government/parliament for public and private players to make a focus on the issue as well as to motivate, provide commitment and legitimacy for the players to work on overcoming the issue. Players who are designated for different measurements are also considered as crucial for continued work. Active and organized collaboration between the players in the food supply chain can create a greater effect and contribution from the players since such collaboration may enable to find common measures within different parts of the food chain, so actions could be taken not to send the food losses or food waste further up or down the supply chain (Swedish Food Agency, 2018). Those contributions from various could create opportunities to do behavioral changes among the consumers, who has become a main contributor of food waste. There is a need to raise consumers’ awareness and motivate them to minimize food waste in buying, handling and usage of leftover food (Swedish Food Agency, 2018). Collecting and developing more knowledge in different issues which are related to food loss and food waste, gaining knowledge about consumer behavior towards reducing food loss and food waste is an urgent action to be accomplished (Swedish Food Agency, 2018). Furthermore, interaction between expertise in different areas is needed to find solutions to tackle this issue. However, it is crucial that everyone who are engaged in food related matters has a responsibility for integrating food loss and food waste issues with their work in long term, and contribute with their maximum effort to achieve global sustainability goal 12.3.

2.9. Bread waste in Sweden

2.9.1. Bread producers and retailers in Sweden

In Sweden, different bakery companies produce and sell fresh bread and bakery products in the market (Iakovlieva, 2021)**.** Pågen, Fazer and Polarbröd are the three main bakery companies in Sweden representing 80% of the Swedish market.

Table 1: Market share of bakeries in the Swedish food supply chain (Iakovlieva, 2021)

Bakery	**Market share %**
Pågen	**38.4**
Fazer	**18.4**
Polarbröd	**23.1**
Private labels	**8.5**
Others	**11.6**

One bakery industry often produce the private label products and those products are sold under the label of the retailer (Iakovlieva, 2021)**.** The local bakeries sell bread mainly through retailers ICA, COOP, etc. (Iakovlieva, 2021). Local bakeries have a market share of 10%, while traditional bakeries have a market share of approximately 2-3%. Some retail stores bake their own bread products in their store which accounts for about 5% of the Swedish bakery market (Iakovlieva, 2021).

Table 2:Market share of the retailers in Swedish supply chain (Brancoli, et al., 2019)

Retailers	**Market share %**
ICA	44.9%
COOP	16.2%
Axfood	15.3%
Bergendahls	6.7%
Lidl	3.9%

2.9.2. Bread categories

Bread is defined as a staple food made by baking a dough with a mixture of flour and water, fermented with baker's yeast or a starter. In the scope of this study, the assessment of bread waste in Swedish national level considered both organic bread products(made with organic grains and other ingredients) and conventional bread, pre-packed and bake-off products in both industrial and homemade production. Bake-off products are baked from pre-made dough in the retail stores or supplied to the retail by a bakery in another store. Bake-off and pre-packaged bread products have a relatively short shelf-life, typically pre-packed bread from one to ten days

and one day for bake-off bread. Bread products which have longer shelf-lives, such as crispbread which last up to one year are also included in this study. Several categories of pre-packed bread in retail shops, such as white, dark and were also considered. Bread products in these categories may vary with the type of flour used (wheat, rye, maize, whole grain, barley, gluten-free, etc. and other ingredients. Bread products supplied with or without a TBA are considered.

2.9.3. Take back agreement

Take-back agreement (TBA) is a trade practice according to what the supplier has the full responsibility of unsold bread at the retailer (Iakovlieva, 2021), which means that the bread manufacturer must pick up leftover bread products (ex. unsold bread) even before they reach the expiration date, the manufacturer has the responsibility to placing bread on the shelves in the supermarket and to order and forecast the future demand for bread and also, bakeries work on the logistical problems related to collection of unsold bread from the store shelves and transportation of those bread for waste management (Iakovlieva, 2021). Bread supplier takes the financial responsibility for the unsold bread which is also referred as 'returned bread' (Brancoli, et al., 2019) thus, retailers pay only for the products they have sold.

As the TBA doesn't give any incentive or power to the supermarkets for handling the bread waste, it is normally handled by the bakeries. Due to this reason, bread products which are subjected to a TBA are not donated to charity or not sold for reduced prices by the retailers, as the retailers do not have the ownership of the bread (Swedish National Food Agency, 2016). This practice has made the relationship between the retailer and supplier less transparent due to the secrecy in the cost of waste management making it very difficult to estimate the actual bread waste amounts for the key actors of food waste prevention such as researchers and retailers. Swedish bread suppliers taking the responsibility of ordering and forecasting practices help to deliver the right amount of bread to the retail (Swedish National Food Agency, 2016). However, due to lack of economic motive of retailers for decreasing the amount of unsold bread as well as poor cooperation between some store managers and suppliers can lead to higher amount of bread returns (Swedish National Food Agency, 2016). This fact confirms that the take-back agreements in the retailer-supplier interface can be the cause of some overproduction of bread which, regardless it's amount may lead to environmental consequences since it still utilizes the resources and cause impacts through the production processes (Swedish National Food Agency, 2016). Approximately half of the bread and bakery products which are sold in supermarkets are subjected to TBAs in Sweden (Brancoli, et al., 2019). When the bread products are delivered in large quantities to the retails, account for the largest impact on the total waste in terms of mass, despite the fact that the relative waste can be fairly small with the

large volumes sold products (Iakovlieva, 2021). However, even less environmental costs are unjustified since the bread is left unconsumed and wasted finally (Swedish National Food Agency, 2016). Therefore, although the take-back agreement was organized to minimize the negative environmental impacts related to landfilling and incineration, the environmental aspects of sustainability is still affected negatively by the effects of overproduction of bread products (Swedish National Food Agency, 2016). The take back agreements were also identified as a risk factor of waste generation in (Brancoli, 2021) and it accounted for the highest waste generation in mass, compared to the other sub categories considered in the study and it was estimated at 15 000 tonnes per year. As a summary, the take-back practices performed by Swedish bread suppliers in the supplier-retailer interface cause negative effects through the asymmetric power and the take-back agreement in terms of retailers may become a source of overproduction which may lead to economic, environmental and social costs. However, there is a potential of addressing this issue by addressing the power asymmetries (Swedish National Food Agency, 2016). and also, TBA is identified as an opportunity to valorize the surplus bread, as TBA enables the segregated collection of bread (Brancoli, 2021). Products which are not subjected to take-back agreements (No-TBA) are often branded by the retailer, such as private label products (Brancoli, et al., 2019). In that case, the retailer takes the financial responsibility for the unsold products as well as the waste disposal. The no-TBA bread products are discarded together with the other in-store food waste. Furthermore, as the supermarket owns such waste, those bread products are subjected to in-store waste prevention actions such as offering discounts or donating to charity (Brancoli, et al., 2019).

2.9.4. Bread waste at bakery, retail and household stages in Sweden

Different studies have used different system boundaries, methods and, also focused on different sectors such as retail, restaurants, household and school service in their bread waste quantifications. Besides bread waste, the losses and waste at bakeries included wastage of dough, flour and other ingredients used to make bread (Brancoli, et al., 2019). Bread losses and waste at bakeries have been quantified in some of the previous studies (Table). According to (Brancoli, 2021) bakery waste was estimated as 12 000 tonnes per year including waste flour, other ingredients and the dough.

Retailers in Sweden have reported less food waste generation compared to the other parts of the food supply chain (Brancoli, 2021). However, retailers can make an influence in waste generation or prevention of waste at other stages of the food supply chain, such as primary production, distribution and consumption. A model adopted by is the the largest bakeries in Sweden for bread distribution with the involvement of full take-back agreement (TBA) between the supplier and retailer

can be taken as an example for the influence by the retailers (Brancoli, 2021) where the retailers attributing a high market power. According to (Brancoli, et al., 2019), 40 240 tons of bread were generated in total in the bakeries and retailer's interface in the Swedish value chain. Majority of the waste has occurred after production stage. TBA products has taken the highest share, with 39% of the waste followed by the production waste (30%) and bake-off products, contributing to 24% of the total waste share (Brancoli, et al., 2019). Products which were not subjected to TBAs contributed for 7% of the waste related to supplier-retailer interface. In many countries, the bread supplier is responsible for transporting bread to the retailer (Brancoli, 2021) since bread has a short lead time and bakeries make sure that the product arrives the retails as soon as possible. In Sweden, bread is distributed individually by each bakery or else, some bakeries have the same reseller route (Brancoli, 2021).

Wasted food is often moved into landfill, which cause significant environmental impacts, such as methane emissions related to anaerobic digestion (Ghosh & Eriksson, 2019). However, in Sweden, landfilling of organic waste has been banned the waste goes to landfill is 2% of total municipal solid waste in while the rest is subjected to material recycling, incineration, digestion and composting. However, avoidable food waste remains where the wholesale sector /retails in Sweden make over 70,000 t of avoidable food waste per year (Ghosh & Eriksson, 2019) which if reduced by 20%, would save 47 million SEK per year.

According to a study done by the Waste and Resource Action Program (WRAP, 2013) bakery waste is the fourth largest fraction in household food waste which accounts for 800,000 million tonnes per year in the United Kingdom. Household level is responsible for a great part of bread waste in Sweden as well. The quantification of household bread waste done based on secondary data accounted for 30 000 tonnes of bread per year according to (Brancoli, 2021) which was 37% of the total waste of bread. According to (Brancoli, 2021), retail waste was estimated at 28 000 tonnes while bakery waste was estimated as 12 000 tonnes per year, both representing 35% of the total bread waste. The similar bread waste volumes at retail and household levels differs with the food waste trends in the Swedish statistics and avoidable food waste in household levels is four times greater than that at retail level (Brancoli, 2021). However, according to quantification of bread waste done by (Brancoli, et al., 2019) bread waste is not concentrated in households, where waste rates are similar at retail and households which shows that it is important to take actions at retail sector to for preventing bread waste.

2.9.5. Bread waste management in Sweden

According to the results from A LCA done in (Swedish Waste Management Association, 2019), Global warming (GW), Stratospheric ozone depletion (OD), Ionizing radiation (IR), Terrestrial acidification (TA), Freshwater eutrophication

(FA), land use and water consumption are some of the potential environmental impacts related to bread value chain, and source reduction of bread waste has been found as the preferred option followed by feed production, donation, beer and ethanol production which complies with the EU waste hierarchy.

Besides the large quantity of wasted bread, due to the distribution channels of bread in Sweden and some other countries such as Austria, Norway, the Netherlands and Germany, product is not mixed with other food waste, so, can be managed separately from other waste streams (Brancoli, 2021). With the involvement of take-back agreement (TBA) between retailer and supplier, as discussed above, as bakeries are responsible for the unsold products and collection and treatment of them, a reverse supply chain is created. Therefore, it enables a clean flow of bread, without mixing with other types of food fractions and different waste management opportunities such as animal feed and ethanol production are provided (Brancoli, 2021). (Brancoli , et al., 2017) have reviled that using bread waste for animal feed is not a practice done by the supermarket chain considered in in that study and Swedish Waste Management Association, shows that anaerobic digestion is found to be the most common method for treating food waste in Sweden. According to (Swedish Waste Management Association, 2019) the worst waste management options are anaerobic digestion and incineration while they are the most common waste management schemes in Sweden. However, the paper 17 indicates that using bread waste as animal feed decreases the environmental impact while offering a revenue for the retail. As discussed earlier, according to The European Union's EU Waste Framework Directive (Commission, 2008), prevention of waste is the most preferred option in the waste hierarchy, followed by reusing, material recycling, energy recovery and waste disposal as the least preferred waste management alternative. However, it can be argued that the waste hierarchy may not always provide the best waste management alternatives as different local conditions such as technologies used for waste treatment and energy supply mix can affect the possible alternatives (Brancoli , et al., 2017) has identified source reduction as the option with highest environmental savings among sixteen impact categories considered in the study where its majority is provided by the avoided production of wheat. The waste management practices and valorisation pathways provide environmental savings for many of the impact categories.

3. Materials and Methodology

3.1. Scope of the study

The study was focused on FLW at later stages of the bread value chain, causes and actions to reduce waste. The study covers the processing(bakeries), retail/food services and household/consumer level of the value chain. The bread considered in this study was bread produced at the national level considering bread in general also including pre-packed bread and bake-off products. The bread considered can vary with the type of flour used (wheat, maize, wholegrain, barley, gluten-free, etc.), type of leavening agents and other ingredients. The pre-packed bread waste at retail were as TBA and non-TBA.

3.2. Data Collection

Both primary and secondary data were collected and used in this study. Surveys and interviews for collecting primary data were conducted on FLW from bakeries, food services like restaurants and school/university canteens and households along apple value chain. Secondary data were collected from research papers, reports and websites to gather data about FLW at early stages of the value chain such as primary production and transportation.

3.3. Surveys on FLW along bread value chain

In primary data collection, 3 different categories of questionnaire were designed for bakeries, restaurants/canteens/bread shops and for households/consumers. Questions included in each questionnaire is attached in Appendix A. The questionnaires were created in “google forms” and distributed to all target groups. All the questionnaires were conducted based on Sweden spring 2022. All the questionnaires were distributed via email, social media formats, different university networks as well as student networks. Questionnaire were sent to the bakeries, retailers and canteens via their official websites, emails, social media pages.

Interviews were conducted for a few bread shops and canteens at shops as well as via telephone calls. Questionnaire for the consumers were also distributed at SLU university premises.

3.4. Secondary data collection of bread losses and waste along the value chain

This is based on a literature study (reviews articles, reports and projects). All the literature used in this paper are referred to in the text. This study is focused on later stages of the bread value chain including bakery, retail and consumption stages. Secondary data sources include research reports and scientific papers. Secondary data collection was conducted between February and April 2022. Selected search words for the study were “bread loss and waste”, “home- made bread value chain”, “environmental impact of bread value chain”, LCA for bread”, and “GHG emissions related to bread”. The major Databases used were Google scholar, and Web of Science (all databases). In some cases, reference list included in the research articles were used to find more relevant sources.

3.5. Secondary data of Food waste quantities along value chain

When estimating FLW, the value chain stages, bakeries (including transport to the bakery, retail as well as consumption levels were considered. Quantities of bread waste were extracted from two research papers and the mean value was calculated in weight (ton). The author was careful about the unit conversions as different studies presented their results in different units. The primary data about FLW were considered without unit conversions as the were expressed in various units and basis.

4. Results

In the results section, both the secondary data and primary data at the present study will be compared. However, as mentioned by (paper 13), such data cannot be compared accurately as the reference and methodology used for waste quantification in different studies may differ. Furthermore, another aspect that might hinder comparison between studies is the risk of excluding some bread waste quantities intentionally or unintentionally from quantification or analysis of bread waste can hinder the comparison between the studies.

4.1. Value chain Mapping

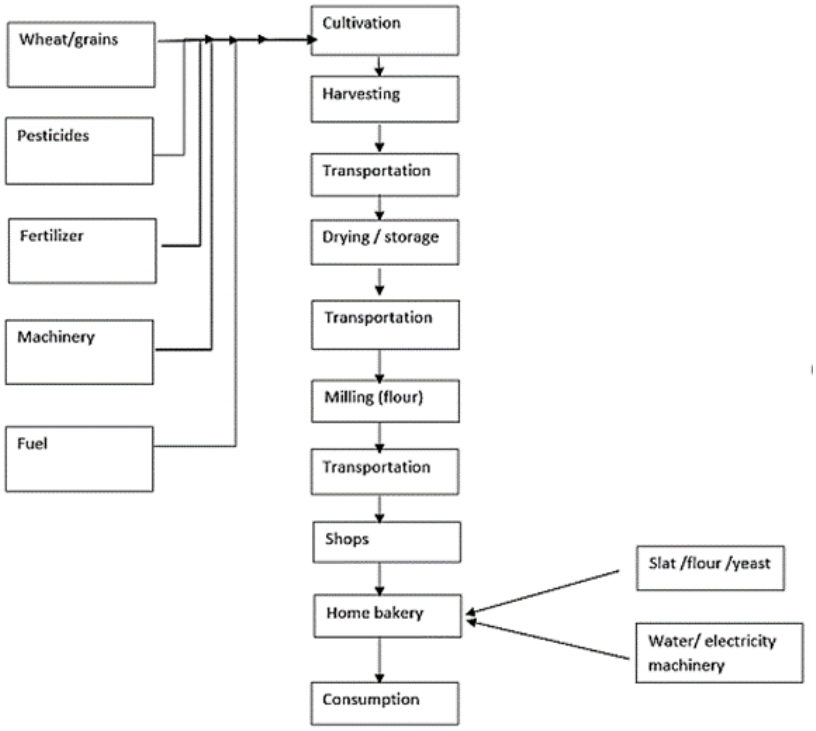


Figure 2: Value chain of home-made bread in Sweden

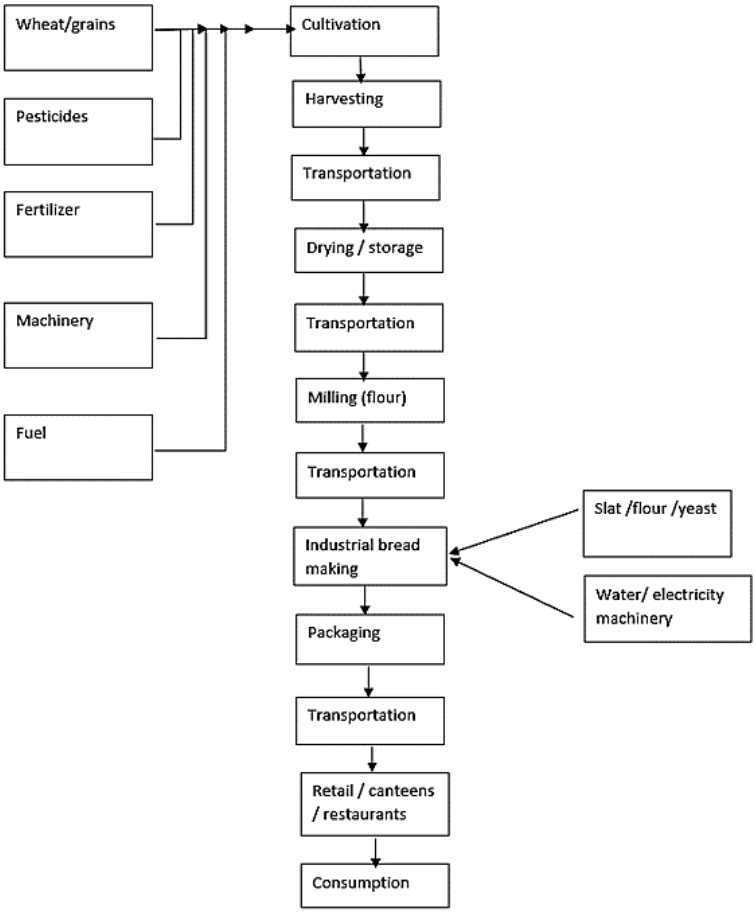


Figure 3: Value chain of industrial bread in Sweden

The bread value chain starts from wheat or grain production to consumption and waste disposal level. As inputs in the farm, machines, fertilizers, different pesticides, fuel, energy and water are used(paper 31). The industrial bread baking technology mostly automated machines. The home-made bread process, purchase ingredients from a shop follows the same major processes like industry, but it is done by hand and baking is done in a kitchen oven (paper 31).

4.2. Estimated FLW values based on primary and secondary data

Secondary data were collected from 10 published reports including the amount of FLW at bakery, retail and household stages of bread value chain. Most of the reports do not contain all the stages of the value chain cover only one of the stages. The collected data is presented in Appendix-B. Table …. is based on secondary data that considering the average FLW values of bread which were estimated at bakery, retail, food service and consumption levels. This average value has been calculated

using the data included 2 research papers (…..). Primary data were used to calculate FLW levels at retail, food service and consumer levels.

4.2.1. Secondary data

Based on data collected from 2 research papers, the estimated amounts of bread waste at bakery, retail and household levels were gathered and the average FLW amounts were calculated. All the bread types in general were considered and bakery level includes all the losses counted for production. Transport and distribution stages are eliminated for the quantification. The estimated values are organized in table 3. And the detailed data are available in the appendix B.

Table 3:Estimated average values of FLW in Sweden

Stage in the value chain	**Average amount of bread loss and waste/ Tonnes per year**	**FLW as percentage of total bread lost and waste along the entire value chain (%)**
Bakery	12020	14.9
Retail	28110	34.9
Restaurants	7150	8.9
Canteens	2640	3.3
Household	29920	37.2
Other losses and waste(farm level, loading, transport, unloading)	610*	0.8
Entire value chain (from farm to consumption)	80450	100

*- Author's own estimation

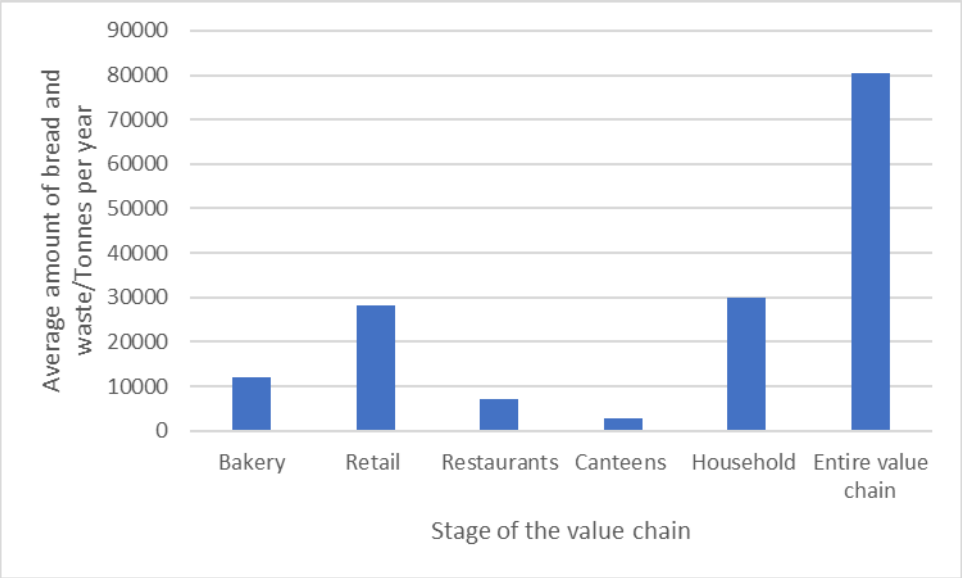


Figure 4:Estimated FLW in Sweden

Based on secondary data in table 3 above, household level has the highest bread waste which is 37.2% of bread waste in entire value chain among the bakery, retail, restaurant and canteen stages along the bread supply chain in Sweden followed by the retail (34.9%), bakery (14.9%) and restaurants (8.9%). Canteens in Sweden showed the lowest bread waste amount.

Bread waste amounts for two different types of bread:

Table 4:Braed waste amounts of two different bread types

Bread type	**Reference**	**Bread waste percentage at retail level of the total bread waste amount (28220) at retail level (%)**
Baked-off bread	(Brancoli, et al., 2019)	34%
TBA	(Brancoli, et al., 2019)	55%

TBA products have a high bread waste percentage compared to baked-off bread.

4.2.2. Survey results

Primary data of bread waste was gathered by a survey conducted on the bakery, retail and household level. However, since bakeries refused to share their information about waste, the bakery waste data will be estimated based on secondary data(see section 5.4).

4.2.2.1. Retail level

The results for retail level were generated from 2 supermarkets in Uppsala, 3 bake shops in Uppsala, 1 bake shop in Stockholm and 1 home- made bread shop in Enköping, totally from 7 retailers in Sweden. The bread waste levels estimated based on the survey results for supermarkets and bread shops are presented in table 5 below. As some of them preferred staying anonymous, the respondents are named with numbers.

Table 5:Results of the retailer survey

Retail*	**Municipality in Sweden**	**The estimated bread waste percentage of the bread kept for sale per day (%)**
Supermarkets		
Supermarket 1	Uppsala	16%
Supermarket 2	Uppsala	4.5%
Average		10.25%
Bake shops		
Bake shop 1	Uppsala	4%
Bake shop 2	Stockholm	0%
Home-made bakery shop	Enköping	0.5%
Bake shops 3	Stockholm	5%
Bake shop 4	Uppsala	Hard to estimate
Bake shop 5	Uppsala	Hard to estimate. It varies a week
Average		4.75%

*-The names of the retailers were kept anonymous.

According to the results from the survey in present study, supermarkets show comparatively higher waste rates;10.25% of the bread kept for sale per day compared to the bake shops (4.75% of the bread kept for sale per day). Both the supermarkets have in store bakeries as well as bread from other bakeries. However, the quantities were estimated by the retailers or shops and they don't have directories about the bread waste quantities. Some bake shops who bake the bread they sell at their own bakeries implies that it is hard to estimate the bread loss and waste at their bakeries and shops which indicates that still there is bread wasted but, no estimation is done.

Results of the estimated bread waste quantities were generated from 1 school canteen in Uppsala, 1 school canteen in Västerås, 2 restaurants in Uppsala, 1 restaurant in Stockholm, totally from 5 retailers in Sweden. The bread waste levels estimated based on the survey results for school canteens and restaurents are presented in table 6 below. As some of them preferred staying anonymous, the respondents are named with numbers.

4.2.2.2. Food service Level

Table 6:Results of the food service survey

Food services*	**Municipality in Sweden**	**The estimated bread waste percentage of bread served per day**
Restaurants		
Restaurant 1	Uppsala	2.5%
Restaurant 2	Uppsala	0.5% (plate waste), zero waste at the kitchen.
Average		1.5%
School canteens		
School canteen 1	Västerås	0.5%(plate waste), Zero waste at canteen kitchen
School canteen 2	Uppsala	2.5%
Average		1.5%

*The names of the canteens and bake shops are kept anonymous

Both the restaurants and school canteens showed similar levels of average bread waste quantities (1.5% of the bread served per day) and of the bread served per day. They mentioned that most of the bread is wasted as plate waste. School canteens show relatively moderate levels of bread waste per day while restaurants have zero or very less amounts of bread waste. The home-made bread shop implied that they have very low waste and sometimes zero waste after sales per day.

4.2.2.3. Household level

The consumer survey gathered results from 133 responses around different areas such as Stockholm, Uppsala, Västerås, Linköping, Vara and Ludvika municipalities in Sweden. Tables 7, 8,9,10 show the results gained from the consumer survey. Background characteristics of the participants:

Table 7:Age group of the respondents

Age group	Number of respondents	Percentage of the total number of respondents
<20 years old	2	1.5
20-30 years old	52	39.1
31-40 years old	53	39.8
41-50 years old	15	11.3
>50 years old	11	8.3
Total	131	100

Table 8:Gender of the respondents

Gender	Number of respondents	Percentage of total respondents %
Female	79	60.3
Male	52	39.7
Total	131	100

Table 9:The country or region of the respondents

Country/ region of the respondent	Number of respondents	Percentage of total respondents (%)
Sweden	82	61.7
Sweden and other European countries	10	7.5
Sweden and other non-European countries	41	30.8
Total	133	100

Table 10:Consumer preference for different types of bread

Bread type	Prefernce when buying	Percentage of total
Organic bread	26	19.5
Conventional bread	29	21.9
Both organic and conventional	27	20.3
Wheat bread	50	37.6
Whole grain bread	76	57.1

Pre – packed bread	48	36.1
Bread straight away from the bakey	1	0.8
No priority	1	0.8

From the survey done through google forms platform and distributed online, 133 respondents participated. Out of them, 60.3% were female and 39.7% were male (see table 8). Regarding the age, 31-40 years old and 20-30 years old were the age groups with highest frequency of participation 39.8% and 39.1%while below 20 years was the least with 1.5% (see table 7). All the participants live in Sweden and 61.7% of them were from Sweden while the least were from other European countries but currently reside in Sweden. Preference of the bread product types of the consumers when they purchase bread were also assessed in the survey. Regarding the purchasing behaviour of the respondents, most preferred type of bread was whole grain bread with 57.1% percentage compared to other types. One respondent indicated that the person does not have any preferred type and his main priority is the price of the bread (see table 10).

Table 11:Percentage of bread wasted from the amount of purchased bread at each household

Range of bread waste percentage of the amount of bread purchased at a time.	Number of responses	Percentage of the total number of responses (%)
0-1%	62	45.9
2-5%	44	32.6
6-10%	20	14.8
11-15%	4	3
Above 15%	5	3.7

Majority of the consumers with 45.9% indicated that the bread waste ranges between 0-1% of the amounts of bread they purchased at a time at their households of the bread they purchase and 32.6% of the respondents waste 2-5% of bread they purchase while only 3.7%, lowest percentage of the respondents waste higher than 15% of the bread they purchase at a time.

4.3. Causes of FLW in bread value chain

4.3.1. Causes of bread waste at bakery level

Results from secondary data are organized as follows:
As (Brancoli, et al., 2019) identifies, waste generated during bread production at the bakeries is influenced by the companies, who have TBA with bakeries and those companies can reduce the waste. It also shows that common cause of bakery waste is unsold bread which is returned due to TAB is the common cause of bakery waste in Sweden. And (Iakovlieva, 2021) showed that bakery waste also occurs due to human factor, technical breakdowns, cancelled orders, etc., which are usually not considered in the data system of small and medium-sized company data systems. Also, (Iakovlieva, 2021) implies that a company might not have information about exact amount of bakery wastes and lack transparency which can hide information about bread waste, and it might prevent a possible joint effort through a collaboration between different actors to address these waste issues. (Iakovlieva, 2021) also assume that overproduction is a common cause of food waste in most of the bakeries, since they want to make sure that they produce sufficient quantities of baked products to satisfy the needs of their customers, rather than having the shelves empty in the retail outlets. Paper 30 brings out that, the lack of intensive effort in retailers to reduce unsold bread duet to the market power they get from TBA and lack of cooperation between the retail managers and bread suppliers may cause higher quantities of returned bread resulting overproduction at bakeries.

4.3.2. Causes of bread waste at retail level

Results from secondary data are organized as follows:
There are many causes identified in different studies which were considered as secondary data sources in this study. The results gained by (Brancoli , et al., 2017) identified that supermarkets in Sweden produce 7% more bread than the sales which are expected sales in order to meet the consumer demands and the difficulty of predicting consumer demands where some factors (ex. weather), (Brancoli , et al., 2017). The consumer demand for a vast range of bread types and freshness causes a necessity for frequent production in large quantities to make sure that fresh bread is available the whole day (Brancoli , et al., 2017). Therefore, the high bread waste amounts may be caused by the demands and consumer behavior. (Iakovlieva, 2021) also shows that constantly changing consumer demands for health and safety issues lead to have a wide range of bread products with various packaging sizes in the market which increases the possibility of bread waste. (Brancoli, et al., 2019) identifies, main waste types at retails are TBA and bake-off products. In-store bakeries are important for bake-off bread production at retails at retail as they can attract customers to the store. High amount of bake-off bread waste can be cause

by the one-day shelf-life and the challenge of maintaining the shelves filled with newly baked bread at the store during the total opening time. (Brancoli, et al., 2019) identified negative correlation between loss rates and sales implying when a large range of products are available to consumers and as there is a subsequent demand for those bread products being stocked, it becomes a is a risk factor for generating high waste since the need for a large inventory to serve a large range of bread products and the uncertain demand increases the risk of waste generation.
Results from primary data:

Table 12:Causes of bread waste at retail and food services

Causes /reasons	**Number of responses**	**Percentage of total responses**
Seasonal variations	4	22.2
Expiry dates	5	27.8
Overstocking	6	33.3
Damaged packaging	3	16.7
Total	18	100

Based on the results from the survey, the causes of bread waste at retail and food services in Sweden are organized in the table…..). As the respondents of the survey with retail and foodservice indicates, the main reasons for bread waste in retail level are overstocking (33.3% of the total responses) and passing expiry dates and best before dates (27.8%) while the other reasons were seasonal variations and damaged packaging. 1 restaurant mentioned that they have zero waste and plate waste is the only reason for a very less percentage of bread waste they get. One school canteen mentioned that they have zero waste at canteen and only cause for a certain less amount of waste is plate waste. One bake shop mentioned that due to the TBA, they get left-over bread from the supermarket. And another bake shop mentioned that, weather and salary date affects the amount of bread that is wasted.

4.3.3. Causes of bread waste at households

Results from secondary data are as follows.
The consumer interview done by (Brancoli , et al., 2017) revealed that consumers believe that the bread waste that they generate are only small amounts and, also, that the environmental impact related to them is low. (Brancoli , et al., 2017) identifies the unlimited access to food and disconnection and lack of knowledge could contribute to wasteful attitudes.
Results from primary data are:

Table 13:Survey results of the causes for bread waste at households

Reason/cause for bread waste	Number of responses	Percentage of the total responses (%)
Bought too much (over purchasing)	39	23.8
Went bad faster than expected/before the best before date	31	18.9
Forgot to use it before it expires	79	48.2
Served too much	15	9.1
Total number of participants	164	100

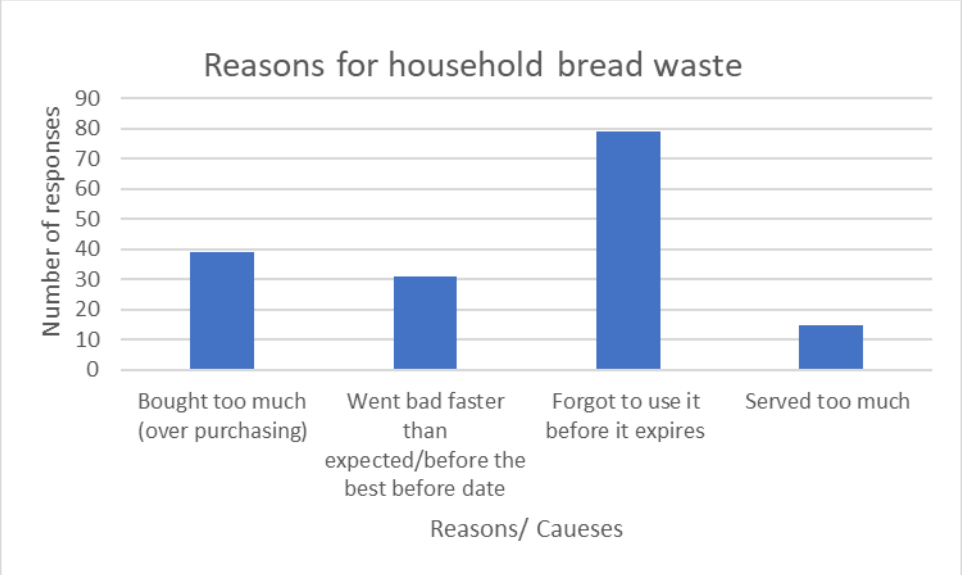


Figure 5: Causes for bread waste at household in survey results

Based on the results from the survey, the main reasons for bread waste in their homes is that they forget to purchase the bread (48.2% percentage of the responses) at they have purchased followed by the reasons that they bought too much bread (23.8%) and the bread became unsuitable for consumption before they consume (18.9). The other reasons which is lowest percentage is serving too much of bread.

4.4. Technologies and practices used to reduce FLW in bread value chain

Secondary data are organized as follows:

To reduce overproduction of bread products at bakeries and reduce bread waste at retails, reduction of product assortment is potential solution (Brancoli, et al., 2019). Customers need to be willing to purchase another product when their preferred bread items are out of stock. According to (Brancoli, et al., 2019), reducing the product assortment has decreased 67% of bread waste as a result of decreasing its range of pre-packed dark and white bread by 25%. Although the sales were decreased by 2% profits were measured to be increased due to the reduction of waste generation (Brancoli, et al., 2019).

According to (Iakovlieva, 2021), in bakeries, accurate forecasting needs to be done prior to production to avoid overproduction which later leads to bread waste. However, due to the indirect negative impacts on the environment, food production companies need to use a sustainable management system aiming to prevent all types of losses. Therefore, (Iakovlieva, 2021) emphasizes that all the causes and factors of bakery waste, can be addressed through lean production tools and techniques. A study (paper 32) done in Belgium in the city of Medellin has revealed that the Lean Manufacturing is one of the most popular practice of waste disposal in the industry and provide great benefits.

As (Iakovlieva, 2021) estimates, bakery waste can be managed in more optimal and accurate way at bakeries. It suggests that selling unsold bakery goods for feed could save costs at bakery as well as cost of waste treatment. However, using unsold bread for yeast production, livestock feed, and donations are not major waste management practices used today (paper 15). Most frequent waste management options used in Sweden are anaerobic digestion and incineration. individual and collaborative efforts are important across the entire supply chain to reduce bread waste that happen due to various circumstances. (Iakovlieva, 2021) also suggests that an active policy needs to be developed to avoid the overflow of TBA bakery products which is acceptable for bakeries in terms of a long-term perspective. Prioritizing measures of preventing the waste generated from unsold bakery products, can lead to a greater reduction in overall waste.

Moreover, paper 15 suggests that consumers' pressure on producers and retailers can stimulate their actions to reduce food losses. (Brancoli , et al., 2017) revealed that communication of the results from their study to consumers may increase awareness of the impacts associated with bread waste, so, reduce the waste at supermarkets as well as households.

(Brancoli, et al., 2020) identifies bread waste flows suitable for different waste management or valorisation practices. Returned bread, if not contaminated with other food waste fractions, is suitable for the most of the waste management and valorisation options. Household waste, as it is a mixed flow with different organic fractions, is suitable for less waste management alternatives. So, they are treated as a fraction of common municipal waste and subjected to anaerobic digestion and incineration in Sweden (Brancoli, et al., 2020). According to (Brancoli, et al.,

2020), return system implemented in Sweden, can also be used in exploring segregated waste management pathways for surplus bread including feed and ethanol production. They can provide higher environmental savings than the common municipal waste treatment practices. According to the results from (Brancoli, et al., 2020), after by properly separating surplus bread from other food waste to avoid contamination with animal originated food, bread can be used to feed animals which has a lower environmental cost compared to incineration and anaerobic digestion. The concern of suing bread in animal feed in terms of the risks of moisture content and the nutrient variability can be minimized by using bread waste as an ingredient of a feed recipe (paper 19). Selling surplus bread as animal feed or as an ingredient of feed, would provide not only reduce environmental cost but also, provide an additional revenue for the bakeries and retailers and also reduce the costs of waste treatment (Brancoli, et al., 2020). (Agency, 2016) also implies the importance of improving the cooperation between the bread suppliers and retailers and also decreasing overproduction which is partially connected to with take-back agreement for decreasing both the economic and environmental costs related to bread waste and provide more benefits for the society.

According to the Pågen AB bakeries (Pågen Bakeries AB, 2022)to keep the freshness of their bread for so long, they maintain very high hygiene requirements in their bakeries such as extra clean air, good cleaning routines and equipment and strict hygiene rules for the employees and keep bread fresh after baking without preservatives. They try to keep their breads with prolong shelf life since they think that long shelf-life is very important as it helps to reduce risk of food waste both at retails and homes. They believe that when the bread shelf is fresh in shops and stores less waste is created, both at stores and homes. Therefore, they try to make bread with longer shelf life so, consumers get more days to eat the bread they purchased before it becomes inappropriate to eat in the stores, can reduce breads being unsold. They also, state that, when they When they bake portion breads, they get leftover dough after cutting out portions. Therefore, they have developed a smart system to reuse leftover dough and turn them into new dough in a circular flow on the line. Furthermore, Pågen AB plan their baking to make sure that they bake as long series as possible which is effective in reducing the risk of creating unnecessary bread waste and wrong baking that could happen due to the oven setting (Pågen Bakeries AB, 2022). When working with recycling, the unsold they recycle 100% the old bread they get back from shops and dough waste from their bakeries. Some of the waste are turned into animal feed through their cooperation with local farmers an remaining waste is used in bioethanol production and becomes renewable fuel. They also donate leftover bread to charity at local level. However, to contribute to a circular system with as little negative environmental impact they work to find new recycling solutions while boosting profitability. They also donate bread to the City Mission’s retail store Matmissionen in Sweden (Pågen

Bakeries AB, 2022). As (Pågen Bakeries AB, 2022) implies, Polarbröd AB freeze their bread as soon as it comes out of the oven to allows uto preserve freshness of the and minimize waste. As the bread thaws within a few minutes, it is convenient. As (Fazer, 2022) mentions in their website, they have sustainability goals significantly reduce food waste by 2030 and strive to minimise wastage by rationalising their production, reusing raw materials, and donating food. Their cafés have reduced waste through selling food via the KARMA and ResQ apps so, people buy food which would otherwise have ended up in the trash.
However, in terms of bread waste management (Iakovlieva, 2021) identifies that the bread products slod with TBA are returned back to the bakeries and or go directly to biofuels production. And also, in that case, feedstocks are collected from supermarkets and bakeries and transported to the logistics hub and then transported to the production facility. Bakery waste like raw materials and ingredients are transported directly from the bakeries for the regulated waste management practices. According to the results of (Iakovlieva, 2021), a small amount of bakery production waste is used as animal feed or used for other other products or tests. Donated bakery products from small- and medium-sized bakeries were mostly used for biogas production through anaerobic digestion. The (Iakovlieva, 2021)found donation less common than using bread for biogas production.

The actions and practices taken by retailers and food service providers participated in the survey is organized below: (see table 14 and 15).

Table 14:Survey results of the actions taken by the reatailers to reduce bread waste

Retail/food service	**Actions, technologies or practices taken to reduce bead waste**
Supermarket 1	As bread waste mainly happens due to over stocking happens due to over estimation of the quantity ordered, prevent it by estimating the amount of bread needed to be ordered prior to ordering Sell bread that are close to best before date with 50% offers in the evenings so consumers get motivated to buy and this reduces bread waste. Provide other discounts like multiple for low prices(3 for 1) to sell them before best before date.

Supermarket 2	Adapt baking based on customer demands. Checking the best before dates every day. Price reduction (offers) for the bread with short best before dates.
Bake shop 1	Plan and adopt the amount of bead need to be baked for sales based on on weather and special dates such as seasons, salary dates etc. The staff writes a report every day when some sorts of bread or pastries is sold out, or how much is left in the end of the day, so the bakers the next day can figure out how much to bake. All the left -over bread and pastry are sold in the "food-saving-app" Karma, where companies can sell products that are bruised, yesterday's pastries, food leftovers from buffés etc. Good for the climate, good for the customers that can buy perfectly fine food for a cheaper amount and good for the companies so they don't have to throw anything away.
Bake shop 2	Stadsmissionen comes and picks up the left-over bread in a day every next morning.
Bake shop 3	No bread is wasted since left over bread are taken to a nearby hospital everyday. Bread trucks owned by the company take the bread to sell. Give left-over bread to Migrationsverket for refugees from Ukraine, they visit the bake shop every night and pick it up.
Bake shop 4	A farmer that come on Mondays and pick a lot up to give for food to their cows and cheep.

	In the store, app “too good to go” is used to not to throw away any bread that is left in our store. Some loafs of bread gets in our freezer and this bread is sometimes given to sagahemmet if needed.
Home bakery and the bake shop	Plan how much bread is needed to produce according to the estimated demand. Left overs are stored in the refrigerator and sell on next day. Further left-overs are donated to a hostel where homeless people live in Enkoping. Share the left bread in the end of the day to a neighbour who farm pigs (animal feed).

As the results imply both the supermarkets try to adopt the production according to the consumer demand and reduce prices and give offers for the bread close to the best before date or baked-off breads in the evening, so reduce bread waste.All the bake shops participated in the survey donate left over bread to feed people or for animal feed.

Table 15: Survey results of ations taken at food service level to reduce bread waste

Restaurent/school canteen	**Actions taken to reduce bread waste**
Restaurant 1	Be careful when preparing food with bread, so do very less mistakes so no need to throw away.
Restaurant 2	Make different dishes from remaining bread in the end of the day for tomorrow. Eg: cake from remaining bread, krutonger for soup. Save only a sufficient amount of bread for a plate to stop plate waste. Plan really well before ordering if there is left over.

Restaurant 3	Try to produce less rather than having too much. If it sells out and customers are left without any bread that´s better then us throwing it away. Prepare sandwiches with left-over, good quality bread and sell for reduce the price on the following day.
School canteen 1	Follow first in first out concept where we make sure we use the bead brought earlier prior to the latest ones so, it prevents expiring bread. Store all the purchased bread in the freezer so, they don't get spoiled. Leftover bread which are already cut or open are dried in the oven and used for soups and make breadcrumbs to use in other dishes which stay longer. Freeze storage helps to avoid spoilage of purchased bread.
School canteen 2	Plan the desired amount of bread needed to serve the number of students who will prefer bread in their plates. Store in the freezer.

According to the results, two of three restaurents prepare different dishes and recipes with longer shelf ife to avoid wasting left over bread and plan the amonts needed before serving. One restaurent is more careful when preparing dishes, so minimize the losses.

According to the primary data, the actions taken by consumers to reduce bread waste at their households are organized in table 16.

Table 16:The actions taken by the households of the survey to reduce bread waste

Action/practice	**Number of responses**	**Percentage of the response of**

		total number of responses (%)
No action is taken	6	4.8
Store purchased bread in the refrigerator (freezing)	43	34.7
Buy, prepare dishes only the necessary amounts/ buy enough/ small sizes(buy less)	31	25.0
Use left-over bread to prepare other dishes ex. Bread crumbs, croutons, puddings	9	7.3
Feed animals	1	0.8
First in first out concept	2	1.6
Meal planning & buy accordingly	8	6.5
Be on track with the expiry date/remember to use before expires	9	7.3
No waste	3	2.4
Use even after best before date until it rotten or tastes bad	2	1.5
Eat everything we prepared /served	1	0.8
Compost	2	1.5
Try different recipes	6	4.8
Buy bread with longer shelf life(ex.knackebrod)	1	0.8
Total	124	100

According to the results, the most taken action to reduce food waste at households is storing bread in the freeze storage until it is totally consumed. The next most frequent action is buying bread and preparing dishes in only the required or sufficient amounts. The least frequent actions were feeding animals and eating everything prepared or served.

5. Discussion

The purpose of this study is identifying and assess the potential FLW along the bread value chain, the GHG emissions associated with FLW, and actions, technologies and practices to reduce FLW.

5.1. Delimination

This study is geographically limited to Sweden. It was difficult to collect FLW of bread in Sweden as the studies and data about the quantities were very limited and less. It was also difficult to accurately identify and assess bread waste and loss quantities data during the survey, especially from bakeries and retailers as most of the producers and retailers were not open and transparent about sharing and discussing data. The study did not include primary data from two of the main bakeries in the Swedish bread market since they did not respond to the survey. As there were no directly weighed quantities of TBA bread with retailers por producers, accurate quantification of bread waste was limited. When collecting FLW data from producers, retailers and consumers, the quantification in one unit was difficult as they had not weighed or quantified the accurate amounts of bread waste or losses at those stages. Therefore, accuracy of interview data and the calculations based on them is not completely determined. Moreover, the possibility of an extensive statistical analysis with a large number of respondents was limited since such quantitative research is time-consuming, complex as wells as resource-intensive. There is a limited number of research carried out based on FLW along the bread value chain in Sweden. Most of those reports are focused on one or two specific stages of the bread value chain. This study focused only on the bakery stage which includes baking and packaging of bread, retail, food service including storage and selling and consumer stage. In primary data collection, no bakery who was contacted was open to respond to the interviews or surveys, so, the data were limited to secondary data. Even as there were only two reports had reported FLW amounts for each stage, the data were based on two secondary data resources.

5.2. Reliability and validity

Questions included about the types of bread products, and reasons for loss or wastage were organized with predefined questions in the semi-structured questionnaire in order to be able to compare the data between the respondents. However, the questions about the actions and practices of waste/loss reduction or prevention were open in order to get more accurate results from different respondents. In addition, as the bakeries, retailers and food services seemed to be not openly responsive about the FLW quantities and not being transparent, there is a risk of not getting actual bread waste data from the survey results.

5.3. The value chain map and the main actors involved in the bread value chain

The entire Bread value chain starts from the farm where the wheat or grain needed for the flour is cultivated (paper 31). As inputs in the farm, machines, fertilizers, different pesticides, fuel, energy and water are used. The harvested grains are dried, stored and transported to the mill for grinding process. Finally, the grains are grinded into the flour and packaged. In the industrial baking chain, the flour and other ingredients such as salt and yeast are delivered to the industrial bakery where the ingredients are turned into bread, packed (sometimes labelled) and then distributed through the transportation system to the retailers/food services/shops/customers who sell them to the end consumers. The industrial bread baking technology mostly runs with automated machines. During home-made bread process, the ingredients for the bread are usually purchased from a shop and the baking process follows the same major processes such as mixing, dividing and forming and then baking. However, those main processes are done by hand. The baking process is done using a kitchen oven (paper 31).

5.4. The estimated quantity of bread FLW (e.g., %)

Based on secondary data, among the bakery, retail and household stages of the Swedish bread value chain, household level has the highest bread waste which is 37.2% of bread waste in entire value chain. The consumer survey gathered results from 133 responses around different areas in Sweden such as Stockholm, Uppsala, Västerås, Linköping, Vara and Ludvika. According to the Background characteristics of the participants, out of 133 respondents, 60.3% were female and 39.7% were male and age, 31-40 years old and 20-30 years old were the age groups with highest frequency of participation 39.8% and 39.1% while below 20 years was the least with 1.5% . All the participants live in Sweden and 61.7% of them were

from Sweden while the least were from other European countries but currently reside in Sweden. Therefore, all the responses were considered in the study as they all are from Sweden. As the responses for the preference of the bread product types of the consumers, most preferred type of bread was whole grain bread with 57.1% percentage compared to other types. One respondent indicated that the person does not have any preferred type and his main priority is the price of the bread which indicates that the bread type and price of bread also affects the purchasing behavior of the consumers. As mentioned above, bread waste in Swedish households was the highest followed by the retail (34.9%), bakeries (14.9%) and restaurants (8.9%). School canteens in Sweden showed the lowest bread waste amount compared to the other stages considered in the study. When interviewing the restaurants and school canteens they mentioned that they have very less bread waste as they take actions prevent wasting bread at their companies. One restaurant at a University and one school canteen mentioned that they have zero bread waste at their kitchen and savings. But they get some plate waste when customers and students get too much bread than they need or depending on the, menu they have for the day. Those plate wastes were considered as the bread waste amounts at those particular restaurant and canteen. However, these results show that the school canteens and restaurants have taken actions maintain practices to reduce bread waste ta their levels which is a positive fact in terms of waste reduction. However, it should be a collaborated effort with their consumers or customers as the plate waste counts for a major fraction of their waste. However, still there are certain amounts of bread being wasted at those levels which has the potential to be lowered or prevented further. The retail and household levels have the highest bread waste quantities showing the necessity of taking actions and practices to reduce waste at those levels. According to the results from the survey in present study, retailers, supermarkets show comparatively higher waste rates than the school canteens, bread shops and restaurants showing similar overall results as the secondary data which is that the retail and household levels have higher bead waste. However, the waste data provided by the retailers and food services were estimates they made and they did not rely on any documents or directories. The retail shops contributed in the present survey were the main supermarket chains in Sweden and they showed two different levels of bread waste. However, they waste higher amounts of bread of what they produce. Some bake shops who bake the bread they sell at their own bakeries implies that it is hard to estimate the bread loss and waste at their bakeries and shops which indicates that still there is bread wasted but, no estimation is done. However, as the results imply, bakeries showed comparatively lower bread waste than retail and household. Pågen AB, one of the main bread producers in Sweden, implies that they have very low amount of bread waste which is about 2% from the baked bread and they are working to reduce them even further. The home-made bread shop implied that they have very low waste and sometimes zero waste after sales per day

as they find it easy to take actions and plan to prevent when producing bread in smaller scales.

According to the results gained from the survey done in the present study, the findings on the magnitude of food waste in bakeries, retail and food service indicate that the losses and waste are variable, depending on the size of the bakery, location of the retail and bakery, the group of consumers, strategy and variety of products. However, according to the household survey results of the present study, majority of the consumers with 45.9% indicated that the bread waste ranges between 0-1% of the amounts of bread they purchased at a time at their households and 32.6% of the respondents waste 2-5% of bread they purchase while only 3.7%, lowest percentage of the respondents waste higher than 15% of the bread they purchase at a time. This result shows that they waste significant amount of bread at households but not a large amount compared to the amounts they purchase. However, even the smaller amounts of waste cause significant impacts on the environment and the economy which means the actions needed to be take to prevent and reduce waste.

The secondary data shows that Sweden has a high percentage(5.2%) of losses in bakeries of total production at processing stage(see table 17). Comparatively, 6.5-8% of bread waste and losses were found in Switzerland (Beretta, et al., 2012) and 1.2% in Norway (Stensgård & Hanssen, 2016). In Sweden, Finland and Switzerland, losses are estimated to be slightly higher. Moreover, according to Pågen AB, one of the main bread producers in Sweden, their bread waste are comparatively low (about 2% from the baked bread) and they are working to reduce them even further (Pågen AB, 2022). And the results reflect that bread products are produced and traded with various percentages in different countries. Thus, quantifying bread waste in the supply chain shows that it is important to take actions in the production stage to losses and waste during processing.

Table 17:Losses during bread production in different countries

Reference	**Country**	**Bread losses during processing**
(Katajajuuri, et al., 2014)	Finland	6.5-8% of the production volume
(Polarbröd, 2022)	Sweden	6.9% losses of total production
(Brancoli, et al., 2019)	Sweden	5.2% of total production
(Beretta, et al., 2013)	Switzerland	5.1% of total production

(Stensgård & Hanssen, 2016)	Norway	1.2% of total production

5.5. The main causes of FLW in bread value chain

Both the secondary and primary data many causes and reasons for bread waste at different levels bread value chain can be identified. According to secondary data, waste generated during bread production at the bakeries is influenced by TBA with retailers and (Brancoli, et al., 2019) claims that unsold bread which is returned to bakeries due to TAB is the common cause of bakery waste in Sweden while (Iakovlieva, 2021) identifies lack of intensive effort in retailers to reduce unsold bread is less due to their market power get from TBA. Therefore, both the studies support each other's implication that, TBA is a main cause of bread waste which is proven by a bake shop interviews in the survey in this study who stated that, TBA bread returns a significant about of bread waste at their bakeries. And also, the lack of cooperation between the retail managers and bread suppliers may even increase the quantities of returned bread. This result implies that the TBA in the retailer-supplier interface can may lead to some overproduction of bread at bakeries. This amount of waste can be justified by the bakeries in terms of economy, with a low economic cost as the market demand for bread has increased in recent years. However, this cannot be justified from an environmental perspective, as wasting natural resources at his scale waste natural resources causing a significant environmental cost. Over production is also assumed to happen as a result of them being trying to make sure that they produce sufficient quantities of baked products to satisfy the needs of their customers and keep the retailer shelves filled with bread, especially in their outlets. This causes bread waste at bakeries. Moreover, human factor, technical breakdowns, cancelled orders also cause bread waste at bakeries. However, those data are usually not considered in the data system of small and medium-sized companies even though they cause a significant influence on bakery waste. Furthermore, both the present study and secondary data suggest that some companies might not have sufficient information about exact amount of bakery wastes at their companies and lack transparency which can hide information about bread waste. This might prevent taking a joint effort and collaboration between different actors in the value chain to address the waste issues.

The secondary data resulted that supermarkets produce 7% more bread than their expected sales in Sweden aiming to meet the consumer demands. This finding from (Brancoli , et al., 2017) is confirmed by the result from (Iakovlieva, 2021) showing that constantly changing consumer demands for health and safety issues cause having a wide range of bread products with various packaging sizes increasing the possibility of bread waste at retail shops. This cause was also found to be causing

bread waste in bakeries as discussed above. Even though reducing over production can prevent bread waste, it may be challenging, due to the difficulty of predicting consumer demands where some factors (ex. weather), are hard to be predicted may cause significant variations of demand. The results of the present study also implies that a main reason for bread waste in retail level is overstocking of bread products to satisfy consumer demands. Therefore, the study can imply that the consumer demands and behavior is a main cause of bread waste at retailers as well as in bakeries due to their demand for a vast range of bread types and freshness of bread which causes a necessity for frequent production of bread in large quantities to make sure that fresh bread is available the whole day. In-store bakeries are important for bake-off bread production at retails at retail as they can attract customers to the store. High amount of bake-off bread waste was identified as caused by their one-day shelf-life and retailers trying to maintain the shelves filled with newly baked bread at the store throughout the opening time. This is mainly identified in in-store bakeries as their bake-off bread production can attract customers to the store. Therefore, in terms of bake-off bread waste at retailers, the consumer demand for bake-off products also causes bread waste. As a negative correlation has been identified between loss rates and sales, availability of a large range of products and a subsequent demand for those bread products becomes a risk factor for generating high waste due to the need for a large inventory and the uncertain demand. The present study also identifies, passing expiry dates and best before dates, seasonal variations and damaged packaging also become significant causes of bread waste at retails in Sweden. However, this study identified that some restaurants and school canteens in Sweden confirm that they have zero bread waste which is a positive sign of engagement of restaurants and schools in reducing bread waste has a great potential. However, even the restaurants and school canteens take actions to reduce bread waste during their sales and stocking, plate waste has become another reason for increased bread waste. It implies the importance of consumer and student behavior towards putting an effort to reduce wastage of bread during their consumption. Moreover, weather and salary date are also found to be reasons for bread waste at bread shops.

Based on the secondary data, it can be argued that, the consumers believe that they generate relatively small amounts of bread waste causing relatively lower environmental impacts. However, this study reveals that, the household bread waste has the highest fraction(37%) of total bread waste in entire value chain. Therefore, there is a necessity to improve awareness of the consumers to reduce wasting bread at household levels. The unlimited access to food and disconnection and lack of knowledge are discussed as main causes of wasteful attitudes among consumers. And the consumer survey of the present study reveals that main reasons for bread waste in their homes is that they forget to purchase the bread that they have purchased, and it shows 48.2% percentage of the responses. It can be argued that

their busy lifestyles and high availability of various types of bread also causes that behavior. Moreover, buying too much bread than they consume was mentioned as the second most frequent reason for bread waste at households accounting for 23.8% of the total responses. 18.9% of the responses revealed that, the bread becoming unsuitable for consumption before they consume as a cause of bread waste. However, those reasons can be argued as interconnected to each other as buying too much and forgetting to consume the purchased bread also can lead the bread to be expired before they consume. Serving too much bread was the least reason and it also supports the fact that, one of the major reasons for most of the causes of bread waste households is led by the unawareness, poor planning of purchase and lack of knowledge among the consumers about how much bread they waste at their homes. However, the causes seem really simple and general cause the most significant amounts of bread waste at households which needed to be avoided with more collaborative actions. As consumers waste the highest fractions of the bread waste in the value chain, it also increases the waste at retails and bakeries as the consumer demand make the producers and retailer overproduce bread to meet consumer needs. Therefore, it can be implied that, there is a significant potential of consumers to increase awareness of the bread that they waste, and impacts associated with bread waste, so, for reducing the waste at supermarkets as well as at bakery levels. However, as many more causes also cause bread waste at retails, bakeries they also need to take more actions and overall action needs to a collaborative action among all the actors in the value chain. In the survey, it was assessed if the supermarkets and bake shops sell bread online and if COVID 19 pandemic has affected their sales of bread. From 7 responses, 4 responses said that they sell bread products online and 42.9% of them said that their online bread sales increased due to the pandemic. Therefore, special global issues such as pandemics also affect the sales of bread which means has an indirect effect on bread wasted.

5.6. The technologies and practices used to reduce FLW in bread value chain

5.6.1. FLW reduction in bakeries

5.6.1.1. Reduce overproduction

Both the secondary and primary data confirm that the overproduction of bread is a major reason for bread waste at both bakery and retail levels. As a potential solution to tackle this issue, reduction of product assortment can be an effective action to be taken by the retailers. As paper 13 reveals, reducing the product assortment has decreased 67% of bread waste as a result of decreasing its range of pre-packed dark and white bread by 25%. It has reduced the sales by 2% thus, as the waste

generations reduced significantly, the profits were increased. This finding implies that reduced product assortment can reduce wastage of bread at bakeries sand retailers while still increasing profits which is beneficial for both the environment as well as the industry. However, in order to implement this action successfully, the customers should be willing to purchase another product when their preferred bread items are out of stock. This finding also reflects the necessity of increasing consumer awareness of the waste reduction not only at their households but also ta retails and bakeries through a responsible consumer behavior. It also shows that an action taken by one actor in the value chain becomes effective when the other actions who are interconnected are also engaged.

Moreover, another potential practice to avoid overproduction at bakeries is accurate forecasting of the amounts of bread needed to be produced based on the consumer demands and sales at retail levels. The forecasting should be done prior to production, so, it can avoid possible bread waste in future. (Fazer, 2022) also mention that they strive to prevent overproduction in their production and cafés through good planning. Improving the cooperation between the bread suppliers and retailers would also reduce bread waste at both the levels by reducing over production. As reduction of overproduction is partially connected to with take-back agreement, actions related TBA will also decrease the economic and environmental costs related to bread waste and provide more benefits for the society.

(Bajželj, et al., 2020) suggests replacing surplus with reserves as an approach to overcome over-production of food and suggests that approach to food system resilience should shift from over-production to reserving food such as proper storage and extended shelf life. The present study considers that approach is applicable to the prevention of overproduction of bread.

5.6.1.2. Lean production and techniques

Since many reasons cause bread waste at bakeries, and due to the indirect negative impacts on the environment, food production companies need to use a sustainable management system aiming to prevent all types of losses. Therefore, the solution that (Iakovlieva, 2021) emphasizes to address bakery waste through lean production tools and techniques can be a potential solution in Sweden. To avoid overproduction and other wastes and losses generated at bakeries, a plan on implementing lean manufacturing at bakeries can be a great focus on elimination of waste. It will allow the bakeries to identify waste and react to waste. This technique may have the potential to eliminate bread wastage at bakeries while improving the productivity and manage waste with lowers cost and less time.

5.6.1.3. Mainatin the freshness of the bread

According to the Pågen AB bakeries (Pågen AB, 2022), they try to keep the freshness of their bread for so long, by maintaining very high hygiene conditions in their bakeries such as extra clean air, good cleaning routines and equipment and also maintaining strict hygiene rules for the employees. This has allowed them to

keep bread fresh after baking even without preservatives. They believe that breads with prolong shelf life help to reduce food waste both at retails and households. They believe that when the bread shelf is fresh in shops and stores less waste is created, both at stores and homes. Therefore, they try to make bread with longer shelf life so, consumers get more days to eat the bread they purchased before it becomes inappropriate to eat in the stores, can reduce breads being unsold. (Pågen AB, 2022) also support the effectiveness of maintaining freshness in waste reduction as they mention that they freeze their bread as soon as it comes out of the oven which allow them preserve freshness of the bread and minimize waste. And also that they confirm that since the bread thaws within a few minutes, it is convenient.

5.6.1.4. Making production plans

Pågen AB state that, when they bake portion breads, they get leftover dough after cutting out portions. Therefore, they have developed a smart system to reuse leftover dough and turn them into new dough in a circular flow on the line. Furthermore, Pågen AB plan their baking to make sure that they bake as long series as possible which is effective in reducing the risk of creating unnecessary bread waste and wrong baking that could happen due to the oven setting (Pågen AB, 2022). Therefore, bakeries can implement their own production plans to reduce the losses during bread processing.

5.6.1.5. Non-TBA products

As no-TBA products are branded by the retailer such as private label products, the retailer is financially responsible for the bread that are unsold as well as the disposal of waste. Such products are usually discarded with the other in-store food waste. However, since the supermarket owns the product, there is a potential of waste by subjecting to the actions taken for other in-store products such as discounting or donation. The involvement of governance by introducing active policies to avoid the overflow of TBA bread would be a long-term solution.

5.6.2. Waste reduction at retails

5.6.2.1. Proper sales planning

Both the supermarkets participated the survey of the current study who are two of the major retailers in Sweden confirm that proper planning of the quantities of bread needed to be ordered from the bakeries allow them to reduce their bread waste. And two of the bake shops, school canteen and two restaurants also confirm that they have zero or less waste as they plan the quantities they produce or serve prior to ordering and serving. As discussed above, secondary results also support that, proper planning of orders, production quantities and sales by adopting to the customer demand allow them to reduce or make zero bread waste at bakeries, retail and also food service levels.

5.6.2.2. Offers and discounts

Both the supermarkets and a restaurant mentioned in the survey that they Sell bread that they sell bread that are close to best before date for reduced prices and offers. Moreover, they give very attractive offers (50%,70%) of the original prices for bake-off products in the evenings as they have a very short shelf life. They find it very effective to reduce bread waste at their retails. However, the author would doubt that as the customers tend to buy the bread that are sold for reduce and attractive prices and then if they are unable to consume them before expires, it would cause unconsumed bread at their households. If the consumers are aware to purchase only the required amounts, the reduced price would be a good option to reduce retail waste. Therefore, offers and price reductions can be criticized for their links to waste by encouraging consumers to purchase more than they need which then might encourage retailers to buy more than they need as well. Therefore, even though the promotions and offers can reduce retail waste, eliminating wasteful promotions are required be practiced as a two-pronged attack where the retailers need to direct responsibility while consumers having a responsible influence on retailer's behavior.

5.6.3. Waste reduction at food services

5.6.3.1. Serving sifficient amounts and variety of dishes

The restaurants and school canteens also mentioned that serving sufficient potions of ordered food based on their experience about the estimated amount that a person would consume helps them to reduce plate waste and also, serving and introducing innovative and new recipes with bread helps them to motivate consumers to reduce plate waste.

5.6.4. Wsate reduction at households

5.6.4.1. Freeze storage

In the consumer survey of this study, the most frequent action of the household to reduce bread waste was mentioned by 41.3% of the total responses as storing purchased food in the freezer. The home bakery also mentioned that they store left-over bread in the freezer and use them in the next day for different recipes while both the school canteens mentioned that they store purchased bread in order to prevent wastage. Majority of those respondents also mentioned that it is an effective action to reduce bread waste. Therefore, storing purchased or left-over bread in the freezer can be considered as a mostly practiced, simple and effective option to prevent bread waste at households as well as food services as freezing keeps the moisture of the bread can be consumed before it goes stale. However, still the consumers need to be aware that they don't forget to consume the bread which is already stored in the freezer. However, forgetting to consume before expires was

one of the main reasons for household bread waste stating the importance of more concerned and responsible consumer behavior towards the issue.

5.6.4.2. Prepare different recipes and dishes from left-over bread

Even if the consumers try to store their bread properly, sometimes they may still end up with a few left-over bread and even the last piece of stale bread. However, instead of throwing them away, try to turn them into different dishes would make them to be able to consumed and prevent ending up in the trash bin. 8.7% of the consumers mentioned in the survey that they produce different dishes such as Croutons, bread puddings and make breadcrumbs which stay longer. This option allows them to enjoy bread in different ways while saving their money. Not only households, but also the restaurants and the home bakeries mentioned that they prepare different dishes such as sandwiches, cake and also, “krutonger” for soup, so they can sell the unsold bread in more attractive forms. These options may be economically beneficial for the consumers and also reduce the impact on the environment.

5.6.4.3. Purchase and prepare only the necessary quantities.

In the consumer survey, 29.8% of the respondents mentioned that they try to purchase only the amounts of bread needed for the consumption at household and after purchasing, they prepare only the required amount so, there is less plate waste. This result reflects that, considerable effort is done by some consumers to reduce food waste by changing their purchasing and consumption behaviors. However, as the waste fraction is really high in households, more consumers need to be aware to practice this behavior.

5.6.4.4. More actions at households

The actions such as feed animals, use even after best before date until it rotten or tastes bad, eat everything we prepared, try different recipes and buy bread with longer shelf life (ex.knackebrod) were some of the actions mentioned by comparatively lower percentage of the household respondents. However, even an action by a single consumer would make a contribution to this collaborative effort in future. However, 8.7% of the respondents try to be on track with the expiry date and remember to use before the bread expires which is comparatively low frequency. But the forgetting to consumer before the bread expires was the most frequent reason which was mentioned by the same group of respondents in the consumer survey. This result implies that the most frequent cause of household bread waste has not been tackled by the consumers by keeping in track and remembering to consume before the read expires. Therefore, it can be assumed in this study that, this situation might be a one of the major reasons for household waste being the highest fraction among the other stages along the bread value chain. This also emphasizes the importance of consumer awareness and effort to take the right action in overcoming this global issue.

5.6.5. Enhance consumer awareness

As discussed above, consumers have a great contribution in waste generation at bakeries, retails and food services which means they need to be aware to be responsible when purchasing bread. On the other hand, the pressure caused by the consumers who are aware of waste reduction can also put a considerable pressure on producers and retailers can stimulate their actions to reduce food losses. Therefore, communication of the results from different studies done on bread wastage may increase consumer awareness of the environmental, economic and social impacts associated with bread waste, so, reduce the waste at bakery, retail, food service as well as households.

5.6.6. Waste management practices

As still a significant amount of bread quantities are generated in most of the stages of the value chain which is also confirmed by the present study, waste management also becomes a major action to be taken to tackle the food waste issue. To manage bakery waste in more optimal and accurate way, selling unsold bakery goods for feed could save costs at bakery as well as cost of waste treatment. Even though, according to Potter's waste hierarchy, source reduction is the most preferred action, using bread for feed is also a good solution as the next preferred action. However, use of unsold bread in yeast production, livestock feed, as well as donations are not practiced majorly as waste management practices used today. (Brancoli, et al., 2020) also support the result of (Iakovlieva, 2021) that, returned bread, if not contaminated with other food waste fractions, is suitable for most of the waste management and valorisation options. However, currently in Sweden, anaerobic digestion and incineration are the main waste management options which are considered as less preferred in the waste hierarchy. Compared to the waste fractions at bakery and retail levels, household waste is a mixed flow with different organic fractions. Therefore, it is suitable for less waste management alternatives. So, they are treated as a fraction of common municipal waste and subjected to anaerobic digestion and incineration in Sweden. The return system implemented in Sweden, can also be used in exploring segregated waste management pathways for surplus bread including feed and ethanol production. They can provide higher environmental savings than the common municipal waste treatment practices. After being properly separated, surplus bread from other food waste for avoiding contaminating with animal originated food, surplus bread can be used as animal feed animals which is a waste management with lower environmental cost compared to incineration and anaerobic digestion. The concern of suing bread in animal feed in terms of the risks of moisture content and the nutrient variability can be minimized by using bread waste as an ingredient of a feed recipe. (Brancoli , et al., 2017) also identifies that use of bread waste as animal feed have the potential of reducing the emissions of CO2eq. by 1549 kg per year than the other waste

management (incineration and anerobic digestion) practiced by the supermarket considered in the study.

As mentioned above, paper 19 also support the fact that, selling surplus bread as animal feed or as an ingredient of feed, would provide not only reduce environmental cost but also, provide an additional revenue for the bakeries and retailers and also reduce the costs of waste treatment. (AB, 2022) also support the effectiveness of using surplus bread as feed as some of the waste are turned into animal feed through their cooperation When working with recycling and donating leftover bread to charity at local level. They also donate bread to the City Mission's retail store Matmissionen in Sweden. These findings imply that main bread producers in Sweden are also engaged and put an effort to reduce waste at their bakeries and shops which is a positive sign of their involvement for the SDGs. However, they also send leftover bread for bioethanol production and renewable fuel to make sure that they recycle 100% the old bread they get back from shops as well as the dough waste from their bakeries (Fazer, 2022) also mention that they donate bread to Stadsmissionens own retail Matmissionen and reduce bread waste. A bread shop mentioned in the survey that all of their left -over bread are sold in the "food-saving-app" Karma, where companies can sell products as customers can buy food food which are in good quality for a cheaper amount and companies don't throw food away. Another bake shop mentioned that, Stadsmissionen comes and picks their left-over bread every next morning. The home bakery mentioned that the left-over bread are donated to a hostel where homeless people live and also send to the neighbour to use as animal feed. Another bake shop donate the left-over bread to Migrationsverket for refugees from Ukraine and also to the hospital. As some of the recievrs come and pick the donations, the bakeries and shops don't get an additional transport cost. These actions taken by leading bakeries, bake shops and even small -scale home bakeries in Sweden shows the potential of donating or selling unsold bread to people with collaboration with food aid ensure that the food is eaten and not wasted which is the most preferred waste management in waste hierarchy. However, the consumer survey resulted that only one out of 133 respondents do composting of their bread waste. However, when discussing about the waste of raw material and ingredient waste, the bakeries involved in the present survey did not mention about them. However, as (Iakovlieva, 2021) implies, bread products traded with TBA are returned to the bakeries and or go directly to the production of biofuels and are subjected to long deliveries as they go through the logistics hub when they are returned. This result also implies the contribution of TBA in implications of bread waste management. And also, paper identifies that a small amount of the bread waste at larger bakeries are used as animal feed or reused for other purposes. However, (Iakovlieva, 2021) has different results regarding the bread waste from small- and medium-sized bakeries, as it mentions that they are mostly used to produce biogas through anaerobic digestion than being donated.

However, donating left-over bread can be viewed as a positive and preferred waste management option it is beneficial for the society, environment as well as the economy.

5.6.7. Collaborative actions

According to the waste quantities, causes of waste and the actions that have taken so far by different actions, it can be stated that, reducing the waste and losses along the bread value chain requires a collaborative effort along the entire chain – from producers to supermarkets and retailers and right through to consumers. Numerous manufacturing, in-store practices, have an important role to play in the reduction of bread waste. However, individual efforts initiate the collaboration in future. Therefore, it is important for consumers to remember that we all can play at least a small role in shifting the retail cultures that cause wastage as well as consumer behaviors encouraging them and also, changing their consumer behaviors to move towards greater sustainability. As poor communication through the supply chain has a significant influence on waste, the clarity of communication up and down the supply chain is critical to tackle bread wastage effectively at production levels. Therefore, both individual and collaborative efforts are important across the entire supply chain to reduce bread waste that occur due to various circumstances in order to achieve the Sustainable Development Goals (SDGs) in future. The policies needed to be implied to make sure the actions are taken by all the actors strategically. To complement reduction od bread waste and to encourage it, policy need to carefully decide what policies are needed to be implemented.

5.6.8. Demand driven bread value chain

The study can state the necessity for a shift to a collaborative and integrated value chain that is responsive to fast-changing customer demands when the actors are work together to tackle the bread waste issues. A demand-driven value chains which applies a combination of human resources and also the technology to maintain inventory throughout the chain which would allow fast response to the changing demand for variety of bread products and thereby reducing inventory will prevent potential food wastage along the entire value chain.

5.6.9. Reduction of FLW and sustainability

The Sustainable development goals focus on eradicating hunger, poverty, environmental protection and prosperity as well as well-being. As SDG Goal 12 aims to “halve global per capita food waste at the retail and consumer levels and reduce food losses along production and supply chains by 2030” (FAO, 2022), reducing FLW along the value chain has the potential to diminish the food production and limit the pressure on agricultural land as well as to reduce GHG

emissions related to food system. However, to contribute to create a circular system with less negative environmental impact, the food system actors need to work to find new recycling solutions while they boost the profitability. The results of these kinds of studies also can be considered when planning to achieve the Sustainable Development Goals (SDGs). How the food is grown, produced and consumed has a significant impact not only on the environment and the society but also on our individual well-being. Therefore, reducing food loss and waste as well as creating a circular economy through innovations will create a more sustainable future and ensure food security and reduce hunger.

6. Conclusion

Food waste is produced from production stage to the consumer stage along the supply chain. Creating resource and energy efficient food systems is important in minimizing the environmental ,social and economic impacts caused by food waste. The study focused on assessing the food waste quantities, causes of bread at bakery, retail and consumer stages of bead value chain in Sweden in order to understand how the bread losses and waste are generated and the actions taken by the actors by collecting primary and secondary data of bread waste through surveys as well as published reports. Considering the total FLW along the bread value chain, house hold contributed to the highest fraction of waste(37.2%), followed by the retail stage (34.9%), bakery (14.9%) and restaurants (8.9%). Canteens in Sweden showed the lowest bread waste amount. Major causes of FLW are over production in bakeries, lack of knowledge regarding the issue, lack of attention, lack of collaborative effort among the actors, TBA agreements, consumer demands for more types of bread products, over purchasing, spoilage, forgetting to consume before spoilage etc. The bread waste and losses and the causes resulted in this study aligned with the results of other studies. The bakeries and food services in Sweden play a role in waste reduction and however, there is a need to limit the losses and waste further less. Moreover, it was noted that consumers can exert a pressure on waste reduction in retail, food services and bakeries as they focus more on satisfying consumer demands. On the other hand, retailers and bakeries can also play a role to control consumer wasteful behavior through product assortments as well as by enhancing the consumer awareness. Most of the respondents consider bread waste as a problem that needs to be tackled as businesses are aware of the waste of money, time, reputation and also food. Strategies and actions were suggested to reduce waste and environmental impact of bread supply chain. These include proper sales and order planning, increasing awareness of FLW, reducing over purchase, freeze storage after purchase, prepare different products from left-over bread which have more shelf life, serve only sufficient amounts at food services, prepare different recipes at restaurants and canteens to motivate the consumers to finish what is served, donate to feed people in need and for animal feed, recycle food rather than wasting. Consumer attitude towards food waste reduction can be changed into a positive direction through education on the amounts they waste and the environmental, social and economic impacts they contribute to

as well as the benefits of overcoming the waste issue and by encouraging them to be responsible when purchasing, consuming food and disposing waste. Waste reduction requires a cooperative and collaborative approach. In that effort, businesses need to shift their priorities towards sustainability, consumers need to have responsible purchasing and consumption behaviors and different organisations and actors need to work closely and together to ensure a smoother, smarter and sustainable production and movement of food in the food system.

7. Reference

Brancoli , P., Rousta, K. & Bolton, K., 2017. Life cycle assessment of supermarket food waste. Resources, Conservation and Recycling, Volume 118, pp. 39-46.

Brancoli, P., Bolton, K. & Eriksson, M., 2020. Environmental impacts of waste management and valorisation pathways for surplus bread in Sweden. Waste Management , Volume 117, pp. 136-145.

Brancoli, P., Lundin, M., Bolton, K. & Eriksson, M., 2019. Bread loss rates at the supplier-retailer interface-Analysis of risk factors to support waste prevention measures. Resources, Conservation & Recycling, Volume 147, pp. 128-136.

Eriksson, M., Strid, I. S. & Hansson, P.-A., 2015. Carbon footprint of food waste management options in the waste hierarchy - a Swedish case study. Journal of Cleaner Production, Volume 93, pp. 115-125.

Mattsson, L. M., Williams, H. & Berghel, J., 2018. Waste of fresh fruit and vegetables at retailers in Sweden – Measuring and calculation of mass, economic cost and climate impact. ELSEVIER, 130(ISSN 0921-3449), pp. 118-126.

Royal Swedish Academy of Engineering Sciences, 2020. A Resource-Effective Food Sector in Sweden-measuring how much food is lost or goes to waste, Stockholm: The Royal Swedish Academy.

Stenmarck, Å., Jensen, C. M., Quested, T. & Moates, G., 2016. Estimates of European food waste levels, Stockholm: RESEARCHGATE.

Stensgård, A. . E. & Hanssen, O. J., 2016. Food Waste in Norway 2010-2015.Final report from the format project., Fredrikstad, Norway: Østfoldsforskning.

AB, P., 2022. Polarbröd AB. [Online]
Available at: https://www.polarbrod.se/en/
[Accessed 16 05 2022].

AB, P. B., 2022. Pågen. [Online]
Available at: https://pagen.com/baking-with-love/sustainability-overview/
[Accessed 14 05 2022].

Agency, S. F., 2018. Action plan for food losses and waste reduction in Sweden, s.l.: Swedish Food Agency.

Agency, S. N. F., 2016. Report summaries from the Swedish Food Waste Reduction Project 2013-2015, s.l.: Swedish National Food Agency.

Åhlander, P., 2016. Food Waste from Swedish Grocery Stores; What can the grocery stores do to reduce it?. GUPEA.

Association, T. S. W. M., 2019. Swedish Waste Management 2019, Malmö: Avfall Sverige AB.

Bajželj, B., Quested, T. E., Röös, E. & Swannell, R. P., 2020. The role of reducing food waste for resilient food systems. Eco System Services, 45(1011 40), p. 13.
Beretta, C., Stoessel, F., Baier, U. & Hellweg, S., 2013. Quantifying food losses and the potential for reduction in Switzerland. Waste Management, 33(3), pp. 764-773.

Beretta, C., Stoessel, F. S., Baier, U. & Hellweg, S., 2012. Quantifying food losses and the potential for reduction in SwitzerlandClaudio. Waste Management.

Brancoli, P., 2021. Prevention and valorisation of surplus bread at the supplier–retailer interface. DiVA portal, Volume 124.

Commission, E., 2008. Waste prevention and management. [Online]
Available at: https://ec.europa.eu/environment/green-growth/waste-prevention-and-
management/index_en.htm#:~:text=The%20Directive%20defines%20a%20'hierarchy,be%20the%20very%20last%20resort.
[Accessed 13 05 2022].

Commission, E., 2022. EU Food Loss and Waste Prevention Hub. [Online]
Available at: https://ec.europa.eu/food/safety/food_waste/eu-food-loss-waste-prevention-hub/eu-member-state-page/show/SE
[Accessed 13 05 2022].

Ejnarsson, . E. & Bengtsson Ekström, S., 2020. Food waste reduction in Swedish food retail: Understanding barriers and incentives. DiVA portal, p. 84.

Eriksson, M., 2015. Supermarket food waste. Acta Universitatis Agriculturae Sueciae, Volume 119, p. 97.

Eriksson, M., 2015. Supermarket food waste- prevention and management with the focus on reduced waste for reduced carbon footprint. Acta Universitatis Agriculturae Sueciae, p. 97.

FAO, 2011. Global Food Losses and Food Waste, Rome : FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

FAO, F. a. A. O., 2022. Sustainable Development Goals. [Online]
Available at: https://www.fao.org/sustainable-development-goals/indicators/1231/en/
[Accessed 16 05 2022].

FAO, F. a. A. O. o. t. U. N., 2022. Food and Agriculture Organization of the United Nations. [Online]
Available at: https://www.fao.org/platform-food-loss-waste/flw-data/en/
[Accessed 11 May 2022].

FAO, F. a. A. O. o. U. N., 2018. Food and Agriculture Organization of United Nations. [Online]
Available at: https://www.fao.org/common-pages/search/en/?q=Food%20loss%20index
[Accessed 13 05 2021].

FAO, F. a. A. O. o. U. N., 2019. Food and Agriculture Organization of United Nations. [Online]
Available at: https://www.fao.org/news/archive/news-by-date/2019/en/?ipp=10&page=3
[Accessed 13 05 2021].

Fazer, 2022. Fazer. [Online]
Available at: https://www.fazergroup.com/sustainability/
[Accessed 14 05 2022].

FUSIONS, E., 2016. EU FUSIONS. [Online]

Available at: http://www.eu-fusions.org/index.php/10-food-waste-wiki/280-food-waste-
definition?highlight=WyJmb29kIiwiJ2Zvb2QiLCJ3YXN0ZSIsIid3YXN0ZScsIiwiJ3dhc3RlJy4iLCJ3YXN0ZSciLCJ3YXN0ZScsIiwid2FzdGUnLiIsImRlZmluaXRpb24iLCJmb29kIHdhc3RlIiwiZm9vZCB3YXN0ZSBkZWZpbml0aW9u
[Accessed 13 05 2022].

Ghosh, R. & Eriksson, M., 2019. Food waste due to retail power in supply chains: Evidence from Sweden. Global Food Security, 20(https://doi.org/10.1016/j.gfs.2018.10.002), pp. 1-8.

HLPE, T. H. L. P. o. E. o. F. S. a. N., 2014. Food losses and waste in the context of sustainable food systems, Rome: Secretariat HLPE c/o FAO.

Iakovlieva, M., 2021. Food waste in bakeries-quantities, causes and treatment. Swedish University of Agricultural Sciences, p. 51.

IVA, R. S. A. o. E. S., 2020. A Resource-Effective Food Sector in Sweden - – measuring how much food is lost or goes to waste- A sector report from the IVA project Resource Effectiveness and the Circular Economy (ReCE), Stockholm: Royal Swedish Academy of Engineering Sciences(IVA).

IVL, S. E. R. I., 2020. Swedish Environmental Research Institute(IVL). [Online]
Available at: https://www.ivl.se/english/ivl/topmenu/press/news-and-press-releases/press-releases/2020-02-20-foodwaste-in-sweden-could-fill-the-ericsson-globe-arena-four-times-over.html
[Accessed 13 05 2022].

Katajajuuri, J. M. et al., 2014. Food waste in the Finnish food chain. Journal of Cleaner Production, Volume 73, pp. 322-329.

Omoleye, O., 2020. Assessment of food losses and waste and related greenhouse gas emissions along a fresh apples value chain. November, p. 52.

Porter, M., 1985. The value chain and competitive advantage. In: Competitive Advantage. Creating and Sustaining Superior Performance. New York: New Press, p. 557.

Program, W. P. & WRAP, 2013. Review of the Waste Prevention Programme for England 2013:Summary report, s.l.: Waste Prevention Program; WRAP.

Swedish Food Agency , 2021. Swedish Food Agency. [Online]
Available at: https://www.livsmedelsverket.se/en/food-habits-health-and-environment/food-loss-and-waste
[Accessed 13 02 2021].

Swedish Food Agency, Swedish Board of Agriculture & Swedish Environmental Protection Agency, 2020. 2020 - Report summaries from the Swedish government commission to reduce food loss and waste 2017- 2019, Uppsala : Swedish Food Agency .

UNEP, U. E. P., 2022. Think.Eat.Save Reduce your foot print. [Online]
Available at: https://www.unep.org/thinkeatsave/about/definition-food-loss-and-waste
[Accessed 11 May 2022 2022 2022].

UNEP, U. N. E. P., 2021. UNEP FOOD WASTE INDEX REPORT 2021, Nairobi: United Nations Avenue.

United Nations Environment Programme, 2021. FOOD WASTE INDEX REPORT 2021, Nairobi: United Nations Environment Programme.

USEPA, U. S. E. P. A., 2021. Sustainable Management of Food. [Online]
Available at: https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy#about
[Accessed 14 05 2022].

Acknowledgement

I would like to express my gratitude to my supervisor Techane Bosona at the Department of Energy and Technology, Swedish University of Agricultural Sciences, Uppsala. I highly appreciate the support and guidance you provided throughout the degree project. I would also like to thank my husband Deeptha Wickramarachchi for the giving me a great support and courage, my parents for the sacrifices done to educate me and all the teachers who taught me in my life.

Apendix

Appendix A: Questionnaires
Appendix A1:Questionnaire for retailers and food services
1. Do you sell/serve both organic (from organic wheat) and conventional bread or bread based products ? / Säljer/serverar du både ekologiskt (från ekologiskt vete) och konventionellt bröd eller brödbaserade produkter?
Checkboxes: 3 options
2.Do you sell bread products online? / Säljer du brödprodukter online?
Checkboxes: 2 options
3.Has online selling increased due to COVID-19 ? /Har onlineförsäljningen ökat på grund av covid-19?
Multiple choice: 2 options
4.What is the estimated bread loss and waste at your retail/canteen/restaurant (in kg or %, per day/per year)? / Vad är den uppskattade brödförlusten och avfallet i din butik/matsal/restaurang (i kg eller % per dag/per år)?
Short answer
5.Among the following causes/ reasons which one best describes your bread wastage? You can select multiple answers. / Vilken av följande orsaker/orsaker beskriver bäst ditt brödsvinn? Du kan välja flera svar.
Checkboxes: 4 options
6. What actions do you take to reduce bread (food) waste in your store/canteen /restaurant ? Vilka åtgärder vidtar du för att minska bröd(mat)svinnet i din butik/matsal/restaurang?
Paragraph
7. Name and address of the retail /canteen /restaurant(optional)/ Namn och adress till detaljhandeln /matsalen /restaurangen (valfritt).
Paragraph

Appendix A.2. : Questionnaire for households

1. Which bread products do you prefer to buy? You can choose multiple answers./ Vilka brödprodukter föredrar du att köpa? Du kan välja flera svar.
Checkboxes: 7 options

2. Do you have the experience of purchasing bread online? / Har du erfarenhet av att köpa bröd online?
Checkboxes: 2 options
3.What percentage of purchased bread is wasted at your home?/ Hur många procent av det köpta brödet går till spillo hemma hos dig?
Checkboxes: 5 options
4. Among the following reasons, which of the following best describes the reason for bread wastage at your household? You can choose multiple answers. / Vilket av följande skäl beskriver bäst orsaken till brödsvinnet i ditt hushåll? Du kan välja flera svar.
Checkboxes: 4 options
5.Have you taken any action to prevent/reduce food waste at your home? If yes, what are those actions?/ Har du vidtagit några åtgärder för att förebygga/minska matsvinnet i ditt hem? Om ja, vilka är dessa åtgärder?
Paragraph
6. What is your age group?/Vilken åldersgrupp tillhör du?
Multiple choice: 5 options
7. Your Gender/ Ditt kön
Multiple choice: 2 options
8. Your experience is from:/ Din erfarenhet kommer från:
Multiple choice: 3 options

Appendix B: Data of FLW in different stages of Swedish bread value chain

Stage	**Wate and losses of bread in (Brancoli, et al., 2019)/tones per year**	**Waste and losses in (Brancoli, 2021)**	**Average /tonnes per year**
Bakery	12040	12000	12020
Retail	28220	28000	28110
Restaurants	7150		7150
School canteens	2640		2640
Households	29870	30000	29920
Other losses and waste			610
Entire value chain (from farm to consumption)	80410	80500	80450

Appendix C: Estimated bread waste data from survey

Retail*	Municipality in Sweden	The estimated bread waste percentage of the bread kept for sale per day (%)
Supermarkets		
Supermarket 1	Uppsala	16%
Supermarket 2	Uppsala	4.5%
Bake shops		
Bake shop 1	Uppsala	3-5%
Bake shop 4	Stockholm	0%
Home-made bakery shop	Enköping	0-1%
Bake shops 5	Stockholm	5%
Bake shop 2	Uppsala	Hard to estimate
Bake shop 3	Uppsala	Hard to estimate. It varies a week

Appendix D: Estimated FLW data from food service survey

Food services*	Municipilty in Sweden	The estimated bread waste percentage of bread served per day (%)
Restaurants		
Restaurant 1	Uppsala	0-5%
Restaurant 2	Uppsala	0-1% (plate waste), zero waste at the kitchen.
School canteens		
School canteen 1	Västerås	0-1%(plate waste), Zero waste at canteen kitchen
School canteen 2	Uppsala	0-5%

Popular Scientific summary

Indrachapa D. Balasooriya

Master's in Sustainable Food Systems, SLU, Sweden

Master's thesis: Food losses and Waste at Bakeries, Retail and Household Levels– A Case of Sweden

Reducing food waste is necessary to assure food security and overcome environmental issues. This Master's thesis study was aimed to assess food losses and waste (FLW) along bakery, retail, food service and household stages of bread value chain in Sweden including the causes of bread waste and potential measures to reduce losses and waste. The study was based on both quantitative and qualitative analyses. Primary data were collected via surveys and secondary data were used from research articles. According to the results, the food losses and waste was 80450 tonnes per year in the entire Swedish bread supply chain. Household contributed to the highest waste fraction (37.2%) of bread waste in entire value chain among the bakery, retail, restaurant and canteen stages followed by the retail (34.9%), bakery (14.9%) and restaurants (8.9%), Canteens (3.3%). The major causes of food losses and waste in household were forgetting to consume after purchase and over purchase of bread. The frequent cause for bakery waste were over production, take back agreement and poor production planning. Overstocking and passing expiry dates were identified as the most frequent causes of bread waste at retail and food service levels. Furthermore, lack of knowledge regarding the issue, lack of attention, lack of collaborative effort among the actors, demand-driven food system, consumer demands for more types of bread products, etc. were identified as more causes. Strategies and actions are needed to reduce waste and losses. This study identified that, proper sales and order planning, increasing awareness of food losses and waste, reducing over purchase, freeze storage after purchase, prepare different products from left-over bread which have longer shelf life, serve only sufficient amounts at food services, prepare different recipes at restaurants and canteens to motivate the consumers to finish what is served, donate to feed people in need and for animal feed, recycle food rather than wasting are the main actions that can be taken reduce bread waste in Sweden. Moreover, waste reduction requires a cooperative and collaborative approach. Therefore, the stakeholders need to shift their priorities towards sustainability while consumers need to have responsible purchasing and consumption behaviors. Different organizations and actors need to work closely and together in order to ensure a sustainable food production and movement of food in the food system.

.