Retail Food Wastage

a Case Study Approach to Quantities and Causes

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Cover: Wasted apples
(photo: M. Eriksson)

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Abstract

Food wastage is a problem along the entire food supply chain and gives rise to great financial losses and waste of natural resources. The retail stage of the supply chain contributes significant masses of waste. In order to introduce efficient waste reduction measures, the wastage problem must first be properly described. Causes of wastage need to be identified before potential measures can be designed, tested and evaluated. This thesis quantifies retail food wastage and analyse its causes with the aim of providing information that can be used to suggest potential waste reduction measures.

Food wastage was quantified in six supermarkets in the Uppsala-Stockholm region of Sweden. Data were recorded during 2010 and 2011 by the retail company in a daily waste recording procedure. In addition, suppliers contributed data on deliveries and rejections. The main meat and deli supplier also contributed data on wholesale pack size and shelf-life, which allowed the relationship between these and their effect on waste to be analysed.

The waste of the fresh fruit and vegetables department was dominated by the pre-store waste caused by rejections, 3.0%, whereas the in-store waste was 1.3% consisting of 1.0% recorded waste and 0.3% unrecorded waste in relation to mass delivered. Fresh fruit and vegetables waste was mainly attributable to a few products, with the eight most wasted product types contributing 67% of waste within the department. The most wasted product was tomatoes, with 106 tons of waste during the two-year test period for the six stores, followed by bananas with 90 tons and lettuce with 82 tons.

Supermarket cheese, dairy, deli and meat departments all had less wasted mass and smaller percentage waste than the fruit and vegetables department. The top eight most wasted products within each of these departments contributed between 22% and 39% of the mass.

Organic products were found to cause higher percentage waste than conventional products. One systematic reason for this was the lower mass sold per article for organic products. For these products, increased shelf-life and decreased minimum order size, were found to be as effective a measure for waste reduction as increased turnover.

Keywords: Food waste, retail waste, supermarket, in-store waste, pre-store waste, organic food.

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The whole problem with the world is that fools and fanatics are always so certain of themselves, and wiser people so full of doubts.

Bertrand Russell

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Eriksson, M., Strid, I. & Hansson, P.-A. (2012). Food losses in six Swedish retail stores - wastage of fruit and vegetables in relation to quantities delivered. *Resources, Conservation and Recycling* 68, 14-20.

II Eriksson, M., Strid, I. & Hansson, P.-A. (2012). Wastage of organic and conventional meat and dairy products - a case study from Swedish retail. *Submitted for publication*.

Paper I is reproduced with the permission of the publisher.

The contribution of Mattias Eriksson to the papers included in this thesis was as follows:

I Carried out the planning of the study in cooperation with co-authors. Performed data collection, observations in stores, physical measurements and analysis of data. Interpreted data and wrote the manuscript together with the co-authors.

II Carried out the planning of the study in cooperation with co-authors. Performed data collection, observations in stores, calculations and analysis of data. Interpreted data and wrote the manuscript with input from the co-authors.

1 Introduction

Wastage, loss or spoilage of food is an efficiency issue that has seen an increased focus from media, research, politicians, companies and society during recent years. This could be due to the three main problems connected with wastage of food. First, there is a moral issue about throwing away food when people in parts of the word are starving (Stuart, 2009) and this could lead to future food crises (Nellemann *et al*., 2009). Second, the natural resources on earth are limited and foods that are produced in vain are wasting these resources (Ridoutt *et al*., 2010; Steinfeldt *et al*., 2006). Third, a lot of money is lost when food goes to waste instead of being used for its intended purpose (SEPA, 2011; Buzby *et al*., 2011; Lee & Willis, 2010; Ventour, 2008).

These three problems are linked to each other and to wastage of food, but simply reducing food waste would not solve the problems. For example, if the estimated 1.3 billion tons of food that are wasted every year (Gustavsson *et al*., 2011) were not produced at all, the result would be less use of natural resources but another consequence could be an economic crisis and unemployment for many people working in the food sector. This makes reducing food waste a complex problem with structural obstacles based in the modern lifestyle of the rich part of the world. Thus, for resource efficiency reasons, losses of food will always be problem, which was the perspective adopted in this thesis.

1.1 Losses in the food supply chain

Food is traded and transported on a global market and the losses, costs and environmental impact of production and distribution are also experienced all around the globe. The environmental impact originates in all stages along the food supply chain (FSC), but often particularly in the early stages, during agricultural production (Angerwall *et al.*, 2008). Along the supply chain, many sub-processes are needed to get the food products from the field to the fork of the consumer. Most of these sub-processes require resources such as land and clean water for farming or energy for transportation and industrial processes. For this reason, waste occurring at the end of the food supply chain is worse than waste occurring earlier, since more sub-processes have been in vain. This is illustrated in Table 1, where the marginal effect of reducing food wastage increases in the later stages of the supply chain. Since sub-processes also cost money, the waste is moved back in the supply chain if possible and often does not even enter the chain if it has low potential to be consumed in the end (SEPA, 2011, 2012). There are indications that a large share of the total food wastage originates from the agricultural sector, *e.g.* a recent study showed that 18% of the food wastage within the German food supply chain originates from the agricultural sector (Göbel *et al.*, 2012).

Table 1. *Estimated yearly wastage of food in Sweden divided according to food supply chain (FSC) sector and the economic benefit of reducing waste (SEPA, 2012a; Jensen et al, 2011)*

FSC sector	Waste (ton)	Waste per capita (kg)	Marginal benefit to society of reduced waste (SEK/kg)	Marginal benefit to individual or company of reduced waste (SEK/kg)
Household	675 000	72	81	62
Restaurants and catering	125 000	13	31	12
Retail	39 000	4	25	6
Industry	171 000	18	25	6

One reason for the lack of data in the agricultural sector is the difficulty in measuring and defining food wastage. Plants and animals intended for the food industry can contract diseases and therefore never become what is legally defined as food (EC, 2002). Plants can also be left in the field if the market price for the products at harvest is too low to cover the costs of harvesting and other processes that make the produce sellable to the customer. Much of the food that is lost in the early stages of the food supply chain can be considered a by-product that is used in other food production processes, *e.g.* tomatoes with visible defects that are unsellable to the customer can be used for tomato ketchup. Food losses can also be used as animal feed or in biogas production, but any degradation in level in the waste hierarchy (EC, 2008) is equal to a loss of resources, and often also money. Therefore degradation of food is always less good than the intended usage from an environmental perspective, even though the higher levels (*e.g.* animal feed) in the hierarchy are better than the lower levels (*e.g.* incineration).

1.2 Waste quantification

1.2.1 Common methods

Wastage can be quantified in several ways but common methods are:

- Material flow analysis (MFA)
- Interviews and questionnaires
- Waste recording
- Waste collection.

Definitions and system boundaries make wastage in the agricultural sector of the FSC difficult to quantify. The methods used in the literature include MFA applied on the total production and consumption statistics for an entire country (Göbel *et al.*, 2012) or for a few products (SCB, 2010). The MFA method can also be used for the food processing industry, where the difficulties in separating by-products and losses are similar to those in the agriculture sector. MFA can also be used on specific stages in the FSC, and to get an overview of the whole value chain. The results obtained can be presented as an overall picture (Göbel *et al.*, 2012) (Figure 1).

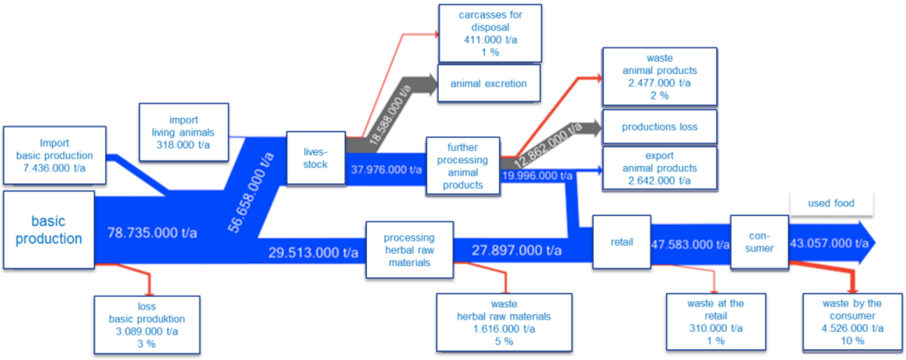

Figure 1. Flow chart with an overview of the German food supply chain showing food waste streams (Göbel *et al.*, 2012).

Another method used for quantification that can provide an overview of waste is interviews or questionnaires with key representatives of companies or organisations (Stenmarck *et al.*, 2011). This method can be used for all steps of the value chain and the answers it seeks can be based on accurate numbers, but there is a risk of variations in system boundaries or definitions between the organisations. There is also a risk of the respondents underestimating their own wastage, as shown for Norwegian households by Hanssen & Schakenda (2011).

The information sought by interviews and questionnaires can often be obtained by recording the waste. This is often done in companies to keep track of how much money is wasted, with the aim of managing costs. However, these figures are often kept internal within the company in question in order to keep them out of reach of competitors. Here too, the exact definitions and system boundaries can differ between organisations, but due to the resolution and amount of data obtained, waste recording is often a good source of data (Stenmarck *et al*., 2011). For households this method can be used in the form of a waste diary and sometimes also collection of receipts (Silvennoinen *et al*., 2012).

The waste collection method of food waste quantification is the main method used for household waste, as different types of food can be analysed and the method can determine whether the waste was avoidable or not (Andersson, 2012; Ventour, 2008). This method provides valuable information of what is actually wasted, since the waste itself can be analysed rather than data on quantities.

The choice of method often determines whether the results are presented as a mass or a value. Percentage waste is often calculated in relation to sold value if monetary units are used. If mass units are used the comparison can also be in relation to mass delivered. There is a lack of transparency in this case and the results can therefore be difficult to compare when the units and comparisons differ.

1.2.2 Retail food waste

The retail sector of the food supply chain is not the largest contributor to food wastage. According to a recent estimate for Germany, the retail sector contributes 3% of the wastage in the whole FSC (Göbel *et al*., 2012). The retail contribution in the Swedish supply chain (excluding agriculture) is estimated to be 3.8% (Jensen *et al*., 2011). While retail percentage waste is lower than in other sectors of the FSC, the amounts are still high and concentrated to a limited number of physical locations. According to calculations by Jensen *et al*. (2011), 39 000 tons of food are wasted in the Swedish retail sector every year. For the whole European Union, the estimated retail food wastage is 4 433 000 tons per annum (EC, 2010).

It is not only the amounts of wastage that make the retail sector important, but also the link between producers and consumers. This makes it possible for retailers to communicate with consumers in order to increase their environmental awareness and also to choose suppliers and producers that fulfil their corporate responsibility. Retailers are particularly important for the Swedish FSC, since a few large companies dominate the market (Table 2). For example, the market share of the five largest food retailing companies in Sweden amounted to 94.7% in 2010, which was the highest in Europe, where the average level was 69.2% (Vander Stichele *et al.*, 2006). These companies also own or control large parts of the distribution chain, and via private brands also some of the production.

The Swedish retail waste has been quantified in a few previous studies, but only some parts of the companies and business sectors listed in Table 2 have been investigated (Table 3). In all these studies, different system boundaries, methods and units have been used. In addition, different products have been studied, making comparisons difficult, although the results from the studies do not vary widely. Since different methods of quantification are possible, there is a need for transparency and method description.

Table 2. *The major brands and corporate ownership in the Swedish retail market, divided into five business segments, and a description of these segments according to Axfood (Axfood, 2010)*

Corporate group	Hard Discount 5% of market	Low Price 11% of market	Hypermarket 22% of market	Conventional 45% of market	Convenience 17% of market
ICA 46% of market			ICA Maxi	ICA Supermarket ICA Kvantum	ICA Nära
COOP 20%of market			COOP Forum	COOP Konsum COOP Extra	COOP Nära
Axfood 20% of market		Willys PrisXtra		Hemköp	Tempo Handlar´n
Bergendahls 5% of market			CityGross	Matrebellen	Matöppet
Others 9% of market	Lidl Netto			Vi-butikerna[1]	7-Eleven Petrol companies
Description of sectors	1100-1800 articles Price index –[2] Residental areas External areas	7500- articles Price index 88-97 Residental areas External areas	12000- articles Price index 93-97 External areas	10000-15000 articles Price index 96-110 Residental areas Urban areas	1000-3000 articles Price index 104-130 Residental areas Near high traffic roads

[1] Loosely connected to Axfood
[2] To few articles to calculate a price index

Table 3. *Food wastage from Swedish retail and wholesale according to different sources*

No. of shops studied	Business segment[1]	Type of outlet[1]	Type of products	Waste (%)	Method, units and comparison
1	Supermarket	COOP Forum	Perishables	3.3	Recording, value[1]
2	Traditional	COOP Konsum	Perishables	4.0	Recording, value[1]
6	Low-Price	Willys	Perishables	4.4	Recording, mass, delivered[2]
477	Traditional	COOP Konsum	All	8	Collection, mass, sold[3]
1	Traditional	COOP Extra	Tomatoes	1.1	Recording, mass[4]
4	Traditional		Tomatoes	2.9	Questionnaire, value, sold[5]
5	Supermarket		Tomatoes	1.6	Questionnaire, value, sold[5]
1	Traditional	COOP Extra	Apples	0.9	Recording, mass[4]
4	Traditional		Apples	0.88	Questionnaire, value, sold[5]
5	Supermarket		Apples	1.4	Questionnaire, value, sold[5]
1	Traditional	COOP Extra	Meat	1.6	Recording, mass[4]
1	Supermarket	ICA Maxi	Meat	3.7	Questionnaire, value, sold[6]
4	Traditional	ICA Supermarket	Meat	5.5	Questionnaire, value, sold[6]

[1] Using the same categorisation and termes as in Table 2
[2] (Andersson *et al*., 2010)
[3] (Eriksson & Strid, 2010)
[4] (Nilsson *et al*., 1995)
[5] (Becker, 1985)
[6] (Gustavsson & Stage, 2011)
[7] (Pettersson, 2005)

Foreign studies also indicate that retail food wastage for different product groups is often between 0 and 10%, which is similar to the range reported in Swedish studies (Table 3). Many previous studies have focused on fruit and vegetables, which often give high percentage waste, *e.g*. 10% for the European retail distribution sector according to Gustavsson *et al.* (2011). Fehr *et al.* (2002) reported 8.76% retail waste in Brazilian supermarkets, while waste in the United States retail sector is reported to be 11.4-12% for fresh fruits and 9.7-10% for fresh vegetables (Buzby *et al*., 2009, 2011). For Norway, measured wastage in shops with perishable food departments was 3.35% during 2011 (Hanssen & Schakenda, 2011).

1.2.3 Organic food waste.

Active work to reduce waste is a potential way of working with sustainability for retailers. Another way of addressing the corporate responsibility connected to environmental issues is to obtain environmental certification for retail outlets (Axfood, 2011). The three main supermarket certification systems currently used in Sweden do not yet address the problem of food waste within supermarkets (Sjöberg, 2012), but all require supermarkets to carry a basic selection of organic products (KRAV, 2012; Nordic Ecolabeling, 2010; SSCN, 2009). However, since the waste problem is not taken into consideration in the certification process, it is likely that the effects on waste of increasing the range of organic products offered have not been evaluated. For example, if carrying a broader range of organic products increases the amount of waste, this can reduce the environmental benefits of organic production.

Few previous publications have studied waste levels for organic and conventional food products. Bjurkull (2003) compared the waste of organic (KRAV-certified) milk and eggs against that of the conventional counterparts in three Swedish supermarkets and found that organic milk had an average waste of 0.4% and conventional milk 0.07%. Eggs showed the opposite pattern, with organic waste of 0.06% compared with conventional egg waste of 0.3%.

This knowledge raised the question of whether organic products had higher percentage waste than the corresponding conventional products and the reason for any differences.

1.3 Waste reduction

In organisations and companies, waste reduction is often sought by copying the best practice within the organisation or by finding inspiration from other successful examples of waste reduction measures (Lagerberg Fogelberg *et al*., 2011; EC, 2010). Whether the suggested measures actually reduce the waste and by how much are seldom reported, and therefore it is difficult to compare different measures and decide on the most efficient methods in order to reduce waste. Therefore, in this thesis a more analytical approach was adopted, based on the plan-do-check-act methodology used for environmental management systems in order to reduce waste (Swedish Standards Institute, 2010). This involves:

1. Quantification of waste
2. Analysis of causes
3. Introduction of measures
4. Evaluation of measures

The first step in reducing wastage is to describe the problem and the underlying reasons, try out solutions and then evaluate how well the solutions have actually reduced the problem. Paper I focuses only on step 1 of the plan-do-check-act list (quantification of waste), while Paper II considers steps 1 and 2.

While many of the best practice examples of waste reduction measures lack any deeper analysis of cost effectiveness, they serve as good examples and can lead to reduced waste simply by inspiring companies and personnel. To bring order to all these measures they are generally divided into four subgroups defined by their main focus: Order measures target ordering routines so as to achieve a better match between delivered and sold items. Sales strategies target increased turnover and aim to sell all items. Waste management measures target a reduction in the negative effects of food waste. Technical solutions target better food protection, with increased shelf-life or more robust protective packaging. Sometimes the categories overlap, with measures that focus on several of these areas.

Control, tidiness, interest and good follow-up are described as factors that reduce food wastage (Lagerberg Fogelberg *et al.*, 2011). However, these factors are difficult to clearly specify and are therefore not considered as measures in this thesis. Instead, factors such as interest and good control are considered a basic requirement in order for any measure to work properly. There is also no reason to assume that this is not already the normal situation for Swedish supermarkets. Some main causes of wastage mentioned in reports include expired best-before dates and broken packaging (Andersson *et al.*, 2010). Since a food item can pass its best-before date for many reasons, many of the examples given in this thesis focus on how to get the food sold before this date or not ordered at all, in order to not cause wastage.

1.3.1 Order-based measures

The most basic measure for reducing wastage is to order the exact items that are going to be sold by the next delivery. Therefore, improving the ordering system is one example of a waste reduction measure (Buzby *et al.*, 2009). In order to get more precise orders, Mena *et al.* (2011) suggest the use of computerised forecasting systems. They even give examples of shops using automatically adjusted re-order point systems that place orders so as to avoid human errors (Mena *et al.*, 2011). If such a system is used, it needs correct input from the shops so that all orders are correct. Lagerberg Fogelberg *et al.* (2011) point out that control of both the stock volume and the dates of products are important. In addition, the waste must be monitored by the forecasting system, but measuring waste can by itself be an important waste reduction tool simply by making the waste more visible (Mena *et al.*, 2011; Lee & Willis, 2010).

Improvement of logistics and sharing information with partners along the supply chain are also given as examples of how to improve orders both in-store and along the FSC (Mena *et al*., 2011; Lee & Willis, 2010). Sharing of information can also provide greater possibilities to get more frequent deliveries and to order smaller volumes per order, which have been identified as important factors (Andersson *et al*., 2010; SEPA, 2008). This is taken one step further by Mena *et al*. (2011), who suggest centralised control of inventory for long-life products in order to reduce safety stock and therefore waste.

1.3.2 Sales-based measures

When shops have ordered too much food that will not be sold before the best-before date, other channels are needed to sell the surplus. The simplest and most common strategy is to reduce the price (Lagerberg Fogelberg *et al*., 2011; Mena *et al*., 2011; Andersson *et al*., 2010; Stuart, 2009; SEPA, 2008). This typically involves a 50% reduction in price on the best-before date or even a day before.

If the products are still unsold after the price reduction, they can be used as ingredients within the shop if it has a kitchen, or sold via an in-store restaurant (Lagerberg Fogelberg *et al*., 2011; Mena *et al*., 2011; Stuart, 2009; SEPA, 2008). In this way, potential waste is turned into ingredients and value is added to prolong the shelf-life and attractiveness for customers.

Promotions cause waste (Lagerberg Fogelberg *et al*., 2011) and therefore a clear promotion planning process can help to reduce the negative impact (Mena *et al*., 2011). Some companies even sacrifice availability during promotions to prevent waste or run promotions constantly (Mena *et al*., 2011), so as not to affect waste by creating variations that can lead to waste (Eriksson & Strid, 2011).

1.3.3 Waste management-based measures

When the food cannot be sold even with reduced price or as a part of a cooked dish, it can be given to charity. When given to charity the food loses its economic value, but it remains in the highest level of the waste hierarchy, since it is still used for human consumption (EC, 2008). There are many examples of this kind of waste management with different infrastructure and different possibilities depending on the local situations and possibilities (Lagerberg Fogelberg *et al*., 2011; Stuart, 2009; Alexander & Smaje, 2008; Salhofer *et al*., 2008).

When human consumption is not possible anymore, the different levels in the waste hierarchy set the priority for what to do with the waste. Depending on the local possibilities, a way to increase the environmental value of the food waste can be to source-separate food in order to harvest its biogas potential instead of just its energetic value as done in most parts of Sweden (SEPA, 2012b).

1.3.4 Technical and legal solution-based measures

Technical solutions often focus on increased shelf-life in order to allow the product to be exposed in the shop for a longer time. Refrigeration of vegetables is one example of a method that can preserve the freshness of these products and make them attractive to customers over a longer time (Lagerberg Fogelberg *et al*., 2011). Optimised packaging that protects the product from physical damage and prolongs the shelf-life is another common example of how to reduce waste (Lee & Willis, 2010; Buzby *et al*., 2009). For example, the packaging can use a protective atmosphere (Pettersson, 2005) or vacuum in order to extend the life span of meat (Williams & Wikström, 2011; Hanssen, 2010).

Optimised packaging is one part of the infrastructure and logistic solutions suggested by Parfitt *et al*. (2010) in order to reduce waste. Maintaining the correct temperature in a non-broken cold chain is also important. While the energy for keeping the food cold is not a food waste it is important for the environmental impact of the food, and therefore doors can be used on refrigeration cabinets to save energy (Lindberg *et al*., 2010). Doors can also be a way to improve the temperature control, making it easier to achieve the improved temperature control tracking suggested by Buzby *et al*. (2009) to decrease waste.

The legislation concerning food hygiene can often be complex and difficult to interpret by retailers. Therefore clarification of the legal requirements can be a potential way to reduce waste (Lagerberg Fogelberg *et al*., 2011), so that shops do not waste food to reduce a non-existent hygiene risk. Legislation can also be used to force retail companies to declare waste in order to increase the pressure from society to reduce it (Sjöberg, 2012).

1.4 From waste quantification to waste reduction

To reduce the wastage within the retail sector, there is a need for detailed quantifications to identify basic problems such as how much is wasted, what is wasted, how and when waste occurs. When problem areas are found, the question of why waste occurs can be investigated. So even if the spread of best practice can be a useful way of reducing wastage, a more efficient way could be to answer these basic questions in order to prioritise possible waste reducing measures that have the largest potential to be successful. The measures could also benefit from thorough description of the basic problem in order to be efficient not only in reducing the wasted mass, but also in avoiding negative environmental or economic effects, depending on the purpose of the measure.

Many studies quantify waste and give examples of waste reducing measures. In this thesis it was not possible to cover all the steps listed in section 1.3 (quantification, causes, measures, evaluation), but the first two steps are dealt with in detail, as a foundation for designing future waste reducing measures. The thesis also examines the connection between quantifications and some of the suggested waste reducing measures, e.g. many reducing measures aim to extend shelf-life, but this is likely to have greater potential for success among products with low turnover than products with high turnover. The effort needed to prolong the shelf-life could therefore be concentrated to some critical products rather than all products, if waste reduction is the target.

This thesis covers these basic questions of how much, when and partly why retail waste occurs. This has not been done before in the Swedish low price sector, which has hitherto been uncovered in waste research. This is also one of very few publications investigating wastage of organic food. The results can hopefully be used in order to reduce food wastage from supermarkets and thereby contribute to a reduction in the environmental impact of the food supply chain.

2 Objectives

The main objectives of this thesis were to quantify food wastage from large retail outlets and to analyse systematic causes in order to gain knowledge about potential targets for waste reduction measures. The overall aim was to reduce the environmental impact within the food supply chain.

Specific objectives were to:

1. Develop a structure to describe and quantify food wastage.
2. Quantify wastage of meat, deli, cheese, dairy, fruit and vegetables.
3. Quantify wastage of organic meat, deli, cheese and dairy products in relation to conventional products.
4. Identify systematic causes of wastage of meat, deli, cheese, dairy, fruit and vegetables.

3 Materials and Methods

The work was carried out in six supermarkets located in the Uppsala-Stockholm region in Sweden. All these supermarkets are owned, and were selected for the study, by the head office of Willy:s AB, which is a major actor on the Swedish low price retail market (Table 2). The stores were selected within a specified region close to the university performing the research and to provide a representative view of the whole retail chain with regard to factors such as turnover, percentage waste and profit. Within these supermarkets, the fruit & vegetables, dairy, cheese, meat and deli departments were selected for in-depth study in consultation with the retail company due to their large contribution to food waste and the expected high environmental impact of this waste. The bread department also makes a large waste contribution, but this is managed separately by the supplier and was therefore not included.

3.1 Classification of retail food waste

Food waste can be divided into several categories depending on system boundaries. As described in Paper I, retail food waste was defined in this thesis as products discarded in the supermarkets studied, irrespective of whether they belonged to the supplier or the supermarket. This meant that losses of mass due to theft or evaporation were not considered food wastage and therefore they are included in a separate category (missing quantities) in Figure 2.

Pre-store waste consisted of items rejected by the supermarket at delivery due to non-compliance with quality requirements. This waste belongs to the supplier in accounting terms, since it is rejected by the supermarket, but is usually discarded at the supermarket. Pre-store waste is defined through documented complaints to suppliers, which according to the rules must be done within 24 hours of delivery. This waste is on rare occasions sent back to the supplier for control, but is still wasted. For fresh fruit and vegetables (FFV) there was only one supplier to the supermarkets studied here, but for the other departments the pre-store waste could be divided into internal pre-store wastes, which are rejections to the supplier within the corporate group (DAGAB). External pre-store waste was defined here as rejections to other suppliers, even though the items are sometimes handled by DAGAB.

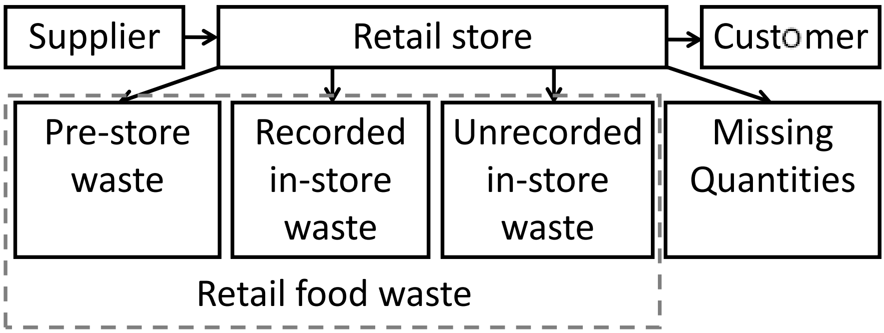

Figure 2. Flow chart with an overview of the waste categorisation used and the physical flow of food marked with arrows.

Recorded in-store waste was defined as food waste occurring after purchase from the supplier. This waste is sorted out and discarded by supermarkets when there is little or no possibility of selling the products. This could be due to exceeded best-before dates or product deterioration for unpackaged FFV.

Unrecorded in-store waste consisted of food waste that was discarded but not recorded. This means that it had the potential to be either pre-store waste or recorded in-store waste if recorded in any of these categories. Unrecorded in-store waste originated from two sources: underestimated mass when recording unpackaged waste; and unrecorded of wasted items. The latter can occur in error or as a deliberate act, *e.g.* it is not cost-effective to record small amounts of waste.

The three food waste categories all contributed to fill up the waste containers of the supermarkets studied but there was also a category of missing quantities. This was due to loss of mass between outgoing and ingoing flows and the two main reasons for these missing quantities are believed to be theft and mass loss due to evaporation. Stolen food is considered not to be an environmental problem, since it is believed to be eaten. Evaporation losses are also not primarily food wastage, since the food items are left, but with a higher dry matter content and smaller mass. However, when visible this might act as a secondary effect, leading to losses of food in one of the waste categories.

3.2 Data collection for recorded waste and rejections

Food that was sorted out and discarded was recorded as part of a daily routine normally performed by the stores and established years before this investigation (Åhnberg & Strid, 2010). This routine was not introduced by the researchers, only used in order to collect data. The routine starts with an inventory in the morning where products considered unsellable are sorted out. Products are considered unsellable if they have passed their best-before or use-by date. Since FFV are sold without a date label, the sorting of these products is based on visual appearance and the unsellable limit is defined by each staff member based on whether they would buy the product themselves (Willy:s, 2010).

Products from the deli, meat, dairy and cheese departments are recorded directly with a mobile scanner connected to the company database (AxBo) and then discarded. Wastage due to poor quality at delivery is economically reimbursed by the supplier if the member of staff presses a one-digit code on the mobile scanner to indicate whether the waste is charged to the supermarket, the main supplier (DAGAB) or other suppliers.

Sorted out fruit and vegetables are placed in the storage room until the end of the shift, when the staff record the waste. Recording is often done by the team leader or other experienced member of staff using the mobile scanner for wastage at the supermarket’s expense. Waste due to rejections is registered first on paper and then transferred to the website of the logistics company (SABA) delivering all fruit and vegetables to the supermarkets. Since all products are owned by Axfood AB when handled by SABA, the data on rejections are then transferred to a database within Axfood.

The records of wasted products are stored in the retail company database. Data on rejections are stored by DAGAB and Axfood and handed out in the form of weekly reports.

3.3 Data collection for unrecorded waste

Through observations and interviews with the staff, it was clear that the recording of wasted fruit and vegetables is not completely accurate. To quantify the missing part of the waste, a control measurement of the waste was performed. This method was closely related to the data collection methods used for household waste surveillance (Andersson, 2012; Ventour, 2008), with the distinction that the waste was not allowed to enter the waste container before recording. This manual recording of otherwise unrecorded waste was the only data collection process that could not harvest data from an existing system within the supermarkets.

The data collection was performed after the staff had recorded the waste, who instead of discarding the waste, left it together with printouts of the record. All fruit and vegetables in the pile were then measured on a set of scales to check the masses, which were then compared with the masses recorded earlier.

During the first measurement of unrecorded waste, only differences between recorded and measured mass were quantified. It then became clear that some items were discarded without being recorded at all, and that some items were recorded without being found in the pile of waste, possibly discarded directly by mistake. Therefore a second quantification was performed taking into account items discarded but not recorded, and *vice versa*. The absence of some items from the waste pile was tracked by asking the staff about every missing item to determine whether the item was expected to be in another location than the waste pile at that time, e.g. if some items were supposed to be discarded later or had already been discarded. All items that the staff did not expect to be in the pile were excluded from the study.

3.4 Data collection for delivered and sold mass

Sold products from all five departments investigated are recorded by the cashier at the pay point in the supermarket, or at a self-scanning pay point. These data are then stored in the financial records that the company is obliged to keep. Most products are recorded with the European Article Number (EAN) code on the packages, but some products, mostly fruit and vegetables sold unpackaged, are weighed at the pay point and identified by a four-digit Price Look-up (PLU) code typed in by the cashier. Mistakes in self-scanning or with the PLU-codes are likely to create an uncertainty in the data. The extent of this problem is unknown, but assumed to have no significant effect on the results in this thesis.

Delivered fruit and vegetables are recorded by the supplier as part of the financial records. These data was used in Paper I in order to calculate the missing quantities.

3.5 Analysis of data

Articles sold piecemeal were allocated a mass based on the mass stated on the package when this was possible. For articles sold without packaging (only FFV), the mass was set using the estimates used by the supplier for each article. The analysis was then performed using Microsoft Excel 2010 and IBM SPSS Statistics 19. All masses stated as tons in this thesis refers to metric tons.

Percentage waste (Q) was calculated either in relation to the actual mass delivered (D) (equation 1) or in relation to estimated mass delivered (equation 2). The sum of sold products (S), pre-store waste (PW) and in-store waste (IW) was used as estimated mass delivered. The difference between the equations is the lack of a 'missing goods' term in equation 2. This had a small effect on the quantification of FFV and resulted in a Q-value approximately 1-5% lower than if equation 1 had been used. For packaged food, the difference between the equations is reported to be very small (Eriksson & Strid, 2012).

$$Q = \frac{W}{D} \tag{1}$$

$$Q = \frac{W}{PW+IW+S} \tag{2}$$

Equation 2 was mostly used in this thesis due to the lack of data on actual delivered mass of dairy, meat and cheese. The exception was in Paper I, where equation 1 was used since delivery data were available for the fresh fruit and vegetables department.

For unrecorded in-store waste, the difference between measured waste and recorded waste was calculated for each supermarket studied. The percentage difference was then used to calculate the difference for a whole year for each store, which gave the mass of unrecorded in-store waste. This mass was then compared against mass delivered using equation 1 in Paper I, but equation 2 in the thesis.

Unrecorded in-store waste was only determined for wasted fruit and vegetables, since other departments were assumed to have low or no unrecorded in-store waste due to the use of EAN codes for waste recording. To determine the accuracy of this assumption, an analysis was performed in which data on delivered deli products were compared with data on sold and wasted products by the same method used for FFV in Paper I.

3.6 Identification of one systematic causes of waste

The causes of food wastage can be divided into systematic causes, which are often small but happen over long time or on many occasions; and occasional causes that are often the outcome of mistakes or rarely occurring events.

Occasional causes were not the focus of this thesis, but a few examples were found using time series of the percentage waste. This was preliminarily done on department level and weekly percentage waste data that clearly deviated from the average were identified. The employees in the particular department were then asked to try to explain why so much was wasted of certain products during the periods.

One systematic cause of waste was analysed in Paper II, which focused on organic products, often found to have high waste ratios. To test the hypothesis that the low turnover in combination with exposure demands, leads to wasted products, the waste quantifications supplemented with data on wholesale pack size and shelf-life for those deli products for which DAGAB had available data, were used. The data on wholesale pack size (WPS) and shelf-life (SL) was combined with the weekly turnover (T) for each store to calculate the β-indicator (β) as shown in equation 3:

$$\beta = \frac{T * SL}{WPS} \qquad (3)$$

The β-indicator was used to explain a part of the organic food waste in the dairy, cheese, deli and meat departments (Paper II), but since the data for both conventional and organic waste were used, the β-indicator can be applied to other products, especially those with low turnover. The β-indicator was developed in Paper II and any corresponding models have not been found in the literature.

For other causes such as rejections and products with large wasted mass, analyses were made from the waste quantifications. Changes from 2010 to 2011 were used as a trend on department level, especially for rejections.

4 Results and discussion

Waste quantification and analysis of causes was the main focus in Papers I and II. Paper I mainly focused on the first step, quantification, of fresh fruits and vegetables during 2010. Paper II focused on organic waste within the dairy, cheese, deli and meat departments, which makes up a small proportion of the wasted amounts, but still have high product specific waste ratios, within these departments. In the following sections of this thesis, the situations described in Papers I and II are extended to provide a full picture of all five departments studied in the six supermarkets during 2010 to 2011.

4.1 Quantification of wasted mass

4.1.1 Departments

The majority (83%, 854 tons) of the recorded mass that was wasted during 2010-2011 in the five departments investigated consisted of fresh fruit and vegetables. Of these 854 tons, 78% was classified as pre-store waste. This is higher than found in Paper I, in which only 2010 was investigated, due to increased waste in 2011 (Table 4). The figure for 2010 (4.4%) was also marginally higher than in Paper I (4.3%) where missing quantities were included in the equation in Paper I (equation 1).

The percentage of retail waste decreased in the dairy, cheese, deli and meat departments from 2010 to 2011. This was due to a large decrease in in-store waste, large enough to compensate for the increased pre-store waste and for a decreased mass of sold products within these four departments. Since the main source of wastage was FFV, the sum shows increased waste between the two years studied. This was due to a large increase in FFV pre-store waste, by 31% from 2010 to 2011. This change corresponded to 91 tons, which is in the same range as the waste from the other four departments combined.

Table 4. *Summary of every category of waste and mass sold for each department and for all five departments combined during 2010-2011. FFV = fresh fruit & vegetables*

Dep.	Year	Mass sold (ton)	Pre-store waste Internal (ton)	Pre-store waste External (ton)	In-store waste Recorded (ton)	In-store waste Unrecorded (ton)	Retail waste (%)
FFV	2010	9 172	289		100	31	4.4
	2011	8 574	380		84.3	35	5.5
Cheese	2010	1 091	0.19	0.04	6.29		0.594
	2011	1 057	0.20	0.81	4.59		0.528
Dairy	2010	11 251	0.00	0.36	38.9		0.347
	2011	10 931	0.86	0.85	34.3		0.328
Deli	2010	1 366	3.65	0.15	21.7		1.83
	2011	1 243	5.75	0.84	10.5		1.35
Meat	2010	1 413	0.34	0.16	21.5		1.53
	2011	1 380	0.68	0.14	16.2		1.22
Annual total	2010	24 292	293	0.71	189	31	2.1
	2011	23 184	388	2.64	150	35	2.4

The unrecorded in-store waste was calculated using the measures described in Paper I. The value increased from 2010 to 2011 due to the increased pre-store waste (Table 4). Since the other departments sold packaged products, these were assumed to have no or very small unrecorded in-store waste. This was based on measurements on deli products, which were found to have no missing quantities or unrecorded in-store waste.

4.1.2 Products with large wasted mass

In analyses of the products making up food waste, it is important to point out where the actual problems are to be found. Paper I showed that the products making the largest contribution to FFV in-store waste were everyday fruit and vegetables, which are sold in large quantities, and not the exotic fruits, which have higher percentage waste. For organic deli products, the largest waste contribution also came from products sold in large quantities, *e.g.* meatballs and Falun sausage (Paper II). Since Paper I only deals with in-store waste during 2010 in the analysis of wasted products, and Paper II only organic products, Table 5 presents data on both pre-store and in-store waste during both years in all six supermarkets.

For each of the five departments a few articles represented a large share of the total waste (Table 5). The most extreme was the FFV department, where five products contributed almost half (48%) the department's waste. In the other departments, the top eight most wasted products contributed between 22% and 39% of the waste within each department.

Table 5. *The eight products from each department with the most wasted mass during 2010-2011*

Product[1]	Mass sold (ton)	Pre-store waste (ton)	In-store waste (ton)	Retail waste[2] (%)	Share of department waste (%)	Aggregated share of waste (%)
FFV						
Tomatoes	1 497	79.0	26.8	6.6	12.4	12.4
Bananas	1 488	76.7	12.9	5.7	10.5	22.9
Lettuce	682	55.8	26.0	10.7	9.6	32.4
Potatoes	3 144	23.2	46.6	2.2	8.2	40.7
Sweet peppers	543	41.5	21.3	10.4	7.4	48.0
Oranges	1 010	45.1	13.2	5.5	6.8	54.8
Apples	1 405	40.2	14.5	3.8	6.4	61.2
Clementine/Satsuma	627	41.5	7.27	7.2	5.7	66.9
Cheese						
Herrgård cheese 28%	105	0.135	0.719	0.80	7.1	7.1
Gouda cheese 28%	244	0.031	0.734	0.31	6.3	13.4
Brie cheese	32	0.006	0.668	2.1	5.6	18.9
Präst cheese 35%	107	0.350	0.214	0.53	4.7	23.6
Grevé cheese 28%	80	0.225	0.325	0.68	4.5	28.1
Household cheese 17%	85	0.023	0.442	0.54	3.8	31.9
Household cheese 26%	223	0.042	0.393	0.19	3.6	35.5
Edamer cheese 23%	57	0.018	0.388	0.70	3.3	38.9
Dairy						
Medium-fat milk 1.5%	3 077	0.029	4.80	0.16	6.4	6.4
Eggs	1 194	0.477	3.89	0.36	5.8	12.2
Low-fat milk 0.5%	1 197	0.019	3.81	0.32	5.1	17.3
Whole milk 3%	1 892	0.024	3.63	0.19	4.9	22.2
Orange juice	1 432	0.098	3.44	0.25	4.7	26.9
Low-fat sour milk	175	0.042	3.38	1.9	4.6	31.4
Whipping cream 40%	331	0.002	2.88	0.86	3.8	35.3
Medium-fat milk (ESL[3])	1 640	0.011	2.50	0.15	3.3	38.6
Deli						
Barbecue sausage	160	0.482	2.29	1.7	6.5	6.5
Hot dogs	114	0.410	1.66	1.8	4.9	11.4
Meatballs	61	0.084	0.863	1.5	2.2	13.6
Lightly smoked pork loin	46	0.047	0.804	1.8	2.0	15.6
Blood pudding	101	0.082	0.836	0.90	2.2	17.8
Falun sausage	76	0.139	0.639	1.0	1.8	19.6
Prins sausage	21	0.031	0.621	3.1	1.5	21.1
Wiener sausage	41	0.011	0.431	1.1	1.0	22.2
Meat						
Minced beef	847	0.014	2.81	0.33	7.2	7.2
Grilled chicken	23	0.009	1.83	7.3	4.7	12.0
Mixed minced meat	136	0.003	1.40	1.0	3.6	15.5
Sliced pork loin with bones	68	0.003	1.35	2.0	3.5	19.0
Whole chicken	213	0.041	0.964	0.47	2.6	21.6
Sliced pork cutlet with bones	65	0.006	0.977	1.5	2.5	24.1
Ecological minced beef	31	0.002	0.687	2.2	1.8	25.9
Chicken breast file	106	0.002	0.612	0.58	1.6	27.4

[1] Every product consists of one or several articles with e.g. variation in pack sizes and brands.
[2] Pre-store waste and Recorded in-store waste.
[3] Extended Shelf Life.

Since the results of the quantification are presented in terms of mass in this thesis, there is a focus on bulky products with a high water content, such as fruit and vegetables. This is clearly apparent in Table 5, where the products within each department with the largest wasted mass are listed. Everyday products such as tomatoes, bananas, lettuce, milk, sausages and minced meat were found at the top. The percentage waste from tomatoes (6.6%) does not correspond well with the results of other studies (Table 1) when pre-store and in-store waste are combined. However, the recorded in-store waste of tomatoes (1.7%) corresponds well with the 1.6% reported by Becker (1985) and Gustavsson & Stage (2011). For apples too, the recorded in-store waste (0.99%) corresponded better to the 0.9% reported by Becker (1985) and the 0.88%-1.4% reported by Gustavsson & Stage (2011) than retail waste including pre-store waste.

4.1.3 Organic waste

During 2010 and 2011, 1639 tons of organic food were sold within the cheese, dairy, meat and deli departments. This can be compared with the 28 100 tons of conventional products sold during the same period. The waste of organic products was 0.70%, while the waste of the conventional products was 0.56%. The low numbers of both conventional and organic waste are due to the dominance of dairy products (Table 6).

Table 6. *Description of the range of conventional and organic (Org.) products in the cheese, dairy, meat and deli departments in terms of mass sold, mass wasted, percentage waste and average mass of product sold during the two study years*

Dept., product label	Year	Mass sold (ton)	Pre-store waste (ton)	In-store waste (ton)	Total waste (%)	Average mass of product sold (ton)
Cheese	2010	1072	0.23	5.88	0.57	2.1
Cheese	2011	1050	0.99	4.01	0.47	1.6
Cheese, Org.	2010	4.45	0.00	0.08	1.88	0.50
Cheese, Org.	2011	4.76	0.01	0.10	2.41	0.40
Dairy	2010	10430	0.35	37.3	0.36	15
Dairy	2011	10209	1.63	30.3	0.31	12
Dairy, Org.	2010	843	0.00	4.69	0.55	15
Dairy, Org.	2011	721	0.09	3.98	0.56	9.9
Deli	2010	1363	3.79	21.6	1.83	2.0
Deli	2011	1239	6.58	9.12	1.25	1.5
Deli, Org.	2010	3.20	0.01	0.10	3.25	0.40
Deli, Org.	2011	4.12	0.01	0.09	2.32	0.46
Meat	2010	1388	0.51	20.5	1.49	3.1
Meat	2011	1350	0.81	13.8	1.07	2.1
Meat, Org.	2010	28.0	0.00	1.14	3.90	0.61

The average mass of each product sold was less for organic products than for conventional in all four departments. For conventional food, the mass sold of each product decreased from 2010 to 2011 in all four departments, as did the percentage waste. This means that for conventional products, percentage waste decreased with decreased turnover. For organic products the opposite pattern was found. For example, percentage waste for organic cheese and dairy increased from 2010 to 2011, while the average mass sold of these products decreased (Table 6). For organic meat and deli products, percentage waste decreased while the mass of product sold increased.

4.2 Analysis of causes of retail food waste

The waste quantification results identified several potential areas where waste reduction measures could be focused. All of these are based on the assumption that reduced wasted mass is always desirable for supermarkets. In reality, however, the waste reduction measure must also be cost-effective in order to keep the supermarket profitable. Only profitable supermarkets will survive in the long-term perspective and therefore it is important to introduce measures that are good for environment while also maintaining or increasing profits, but extended analysis is required to include both perspectives.

A part of the wastage was due to occasional reasons such as mistakes and special occasions. Mistakes cannot be completely eliminated, but simple and efficient routines that are followed can help to avoid them. Special occasions, *e.g.* promotions or holidays, cause waste since they can be difficult to predict, but good ordering systems that base the orders on statistics from previous holidays can be useful. Since the outcome of promotions is difficult to predict, promotions could be terminated in order to decrease waste, but since they are used to attract customers there can be other consequences of their termination.

An example of an occasional cause of waste during the time period investigated was one double order of dairy products for store 3 in summer 2010, which caused 31% of the annual dairy waste in that store. Another example is grilled chicken in store 1, which had a percentage waste of 48% during one week in autumn 2010 due to failure of the “first in-first out” principle, which left a stock of old chickens that had to be discarded when they passed their best-before date

4.2.1 Products with low turnover

The supermarkets studied work to minimise mistakes and failures in routines and policies, but systematic causes of wastage can arise from some routines and policies and these were therefore the primary focus in this thesis. Lower turnover was found to be a major cause of the higher percentage waste for organic products in comparison with conventional alternatives (Figure 3 and Paper II). For other products there was also a connection between low turnover and high percentage waste (Papers I and II).

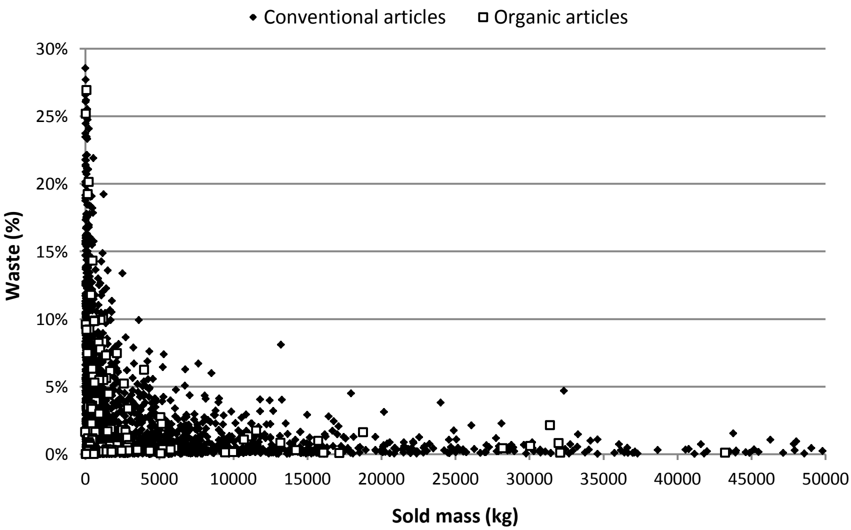

Figure 3. All conventional and organic articles from the cheese, dairy, deli and meat departments with percentage waste and mass sold, 2010-2011. Both axis are cut.

Products with high percentage waste were found to be sold with low turnover (Paper I and II). There are several potential strategies to reduce the wastage of these products. One is of course to stop stocking some products with high percentage waste. Reducing the range of products offered can also increase the turnover of the remaining products.

Many of the products with low turnover also have a small amount of wastage, even though the percentage waste is high. These products can therefore be considered a minor problem, but this is highly dependent on the unit of measure. This thesis quantified masses and therefore low turnover products had low absolute values. If another unit had been used the results might have differed significantly, since some of the low turnover products have a large environmental impact (Strid, 2012).

Organic products were found to have higher percentage waste than conventional products within the cheese, dairy, deli and meat departments (Paper II). One major cause of this difference was the lower turnover, or mass sold per article, of organic products. Findings by Hanssen & Schakenda (2011) and Gustavsson & Stage (2011) confirm that larger turnover gives smaller percentage waste. There are environmental policies that make decreasing the organic range offered by supermarkets impossible (Axfood, 2011) and increased turnover of organic products takes time to achieve.

Expiry of the best-before date is often listed as a reason for retail waste (Andersson *et al.*, 2010) and this has effects on turnover as the products are not sellable any more (Willy:s, 2010). The β-indicator calculated from turnover, shelf-life and wholesale pack size (equation 3) was used here to describe the influence of these parameters on percentage waste (Figure 4).

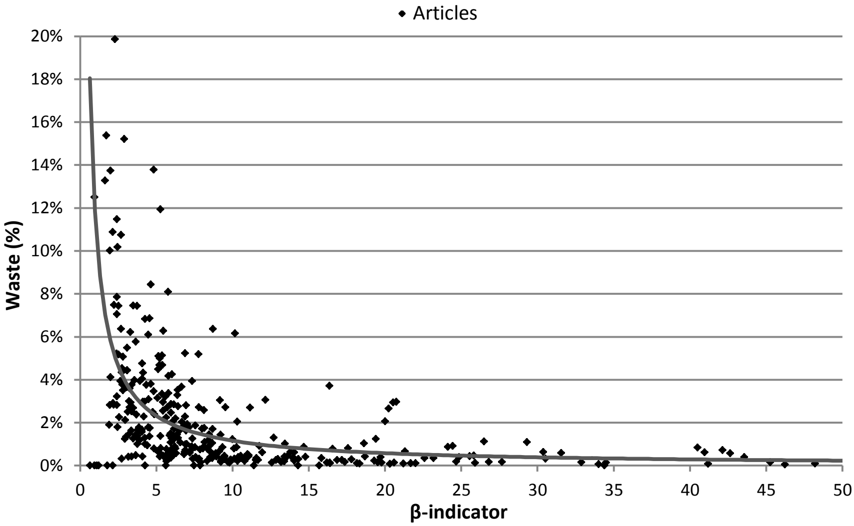

Figure 4. Expanded plot of the β-indicator and percentage waste for 345 deli articles, with a logarithmic trend line described by the equation y=0.116/x; R^2=0.347. Both axes are cut.

For these products, the β-indicator shows that extended shelf-life and decreased minimum order size are potential ways to decrease waste. Owing to the logarithmic relationship between the β-indicator and percentage waste, articles with a low β-indicator have potential to reduce percentage waste with extended shelf-life and decreased minimum order size. The β-indicator was calculated here using only deli products, which makes the conclusions weaker when applied to other products, but the effect of the β-indicator can be even stronger for products with shorter shelf-life, such as fresh meat and some dairy products.

For the organic deli products with the most wasted mass, there was significant potential to reduce the waste if they followed the model with the β-indicator. As calculated in Paper II, a 50% reduction in the wholesale pack size could potentially lead to a 50% reduction in the waste. A condition for this is of course that the staff manage to trim the orders more efficiently and thereby reduce the waste.

Many waste reducing measures aim to prolong the shelf-life by lowering the storage temperature, or by introducing more advanced packaging. For these measures, the β-indicator can be useful in identifying the products for which this measure has the highest potential. For example, it may be far more efficient to invest in packaging for a product with low turnover, since increased shelf-life has a potentially large effect on the waste. For products with a high β-indicator, increased shelf-life has low potential to affect the waste, since the food is still sold before the best-before date, so other causes should be targeted instead.

4.2.2 Rejections

Rejections in the FFV department were the largest source of wasted mass of food in the six supermarkets studied. The amount of pre-store waste also increased from 2010 to 2011 (Table 4), which indicates an increasing trend of rejection. The linear trends of pre-store waste for each store increased for all supermarkets except no. 2. For all six supermarkets combined, the pre-store waste increased and the in-store waste decreased slightly (Figure 5), which gave an overall increase in total wastage of fruit and vegetables.

Since pre-store waste by definition is caused by rejections, this trend indicates a decrease in the quality of goods delivered. However, store personnel gave two explanations for the increased rejections, decreased quality of goods delivered and stricter quality requirements. Since the quality requirements are not defined in detail by the supplier or retail company, it is possible for a supermarket to create an internal policy on acceptable quality.

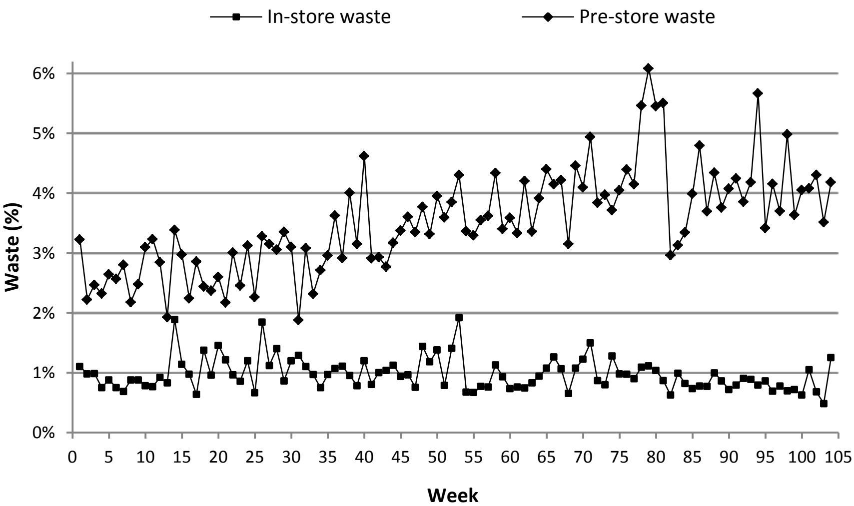

Figure 5. Weekly pre-store and in-store wastage of fruit and vegetables in the six supermarkets investigated during 2010-2011.

An example of how the internal policy affects delivery quality and acceptance was found when looking at bananas (Figures 6 and 7). Supermarkets 1 and 2 are located in the same city and therefore receive deliveries by the same truck, which makes the handling of the goods equal until it reaches the stores. Because of this, the quality of the FFV should be the same in both stores, but there were large differences between the supermarkets during 2011.

In the beginning of 2011, supermarket no. 1 decided to sharpen its policy and stop accepting bananas with questionable quality, in order to only let premium quality enter the stores. This new policy had a large effect on the in-store waste of bananas, which decreased to only 120 kg during 2011, a 93% reduction from 2010 (Figure 6). Shifting in-store waste to pre-store waste was effective in reducing banana in-store waste and thereby the cost of banana waste to supermarket no. 1.

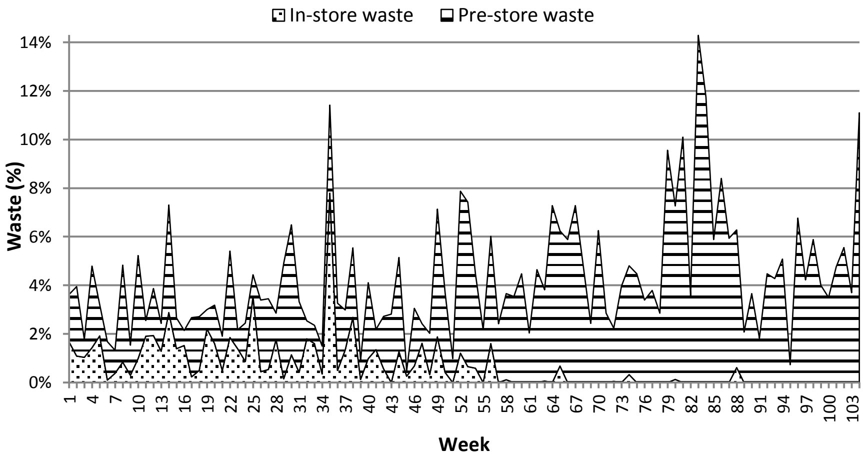

Figure 6. Stacked weekly pre-store and in-store banana waste during 2010-2011 in supermarket 1.

Supermarket no. 2 did not change its quality policy, and had a larger mass of in-store wasted bananas than supermarket no. 1 during 2011. This means that the cost of wasted bananas was higher in supermarket no. 2 than in supermarket no. 1, even though it threw away 74% fewer bananas overall than supermarket no. 1 during 2011. Thus the policy change had a rapid effect, since the difference between the supermarkets was only 10% in 2010.

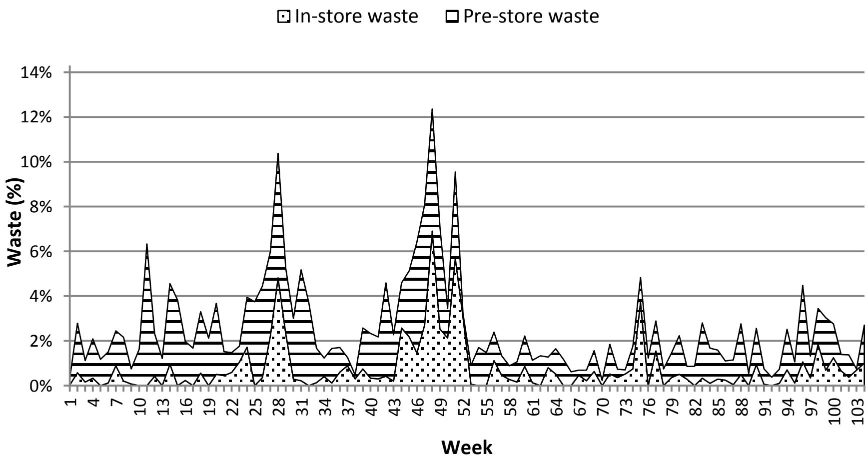

Figure 7. Stacked weekly pre-store and in-store banana waste during 2010-2011 in supermarket 2.

If the banana example is representative of the cause of the total increase in pre-store waste, this policy shift is by far the largest cause of wasted mass in the supermarkets. The difference in pre-store waste of FFV between 2010 and 2011 was 91 tons, which is more than the annual retail waste of the other four departments combined (76 tons in 2011).

The trend for increased pre-store waste was also observed in the other four departments, but in comparison with FFV both the mass wasted and the percentage waste were small (Table 4). The trend was mostly concentrated to supermarket no. 4, which contributed 45% of the combined pre-store waste in cheese, dairy, deli and meat within the six stores during 2011. The same store was found to have the highest pre-store waste of FFV during 2010 (Paper I).

The increased pre-store waste could be a consequence of waste reduction measures in previous steps in the supply chain, meaning that if the producer and supplier allow through products with questionable quality, the wastage might just move to a later stage in the supply chain. However, the banana example indicates that changes in quality are unlikely to have caused this increased waste.

Shifting the waste from in-store to pre-store is a way to save money for the supermarket. This could be seen as against the rules, but since there are no actual quality control limits, the rules are easy to redefine in a way that is more beneficial for the department or supermarket in question. This transfer of cost also sets aside the polluter pays principle, which is fundamental in environmental regulations (EC, 2008). If the shift from in-store to pre-store waste were to keep the sum on a fixed level, this would only be a question of how to allocate costs and profits within the corporate group. Since the total waste increased, it is indicated that waste without visible cost means more waste. If the waste does not have economic consequences for the supermarkets, they do not have to work extra hard to get accurate orders. If the orders are too big and the supermarkets cannot sell everything, they have the possibility of rejecting the excess as pre-store waste, thereby avoiding the economic consequences of bad ordering.

An efficient way to reduce the pre-store waste can be to change the system completely and re-establish the polluter pays principle. Since the majority of the waste in this study was caused by rejections, this measure has the potential to significantly reduce the mass of food waste.

The pre-store waste is seldom described in other studies, either because this waste category is small enough to be neglected, or because it appears in the interface between supplier and retailer, which makes it more hidden. However, even when this interface was described as a waste-causing step in the FSC (Mena *et al.*, 2011), the problems with rejections was not mentioned. This means that this can be an isolated problem within the company investigated in this thesis. Even if this is the case, it is a growing problem, as a historical comparison confirms, since SABA was reported to have 2.5% waste of FFV including in-store rejections in relation to mass sold some 30 years ago (Becker & Jonsson, 1985). It can therefore be concluded that more knowledge is needed about this problem in order to prevent it from causing waste.

4.2.3 Products with large wasted mass

Most of the mass wasted was caused by products with high turnover and low percentage waste (Paper I). The eight products within each department with the largest wasted mass accounted for 67% of waste for FFV, 39% for cheese, 39% for dairy, 22% for deli and 27% for meat (Table 5). This means that much of the waste within each department is concentrated to a few products. For these products sold in large masses, the turnover has a small effect on percentage waste (Paper II).

In the FFV department, potatoes were the only product in the top eight most wasted that had the majority of the waste in the in-store waste category. For the other products, rejections can be described as the main cause of waste. Potatoes were sold both packed in bags (with a best-before date) and as loose weight. The majority (83%) of the potato in-store waste came from products sold in bags, even though packaged potatoes only contributed 27% of sales. To reduce in-store waste of potatoes, it is clear that packages are a potential target, due to the higher waste for packed potatoes compared with potatoes sold piecemeal. The best-before date of 10 days on packages could be the main problem, since it is set by the expected shelf-life of the potato in each bag with the shortest shelf-life. This also means that the whole bag is wasted if one potato becomes unsellable due to bad quality. When sold piecemeal, the potatoes are chosen by customers on their visual quality and each potato not reaching the standards can be sorted out and discarded as singles. Therefore removal of packages and their associated best-before dates could have a potential reducing effect on potato in-store waste.

Other products that can be identified as potential targets for waste reduction measures are those with both comparatively high percentage waste and a large share of the department waste. Table 5 shows a few good examples of these products, *e.g.* Brie cheese, low-fat sour milk, Prins sausage and grilled chicken. All these products except Prins sausage contributed more than 4.6% of the wastage from the whole department. They also had the highest percentage waste in the list of the eight most wasted products within each department (Table 5).

Prins sausage is one example of a product where the waste differs greatly depending on season. Prins sausage is often eaten on the Swedish holidays Easter, Midsummer and Christmas, which are marked in Figure 8. On four of six possible occasions in the study period, the waste exceeded 20% two weeks after these holidays. These four waste peaks corresponded to 575 kg, or 35% of all Prins sausage in-store waste during 2010 and 2011 in all six supermarkets.

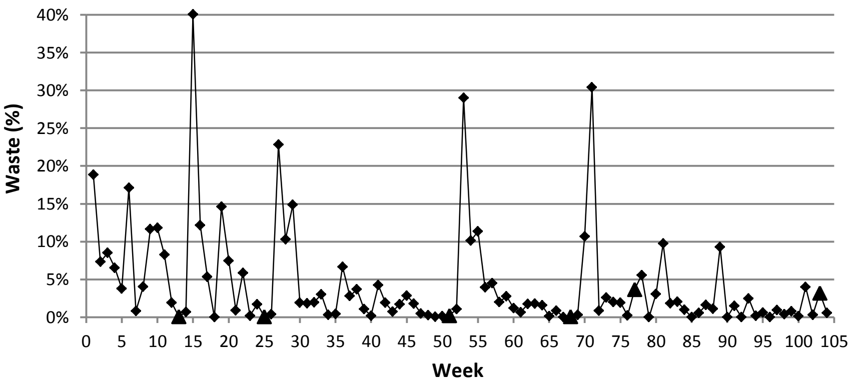

Figure 8. In store wastage of prins sausage during 2010 and 2011 with Easter, Midsummer and Christmas marked with a triangle at week 13, 25, 51, 68, 77 and 103.

Since all supermarkets feel obliged to have a large stock of this product during the holidays, there is a large risk of high wastage afterwards. A way to reduce this wastage could be to enter more historical data into the computerised ordering system that is used by the supermarkets. The system uses historical sales figures for every product and from these statistics can predict the future sales of products. One way to reduce the waste would therefore be to trust the system and not add products just to be sure of not running out, as in the examples mentioned by Mena *et al*. (2011).

One measure to reduce wastage of grilled chicken in one of the supermarkets was analysed by Nilsson (2012), who found out that a reduction in price in combination with an early stop on refilling at the end of each day reduced the waste. Stopping refilling even earlier than the last hour would potentially make the wastage even lower, since fewer chickens would be left in the hot cabinet at the end of the day.

4.3 Data quality and choice of methodology

4.3.1 Quantification methodology effect

The difference between mass of products delivered and mass sold during 2011 was calculated for the deli department in order to determine the potential unrecorded waste in this department. The sum of pre-store waste (0.59%) and recorded in-store waste (0.83%) was calculated to be 1.42%. The difference between delivered and sold products was also 1.42%. The difference between these numbers equals the amount of unrecorded in-store waste and missing quantities, in this case 0.0%.

4.3.2 Units and comparable mass

Choice of analytical method had an effect on the results presented in this thesis. First of all, all results are presented in terms of mass, which gives bulky products with high water content, *e.g.* fruit, vegetables and dairy products, a large influence on the results. If the results had been presented using the monetary value of the waste, more expensive products, *e.g.* aromatic plants such as basil, would have been on the most wasted list, but not potatoes. The results could also be presented in terms of global warming potential, as CO_2-equivalents, in order to indicate the environmental effects of the wastage. Usage of any of these units would shift the focus relatively more to meat and cheese products rather than FFV and dairy. The weakness of using mass units in this kind of study is that the products with a large environmental impact can be associated with small values, which can be interpreted as meaning that they are not important (Strid, 2012). For this reason, the monetary value is likely to correspond better to environmental impact than mass units. The strength of using mass values is good transparency, since the unit is well-defined and does not change along the food supply chain, except during processing. Both monetary values and values describing the environmental impact need detailed definitions and have a tendency to differ over time and along the value chain even without processes that change the properties of food stuff, *e.g.* the value of products increases not only when they are processed but also when they change owners, are handled or are kept in a cold storage.

Using a mass unit makes the results comparable with other studies. However, it is not only the units that make comparisons complicated. Results based on monetary values are often compared with the value of sold products, since this is the basis of income in a company and what all costs must be compared against. When percentage waste is as low as it was in this study, this causes no significant problems, since percentage waste of 1.00% calculated with equation 1 corresponds to a value of 1.01% if the waste is compared with the sold value instead. The choice of comparison becomes more influential for the results with higher values of percentage waste.

4.3.3 Study objects

The six supermarkets in the material were selected by the parent company, which introduces a possible bias, even though the company claimed that they represented the average. It is likely that the company chose stores with low percentage waste, since this tends to be something shameful and might repel customers if information about high waste became publicly available. Therefore the supermarkets studied can be expected to represent an average Willy:s store or have lower percentage waste than the average Willy:s store. The selected stores were also found to be larger than average in terms of turnover of FFV (Paper I), which further increases the potential for them to waste less than average (Hanssen & Schakenda, 2011). However, even if the representativety cannot be proven, all supermarkets within the company are based on a detailed concept (Willy:s, 2010), making large variations between individual supermarkets unlikely. The level of waste in the six supermarkets investigated is therefore unlikely to differ greatly from the average supermarket within the Willy:s chain.

4.3.4 Data collection and accuracy

Material flow analysis showed that the unrecorded waste category and missing quantities differed in size between departments. These two categories are a good indicator of the quality of recorded data. If large quantities are lost without any reasonable explanation, a likely cause is that the recording of waste does not function well and items are discarded without recording. From the analysis, it is clear that data based on EAN code scanning are more accurate than data based on estimated weights. Therefore the results for cheese, dairy, deli and meat can be considered more accurate than those for FFV. This is true even though efforts were made to quantify unrecorded in-store waste of FFV by physical measurements.

4.4 Concluding discussion

In order to reduce the environmental impact of the food supply chain, reducing food wastage in the retail sector is an important area. The first step in the process of reducing retail food waste is to describe the problem, both in terms of how much and what is wasted, but also why these items are wasted. This thesis described and quantified different categories of retail food wastage and identified the products within each department that make a large contribution to the overall waste. These quantifications showed that rejections within the fresh fruit and vegetables department wereas a major cause of wasted mass. This problem should therefore be targeted when designing waste reducing measures.

For the products with the largest share of wasted mass within each department, there are different causes for the waste. Apart from rejections, this could be a seasonable problem as for Prins sausage, or a shelf-life issue as for packaged potatoes, or an order size problem for organic products. The three-hour shelf-life for grilled chicken can also be a problem that causes waste for this specific product. However, while there are different causes of wastage, most of the products with a high waste level have a common issue on a more general level, availability and variation. In order to keep the customers attracted, the supermarkets place a high priority on having a wide range of products available and full shelves at all times, even if the price for this is wastage of food. According to the company policy, grilled chicken is simply not allowed to sell out (except just before closing) and the shelf with Prins sausage must not be empty at Easter and Christmas, since this may discourage customers.

This wide assortment of products creates lower turnover for each product, which put them at risk of not being sold before the best-before date, and therefore becoming waste. Neither supermarkets nor customers are likely to voluntarily give up the freedom of having a large variety of easily accessible food and therefore cost-effective and smart solutions, satisfying both customers, retail companies and ambitious waste targets, are needed in order to get a sustainable food supply chain, unless attitudes can be radically changed.

5 Conclusions

The introduction of different food waste categories (pre-store waste, recorded in-store waste, unrecorded in-store waste and missing quantities) made it possible to describe and quantify different flows of food losses within six large supermarkets.

The largest mass of waste for the six stores during 2010-2011 occurred in the fresh fruit and vegetable department (919 ton), followed by the departments for dairy (75 ton), deli (43 ton), meat (39 ton) and cheese (12 ton). The largest proportion (65%) of the total wasted mass from these departments (1023 ton) was due to rejections of fresh fruit and vegetables, which contributed 669 tons of waste.

Organic products were found to have higher percentage waste than conventional products. One systematic cause of this was the lower mass sold per article for organic products. Increased shelf-life, decreased minimum order size and increased turnover were identified as potential waste reduction measures for these products.

A large proportion of the waste in all departments was concentrated to a few products. It is therefore suggested that waste reduction measures should focus on the individual problems associated with these particular products, rather than all products in a department.

6 Future research

Quantification of food waste has emerged as a popular research area in the last few years and the studies reported to date have led to better knowledge about the costs and masses that are wasted in the food supply chain. However, in order to reduce waste, it is not enough to simply describe the problem and propose some possible solutions. Future research must answer two questions:

- Which waste reduction measures are useful in which situations?
- How efficient are different measures (*e.g.* how much do they cost and how much food can be saved)?

A potential measure that should be tested in practice is removal of the rejection on delivery option, or introduction of rules limiting the usage of this system. This could have a decreasing effect on wastage, but needs to be tested in a range of different supermarket chains and store sizes. Another possible area of research is to identify products with a low β-indicator, reduce the wholesale pack size for those and then evaluate the actual change in wastage.

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