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Waste of fresh fruit and vegetables at retailers in Sweden – Measuring and calculation of mass, economic cost and climate impact

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ABSTRACT

Food waste is a significant problem for environmental, economic and food security reasons. The retailer, food service and consumers have been recognised as the parts of the food supply chain where the possibility of reducing food waste is greatest in industrialised countries. In this study, primary data on fresh fruit and vegetables (FFV) waste collected through direct measurements in three large retail stores in Sweden were analysed from the perspectives of wasted mass, economic cost and climate impact. A method of measuring and calculating the economic cost of FFV waste was developed and includes the cost of wasted produce, the cost of personnel time for waste management and the cost of waste collection and disposal. The results show that seven FFV categories, which have been termed “hotspot categories”, contributed to the majority of the waste, both in terms of wasted mass, economic cost and climate impact. The “hotspot categories” are apple, banana, grape, lettuce, pear, sweet pepper, and tomato. The cost benefit analysis conducted showed that it is economically wise to invest in more working time for employees in waste management to accomplish a reduction of wasted mass and climate impact without an economic loss for the store. These results are relevant for supporting the implementation of policies and initiatives aimed at food waste reduction at retail level.

1. Introduction

It is estimated that almost one third of the food produced for human consumption is lost or wasted globally (FAO, 2011). This leads to a significant environmental impact in terms of inefficient use of natural resources (Garnett, 2011), as well as an economic cost (FAO, 2013; Buzby and Hyman, 2012) and also social and moral implications (Stuart, 2009). Food waste is an issue of importance to global food security, as 795 million people suffer from undernourishment (FAO, 2015) and the world population is projected to increase to 9.6 billion by 2050 (UN, 2013). The growth of the population will lead to an intensified use of natural resources (Godfray et al., 2010) and the increase of global demand for food is projected to increase by 70% by 2050 (FAO, 2009). To make the food supply chain sustainable – both feeding the world's growing population and reducing the environmental impact – the development of strategies to reduce food loss and waste throughout the food supply chain is essential (Beddington, 2011; Garnett, 2014). The extent of food loss and waste and the unnecessary use of resources have received increased attention; it is a topic of considerable interest from both the public and private sectors. Several important actors, such as the United Nations and the European Union (UN, 2015; EC, 2015), the governments of the US and France (USDA, 2016; Ministère de la Transition écologique et solidaire, 2015) and international companies (Tesco, 2014) have recently adopted goals for food loss and waste reduction. To incorporate global agreements of halving food waste by 2030 (UN, 2015), more comprehensive and detailed information is needed to better understand which food, and how much of it, is discarded. Besides measuring the waste amount, detecting the causes and identifying the “hotspots of wastage” (Priefer et al., 2016), where large waste reduction effects could be achieved with low effort, is also a necessity in order to set and implement reduction targets.

1.1. Food waste in the food supply chain

Throughout the food supply chain, food is wasted by a large number of actors for different reasons (FAO, 2011; Parfitt et al., 2010). The definition of food waste refers to food being wasted at retail and consumer level and consists of food appropriate for human consumption being discarded or not consumed by humans. This includes food which has spoiled prior to disposal and food that was still edible when thrown away; it is often related to retailer and consumer behaviours (Thyberg and Tonjes, 2016; FAO, 2013; Parfitt et al., 2010). Food waste in Europe and North America occurs predominantly during retail and

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consumption (FAO, 2011). An estimation of European food waste levels (Stenmarck et al., 2016) reveals that 70% of the EU food waste arises in the household, food service and retail sectors. The retailer, food service and consumers have also been recognised as the parts of food supply chain where the possibility of reducing food waste is greatest in developed countries (FAO, 2011; Stenmarck et al., 2016). The environmental impact of food loss and waste adds up along the supply chain after being transported, stored, packed and processed (Beretta et al., 2013). When food is wasted at the end of the supply chain, it is more costly in terms of resources and economic cost compared to losses earlier in the supply chain.

The contribution of retail waste to the total amount of food waste is small and corresponds to a low percentage of waste compared with other steps in the food supply chain (FAO, 2013; Stenmarck et al., 2016). However, an individual retailer produces a large amount of waste at the same physical location and even a minor percentage reduction can give major reductions in terms of lowering the amount of wasted mass and lowering the economic costs. The retail sector is a strong actor in the supply chain (Beckeman and Olsson, 2011) and can put pressure on suppliers and influence consumers. A previous study (Eriksson et al., 2017) showed that take-back agreements between suppliers and retailers played a significant role in the amount of food which was wasted. At wholesalers and retail stores in Sweden, the total amount of food waste in 2012 was estimated to be 70,000 t, of which 91% was considered unnecessary or avoidable food waste (Swedish Environmental Protection Agency, 2014).

At retail level, fresh fruit and vegetables have been identified as the main contributor to the amount of the wasted material, hereafter referred to as 'wasted mass', (Scholz et al., 2015; Stenmarck et al., 2011; Buzby et al., 2009). A recent study (Brancoli et al., 2017) showed that the most wasted products at retail level were found to be either bread or fruit and vegetables, of the total wasted mass at the retailer, 30% originated from bread and 29% from the fruit and vegetable department. Similar result was presented from a study in Italy were the wasted weight from fruit and vegetables corresponded to 34% of the total wasted mass at the retailer (Cicatiello et al., 2017). The total value of food waste at the retail and consumer levels in the United States, considering retail prices, was $165.6 billion in 2008, where fruit and vegetables corresponded to 26% of the total value (Buzby and Hyman, 2012). In a study from Austria at retail level, the monetary value of fresh fruit and vegetables accounted for 53% of the total value of food waste (Lebersorger and Schneider, 2014). From an environmental perspective, in a study at six retail stores in Sweden, fruit and vegetable departments contributed to 46% of the total waste of the carbon footprint (Scholz et al., 2015).

1.2. Waste categories at retailer level

In the retail sector, the FFV waste are the produce subjected to rejection at delivery at store, or those which are removed from the department and discarded. Some studies on FFV waste at retailer level which have been conducted previously have described the procedures used in fruit and vegetable departments (Eriksson, 2012; Åhnberg and Strid, 2010). A flow chart for the fruit and vegetables at retailer level and the different waste categories is described in Fig. 1 (modified from Eriksson et al., 2012).

When fresh fruit and vegetables are delivered to the store, the store can, after quality control, accept the produce or, if the produce does not comply with the quality requirement, reject it. The cost of the pre-store waste (Eriksson et al., 2012) is reimbursed by the supplier and does not contribute to a monetary loss from the retailer's point of view. The definition of in-store waste has been established in previous studies (Eriksson et al., 2012; Hanssen and Schakenda, 2011) and can be summarised as the waste which occurs in the store after the produce from the supplier has been accepted. Invisible in-store waste depends on several factors, for example, mass loss due to evaporation, theft, the produce being discarded without being recorded and an employee's capability when estimating the weight and registering the data (Eriksson et al., 2012).

1.3. Aim and scope

The scope of this study is to increase the knowledge of the in-store waste of fresh fruit and vegetables at retailer level. This will provide a better understanding and input in the assessment of which FFV categories retailers can work with in order to reduce waste, make informed decisions and implement targeted waste reduction actions. The aim of this study is to examine which FFV categories provide the highest amount of in-store waste and calculate the respective waste quotas. The economic aspects of waste are also studied, since this is the dimension that stores operate in. This has not previously been investigated in relation to specific FFV categories and food waste. Therefore, this study examines which FFV categories have the largest economic cost, including the economic loss of the wasted produce, the cost of an employee's time spent on waste management and the cost of waste collection and disposal. Moreover, the FFV categories with the highest climate impact are also studied. Additionally, the study examines if it is cost effective to spend more resources on man-power for waste management in order to reduce the wasted mass and the cost of waste. As a final point, the differences of the results in regards to whether the waste is measured in terms of wasted mass, economic cost or climate impact is discussed.

2. Materials and methods

On-site investigations were made at three large retail stores in mid-Sweden. The case study started in 2012 with an exploratory series of semi-structured interviews, (interview method is described by Kvale and Brinkmann, 2014) and participating observations (method is described by Yin, 2009) with employees in the FFV department at one store. Based on the outcome from the exploratory study, a method for measuring the waste and of calculating the economic costs was developed. Two additional stores from different cities were selected to be included in the study. The main study, which included all three stores, took place between 2013 and 2014, and the methodology was uniform for all stores. Data of in-store waste (see Fig. 1), sold quantities and purchase price were received from each store from 1 January to 31 December 2013 in the form of extracts from the stores' respective databases. To calculate the personnel cost for waste management, information regarding the stores' daily working routines and waste management procedures were obtained by participating observations at the FFV departments during three days at each store. To validate the

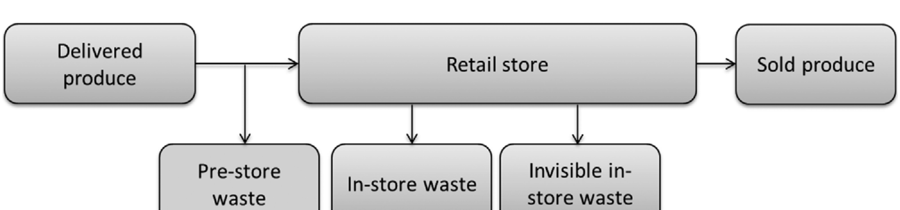

Fig. 1. A flow chart for the fruit and vegetables at retailer level and the different categories of waste.

data, an investigation of the similarities and differences of the working routines between the stores was undertaken, and complementary questions were discussed with the employees. With the intention of not interfering with working routines, the visits were scheduled in co-operation with the employees, and the employees were instructed not to change their daily working routines for the visits. In total, six employees from the fruit and vegetable departments were observed and interviewed. The observations and interviews were documented through field notes and photos for future reference and analysis, and the compilation of the field notes was completed the same day. Follow-ups, both during the three-day visits and later by phone-call, were conducted to clarify and confirm the data. The results from the calculations were reviewed and verified by the employees in the fruit and vegetable departments, and also by the storeowners and managers.

2.1. The stores

The stores included in this study are franchise owned by different individuals and are members of the same retail chain called ICA. The stores are large supermarkets, belonging to the hypermarket segment (Guy, 1998), with a sales area of between 5100 to 7000 square metres. The ICA Group is one of the Nordic region's leading retail companies and is the largest player in the Swedish food retail market with a market share of 48% (Axfood, 2013). The stores are geographically located in the same region, use the same ordering tools and main suppliers, have similar product ranges, as well as similar storing and cooling facilities. The food waste is collected by a waste company and is sent for incineration.

2.2. Wasted mass

The employees at each store register the in-store waste, which consists of both packed and unpacked FFV. This procedure has been used for many years by the stores for internal waste follow up and is performed independently of this study. Each line of the in-store waste data consists of information regarding: type of FFV, if it was sold in bulk or packed, the weight, the number of waste registrations and the purchase price per item. In total, data from 40,103 waste registrations were used for the analysis. The same type of FFV was combined into one category, for example, all different types of apples became one category, regardless if the FFV was sold in bulk or packed. The same operation was performed with all types of FFV. The stores do not have exactly the same product ranges, and the number of different categories was 64, 74 and 76 respectively. When all the data was combined, 81 separate categories were revealed. For each category, information on wasted mass, waste quota and economic cost were calculated, both for each store and it was then accumulated for all three stores in order to give the average data. Sold products are registered by the store when the customers pay for it. The in-store waste quota is defined as the in-store waste in relation to the sold mass amount and is calculated by using the equation: Waste quota = In-store waste/(In-store waste + Sold quantity).

2.3. Economic cost

The economic cost is defined as the sum of the cost of wasted produce, the cost of personnel for waste management and the cost of waste disposal, including the cost of waste collection. The equation was described as: Economic cost = Cost of wasted produce + Personnel cost for waste management + Cost of waste disposal. For the analysis of economic cost, the purchase price was used and obtained from the stores. The employee's time spent on waste management, including the sorting and removal of bad produce, waste registration and waste disposal were timed in each store over two days. The person who was mainly responsible for the waste management was observed and all activities were timed. The time was divided into the number of waste registrations that were done during the timed occasions. The time per registration was then used to calculate the average personnel cost per registration, which in turn was used to calculate the personnel cost for waste management per category. Data on the personnel cost, including salary, social security and pension, etc. was obtained from each store for the year 2013. Data regarding the cost of waste disposal, based on the weight and volume of waste and transportation was obtained from one of the stores for the year 2013 and was verified by the waste company. The data for this store was used to calculate the waste disposal costs for the other two stores.

2.4. Climate impact

The global warming potential (GWP) of the in-store waste was calculated by using the carbon dioxide equivalents of 1 kg of FFV and these were multiplied with the accumulated amounts of the in-store waste per FFV category. The equation can be described as: GWP = GWP value x in-store waste. The GWP were calculated by using the median values from the extensive list recently reviewed by Clune et al. (2017), were the system boundaries were from the farm to the regional distribution centre. For the FFV categories where the specific GWP data was lacking in Clune et al. (2017) some assumptions using similar FFV categories were made and a mean value was calculated (Clune et al., 2017). The GWP values (kg CO2-eq/kg produce) of the top forty FFV categories with the highest mass of in-store waste are listed in Appendix A.

2.5. Cost benefit analysis: cost of waste versus cost of personnel time

The time personnel at the FFV department spent on duties such as ordering, the sorting and removal of bad produce, waste registration and waste disposal can be of importance for the amount of in-store waste (Lagerberg Fogelberg et al., 2011). In the present study, two theoretical cases with increased working time for the employees at the FFV department were set up, and how much those costs corresponded to in terms of reducing the percentage of the cost of wasted FFV were calculated. In the first case of the cost benefit analysis, the economic cost of employees in the FFV department was increased by 100%, and in the second case, the cost of employees was increased by 20%. Calculations were performed for all FFV categories, as well as for the top twenty FFV categories with the largest amount of in-store waste. The equation for calculating the cost benefit were: Percentage decrease of economic cost of FFV waste = Increased personnel cost/FFV cost. The equation for calculating the cost benefit for the top twenty FFV categories with the largest amount of in-store waste were: Percentage decrease of economic cost of waste of the top twenty FFV categories = Increased personnel cost/(FFV cost x the percentage of cost of the top 20 categories).

2.6. Analysis of data

The quantitative data was processed and analysed using spreadsheet calculations. Before starting the detailed analysis of the waste data from the selected stores, the data was checked manually and when any errors and inconsistencies were discovered it was followed up in detail. Where possible, data was corrected and in other cases, the data was excluded from further analysis. The weight of the excluded products corresponded to 0.01% of the total in-store waste weight and none of the FFV categories was overrepresented. The results of the participating observations and interviews were summarised and categorised following the details of the waste management routines at the FFV departments.

2.7. Limitations

Data on fresh fruit and vegetables is included in this study; therefore, dried, canned or frozen produce are excluded. No differences

Table 1
The top twenty fruit and vegetables categories which generate the largest amount of wasted mass, the highest economic cost and the highest climate impact, as well as the respective waste quotas, of the in-store waste at three large Swedish retail stores during 2013.

	Wasted mass			Economic cost			Climate impact		
	Category	Wasted mass (t)	Waste quota (%)	Category	Economic cost (kSEK)	Waste quota (%)	Category	GWP (kkg CO2-eq)	Waste quota (%)
1	Banana	6.4	1.6	Lettuce	274	3.0	Banana	4.8	1.6
2	Apple	5.5	1.9	Fresh herbs	117	7.8	Sweet pepper	4.6	4.0
3	Tomato	4.8	1.6	Tomato	116	1.6	Tomato	2.4	1.6
4	Potato	4.7	0.9	Sweet pepper	109	4.0	Melon	1.9	1.6
5	Lettuce	4.4	3.0	Apple	84	1.9	Avocado	1.8	2.5
6	Sweet pepper	4.2	4.0	Grape	82	3.1	Lettuce	1.6	3.0
7	Melon	3.8	1.6	Banana	69	1.6	Apple	1.6	1.9
8	Pear	3.6	4.5	Berries	67	4.7	Pear	1.1	4.5
9	Grape	3.0	3.1	Pear	65	4.5	Grape	1.1	3.1
10	Orange	1.8	0.9	Potato	52	0.9	Fresh herbs	1.1	7.8
11	Carrot	1.7	1.3	Melon	46	1.6	Potato	0.8	0.9
12	Onion	1.6	0.9	Onion	38	0.9	Berries	0.7	4.7
13	Lemon	1.6	2.1	Avocado	35	2.5	Clementine	0.7	0.9
14	Clementine	1.5	0.9	Carrot	25	1.3	Orange	0.6	0.9
15	Avocado	1.4	2.5	Mango	24	6.9	Aubergine	0.5	9.7
16	Nectarine	1.2	1.7	Mushroom	24	2.2	Nectarine	0.5	1.7
17	Kiwi	1.0	1.6	Cabbage	23	1.2	Pineapple	0.5	2.9
18	Cauliflower	1.0	3.2	Kiwi	22	1.6	Lemon	0.4	2.1
19	Cabbage	1.0	1.2	Lemon	21	2.1	Peach	0.4	6.5
20	Fresh herbs	1.0	7.8	Orange	21	0.9	Kiwi	0.4	1.6

between edible and non-edible food waste are made, as the waste consists of whole products, which are sold as whole products, for example, the weight of peel and haulm are included in the amount of food waste. Additionally, it is assumed that the waste is edible at or before the time it is disposed of and therefore, the study does not differentiate between avoidable and unavoidable food waste.

3. Results

The list of the top twenty FFV categories with the highest amount of wasted mass, economic cost and climate impact obtained from calculations in this study are presented in Table 1.

3.1. Wasted mass

The total amount of in-store waste of FFV for the three stores in 2013 was 68 t, which corresponds to an average waste quota of 1.9 percent. The categories on the top of the list in terms of wasted mass (Table 1) represented 81% of the total waste weight, 77% of the total economic cost and 82% of the total amount of GWP. Looking into the separate FFV categories, banana, apple and tomato are the products which had the largest amount of in-store waste (see Fig. 2a). Banana had the highest amount of waste, which was 6.4 t and corresponded to 9.4% of the total wasted amount (see Fig. 3).

3.2. Economic cost

The accumulated economic cost of the in-store waste for the three stores was 1,628,000 SEK, which corresponded to approximately €165,000. The top twenty categories with the largest economic cost (Table 1) of recorded in-store waste represented 79% of the total waste weight, 81% of the total economic cost and 81% of the total amount of GWP. Lettuce, fresh herbs, tomato and sweet pepper were the top products which represented the highest economic cost. Lettuce had the highest economic cost and more than double the cost compared to fresh herbs, which had the second highest economic cost (see Fig. 2b). Fresh herbs and berries were high up on the economic top list compared to the top list of wasted mass.

3.3. Climate impact

The total amount of GWP for the three stores in 2013 was 32,600 kg of carbon dioxide equivalents. The top twenty categories with the highest amount of GWP are presented in Table 1 correspond to 78% of the total waste weight, 77% of the total economic cost and 85% of the total amount of GWP. Banana and sweet pepper had the highest amount of GWP, and as Fig. 2c shows, there was a significant decrease of tomatoes to third place. Aubergine, pineapple and peach were new categories which ended up on the climate impact top list compared to the top lists of wasted mass and economic cost.

3.4. Hotspot categories

Out of 81 FFV categories in total, a few categories represented the largest share of wasted mass, economic cost and climate impact. When the top ten categories of all three top lists were analysed, it was found that there were seven categories which could be extracted as "hotspot categories", see Fig. 2abc. The "hotspot categories" were banana, apple, tomato, lettuce, sweet pepper, pear and grape. Those "hotspot categories" added up to 31.8 t and 800,000 SEK (€ 81,100), which corresponded to 47% of the total wasted mass and 49% of the economic cost. Fig. 2abc show the amount of wasted mass, economic cost and climate impact and the placement of the "hotspot categories". The share of wasted mass, economic cost and climate impact for the "hotspot categories" as percentage of the total waste is presented in Fig. 3.

3.5. Waste quota

The total amount of in-store waste of FFV for the three stores in 2013 was 68 t, which corresponded to an average waste quota of 1.9%. The FFV categories with high waste quotas (see Table 1) were aubergine (9.7%), fresh herbs (7.8%), mango (6.9%), peach (6.5%), berries (4.7%), pear (4.5%), and sweet pepper (4.0%). The FFV categories with low waste quotas were onion, potato, orange and clementine with a waste quota of 0.9%. When creating a top twenty list with the highest amount of waste quota, sixteen different types of exotic fruits were represented, and the top twenty products on the list represented 2.5% of the total wasted mass and 3.4% of the economic cost.

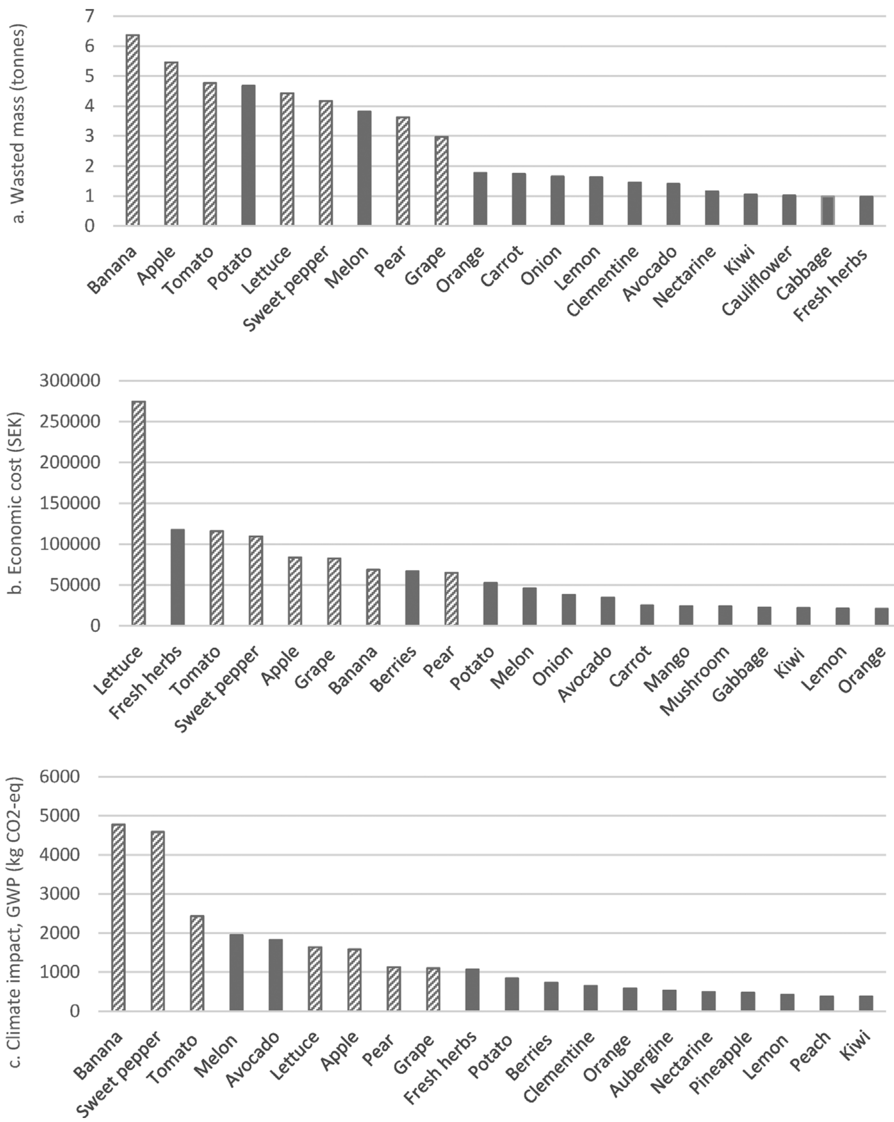

Fig. 2. abc. The top twenty fruit and vegetables categories which generated the largest amount of in-store waste (a), economic cost (b) and climate impact (c) at three large Swedish retail stores during 2013. The highlighted categories belong to the "hotspot categories".

3.6. Cost benefit analysis: cost of waste versus cost of employees' time

Based on the economic costs for the three stores, the allocation between the economic costs of the wasted FFV, personnel and waste disposal are presented in Fig. 4. Of the economic costs, the wasted FFV represented 86%, personnel cost for waste management is 9% and waste disposal cost is 6%.

In the first theoretical case of the cost benefit analysis, the economic cost of employees in the FFV department was doubled as it was estimated that more time could be allocated to waste management in order to reduce the in-store waste. To meet the doubled cost for personnel, a cost reduction of wasted FFV cost needed to be 10% to break even. In the second case, the economic cost of personnel increased by 20% and the reduction of FFV waste needed to be 2% to break even. If the top twenty FFV categories of wasted cost (Table 1) were used in the calculation, which represented 81% of the total wasted cost, a doubled personnel cost required a cost reduction of these top twenty FFV with 12% to break even. When the increased cost for personnel was 20%, the

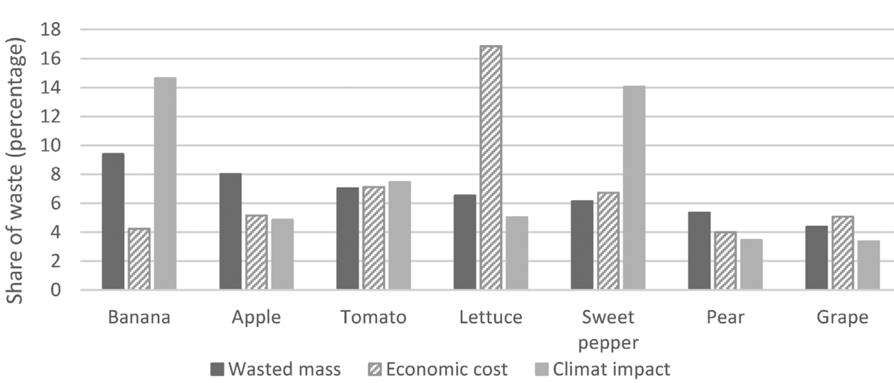

Fig. 3. Share of wasted mass, economic cost and climate impact for the "hotspot categories" as percentage of the total waste.

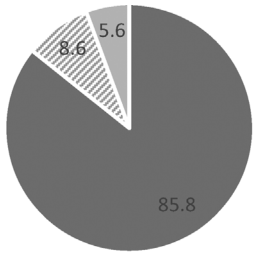

Fig. 4. The allocation between the different parts of economic costs, including the cost of wasted FFV, employees and waste disposal at three large Swedish retail stores during 2013.

reduction from the top twenty list was 2.5% to break even.

4. Discussion

This study used primary data to increase the awareness and in-depth understanding regarding the in-store waste of FFV at retailer level and identified seven hotspot categories. These contributions are in line with recommendations from a recent study (Xue et al., 2017) which identified a gap of primary data on food waste as well as highlighted the need of hotspots to prioritise implementation of reduction strategies.

4.1. Measuring food waste and implementing reduction actions

This study showed small differences regarding which FFV categories ended up on the top twenty lists (presented in Table 1) whether the waste was measured in terms of wasted mass, economic cost or climate impact. Therefore, the retail stores can use the economic top list when prioritising their strategies to reduce the in-store waste of FFV. The top list of economic cost captures most of the relevant FFV categories and the stores already have access to the data regarding economic costs in terms of purchase prices. Furthermore, by using their own data, they do not need to recalculate the wasted FFV into mass or climate impact data. This can make the retail manager confident that by prioritising the reduction of waste at the FFV department from the top lists of economic cost, they will also be able to make significant contributions in the reduction of wasted mass and its impact on climate change.

4.2. Top lists and hotspot categories

Out of the 81 FFV categories, only a few number of categories contribute to the majority of the wasted mass, economic cost and climate impact. Fig. 2abc illustrates the clear decline of the amount of wasted mass, economic cost and climate impact on the top lists. Based on the results from the three top lists, seven "hotspot categories" were identified, and Fig. 2abc show that all "hotspot categories" were at the higher end. Although the "hotspot categories" are on all three top lists, the respective share of the total waste for the three top lists differs and are presented in Fig. 3. In order to reduce food waste and better use personnel resources, retailers can use these results to develop practical applicable measures for those "hotspot categories" by optimising demand planning, ordering and other prevention measures. The "hotspot categories" identified in this study are banana, apple, tomato, lettuce, sweet pepper, pear and grape. The same FFV categories were also present on the top ten lists of FFV categories which generate the largest amount of in-store waste presented by Eriksson et al. (2012). Previous studies of food waste at supermarkets or large retail stores did not take into account the total economic cost, including the purchase cost, the personnel cost and the waste disposal cost, and the results from this study can not be compared. The top three products, which contribute to the largest amount of climate impact in this research, were banana, sweet pepper and tomato. Scholz et al. (2015) identified the same products as the main contributors of carbon footprint waste.

Looking into the separate "hotspot categories", the cause of the waste differs. Some causes of waste depend on best before date labels, the treatment of the FFV by employees and the sensitivity of the product in terms of how easily it is damaged. The category **banana** had both the highest amount of wasted mass and the highest amount of climate impact (see Fig. 2a and c). The wasted of mass of banana was 6.4 t (see Table 1) and corresponded to 9.4% of the total wasted amount (see Fig. 3). **Apple** had the second highest amount of wasted mass (see Fig. 2a). When apples were refilled on the shelves at the FFV department, one box of apples was often held upside down and the apples were damaged by this practice. After this study started, this procedure was changed. The apples are now treated with more care, and the more frequent removal of bad produce has been implemented. The employees have noticed a decrease in the wasted amount for apples; however, in this study the changes were not measured. **Lettuce** had the highest economic cost (see Fig. 2b) and had more than double the cost compared to fresh herbs, which had the second highest economic cost. The economic cost of lettuce was 274,000 SEK, corresponding to almost 17% of the total cost for all FFV categories (see Fig. 3). The high cost depends on the high amount which is wasted and the fact that some of the lettuce products are a labour intensive. When a lettuce product is provided with a best-before date, it needs to be sorted out one or two days before the date expires. **Pear** was eighth place in top lists on wasted mass and climate impact and ninth place in top list on economic cost (see Fig. 2abc), and had the third highest waste quota of 4.5%. Pears have a thin and sensitive peel, so the product can easily be damaged by employees or customers if treated improperly, or they can also be damaged by the stalks from a nearby product. **Grape** was sold both in bulk and in packaging. When sold in packaging, the product was protected during transportation, and at the store it was protected from careless handling from both employees and customers. The downside with this kind of packaging is that if one or two grapes are bad, the employees do not always have time to open the packaging to remove the bad part, so the entire packaging and its contents are discarded. Banana, apple and tomato have the largest amount of in-store waste (see Fig. 2a). However, these products also have the highest turnover and therefore a low waste quota (see Table 1). **Tomato** is on top three on all top lists (see Fig. 2abc) and **sweet pepper** had the second highest climate impact (see Fig. 2c). The causes of waste for these two products are probably a result of a combination of causes and additional research is needed.

4.3. Cost benefit analysis: cost of waste versus cost of personnel time

An important working routine at the FFV department is the frequent removal of bad produce, as it minimises the risk of one bad product contaminating other products, and therefore contributes to a lower waste amount. The cost benefit analysis showed that when the cost of employees was doubled a cost reduction of wasted FFV cost needed to be 10% to break even, which also corresponded to a reduction of 10% of the wasted FFV mass. When the employees' working time for waste management was increased by 20%, it corresponded to a reduction in the cost of waste of the top twenty FFV by 2.5% to break even. Additional time for improved waste management may result in better waste management routines and overview of the stock. A good overview of the stock is also one precondition in making proper orders (Swedish Environmental Protection Agency, 2014). If it is possible to reduce the FFV cost by 2.5% of the top twenty FFV categories when employee costs are increased by 20%, this study has not been able to show it; however, there are some indications which show that it may be possible. When comparing the three different stores and the differences in the time spent on waste management, one of the stores spent less than half of the time on waste management compared to the other two stores. This store had 1.1% higher waste compared to the store with the lowest amount of waste. This implies that it would be possible to reduce the amount wasted and the climate impact without an economic loss for the store.

4.4. Waste quota

Waste quotas are a complementary tool, which can be used when analysing food waste. However, only applying the top list based solely on the waste quota data does not provide a representative list of FFV categories which can be used to identify the most relevant categories for waste reduction strategies. On the top twenty list with the highest waste quota, sixteen different types of exotic fruits are represented. This clearly illustrates that just looking at the fruit and vegetables based on their respective waste quotas gives a relatively low outcome, both in terms of decreased wasted mass and lower economic cost. As presented in Table 1, **fresh herbs** and **berries** are categories with low wasted mass and a high waste quota. Looking further into the top lists of economic cost and climate impact, fresh herbs and berries end up higher on the list for wasted mass. In conclusion, data on waste quotas highlight some FFV categories which could otherwise be neglected.

4.5. Economic incentives for waste reduction

Reducing economic loss is an important motivating factor for change and reducing food waste in the retail sector. Analyses of the economic cost of the in-store waste revealed that 86% of the cost (see Fig. 4) derived from the cost of FFV is based on the purchase price. The personnel cost for the working time on waste management, and the waste disposal cost corresponds to 14% of the economic cost. The results show that it is essential to be aware of and include all parts when discussing the economic costs. Knowledge and awareness about the economic costs of FFV waste can create an incentive for the stores to reduce waste and the economic incentive for the stores may be stronger than by only focusing on incorporating a law concerning reduced retail waste. Waste prevention measures will give additional advantages for the stores, such as goodwill, since awareness about food waste is becoming more well-known and trendy. The economic cost of FFV waste is based on the purchase price, but the actual cost is even higher when the lost profit of the removed produce that will not be sold is taken into consideration. Reducing economic losses will decrease the wasted mass and climate impact at retailer level and contribute to a sustainable food supply chain. The methodology to measure and calculate the economic cost of FFV waste developed in this study could be applicable for other departments in a retail store.

4.6. Reliability and validity

In order ensure that the three stores and the results were comparable a thorough investigation on the stores' waste management and other internal working routines was executed. The outcomes from each store were compared and verified with each other so that the data could be validated. The main working procedures of the stores are the same. All three stores use the same main suppliers, so it was assumed that the quality of the FFV was comparable and the differences of the in-store waste depended on other factors. The stores do not have exactly the same range of FFV categories, as the stores select some different varieties, especially concerning exotic fruits. The number of different categories were 64, 74 and 76 respectively. However, from a methodological point of view, it is not anticipated that these differences between the stores affected the results. The selection of the stores was not representative, but was rather where the authors successfully established contact with the storeowners. However, a previous study (Lebersorger and Schneider, 2014) has shown that retail waste rates of FFV do not differ by geographic region or between urban and rural areas. The results from the calculations and interviews were reviewed and the accuracy of the data was verified by the employees at the FFV department and also by the storeowners and managers in order to avoid misunderstandings and misinterpretations regarding the material. The results in this study are expected to be of relevance for other Swedish retail stores.

4.7. Further work

The total economic cost of waste in relation to specific FFV categories has not previously been explored, therefore, it would be valuable to investigate more stores and different types of stores with the same methodology to examine if the results are consistent. The methodology could also be applied in stores in other countries with similar conditions. Furthermore, the existing investigation could provide a basis for identifying waste prevention measures. Based on the findings from this study, further research which identifies the causes of waste for the separate FFV categories, and especially for the "hotspot categories", should be conducted. Suggestions regarding improvement procedures and establishing a system to monitor and evaluate the results would be needed in order to examine how reducing FFV waste at retail level can be done efficiently. Very little is known about the impact and effectiveness of different measures to reduce food waste and additional research is needed for an effective adoption of good practices.

5. Conclusion

Primary data on fresh fruit and vegetables waste collected through direct measurements in three large retail stores in Sweden has been analysed in this study. A method of measuring and calculating the economic cost of FFV waste was developed. The economic cost included the cost of the wasted produce, the cost of personnel time for waste management and the cost of waste collection and disposal. When analysing all three top lists of waste, it was noticeable that only a few of the FFV categories contributed to the majority of the waste, both in terms of wasted mass, economic cost and climate impact. Those FFV categories, also called "hotspot categories", were apple, banana, grape, lettuce, pear, sweet pepper and tomato. All "hotspot categories" were on the economic top list, so when planning for waste reduction strategies at retail level, the stores should use their own data on economic losses as a base and be assured that they are targeting the accurate FFV categories. If the perspective of minimising the economic cost is used when planning strategies for reduction measures, a significant contribution of reducing the retails' impact on wasted mass and climate change will also be made, and the retailer will contribute to a sustainable food supply chain. The cost benefit analysis showed that it is economically wise to invest in more working time for employees in waste management to accomplish a reduction of the wasted mass and the climate impact without an economic loss for the store. These results are relevant for supporting implementations of policies and initiatives aimed at food waste reduction at retail level.

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Appendix A

Table A1.

Table A1
GWP (kg CO2-eq/kg produce) of the top forty of the in-store wasted fruit and vegetables in mass (Clune et al., 2017).

Category	GWP value	Explanation
Apple	0.29	
Asparagus	0.83	
Aubergine	1.35	
Avocado	1.30	
Banana	0.75	
Beetroot	0.24	
Berries	0.78	Mean value of strawberries, raspberries, blueberries
Broccoli	0.60	
Cabbage	0.23	
Carrot	0.20	
Cauliflower	0.36	
Clementine	0.45	
Cucumber	0.23	
Fig	0.43	
Fresh herbs	1.10	Assumption – greenhouse vegetable with no auxiliary heating
Grape	0.37	
Grapefruit	0.33	Assumption – data of orange
Kiwi	0.36	
Lemon	0.26	
Lettuce	0.37	Varieties of lettuce, field grown
Lime	0.26	
Mango	0.45	Data of stone fruit
Melon	0.51	
Mushroom	0.27	
Nectarine	0.43	
Onion	0.17	
Orange	0.33	
Peach	0.43	
Pear	0.31	
Pineapple	0.50	
Plums	0.45	Data of stone fruit
Potato	0.18	
Radish	0.23	
Root	0.24	
Sharon	0.45	Data of stone fruit
Soup-vegetables	0.22	Mean value of carrot 0.20, rutabaga 0.29, onion 0.17
Sprout	0.26	Assumption – plake beans
Sweet pepper	1.10	Passive and heated greenhouse
Tomato	0.51	Passive greenhouse
Zucchini	0.21	

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