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Food Waste Amount, Type and Origin in Finland –

Focus on Households and Food Services

Doctoral Dissertation

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Academic dissertation

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Abstract

The significance of food waste (FW) arises from its large environmental, economic and social impacts. Furthermore, it affects food security and is a matter of resource efficiency for sustainable food production. In a situation where the world population is growing and climate change is affecting food production, FW should be minimized, to ensure the future food supply and natural habitats. The aim of this thesis was to study FW in the Finnish food supply chain, in households, food services, the food industry and the retail sector. Even though FW is generated throughout the supply chain, the impacts are most significant at the end of the chain. That is why reducing FW in households and food services is especially important. In this thesis, FW amounts and types were studied in the food chain in addition to methods for measuring FW and means for reducing FW in households and food services.

The definition of FW in this thesis included all originally edible food material but not originally inedible material, e.g. coffee grounds. Diary studies were used for studying the FW in households and food services and in the retail and food industry sector surveys and interviews were used. Together 380 of households from different areas in Finland finished the two weeks study period. The amount, type and origin of avoidable food waste were investigated in 51 food service outlets, including schools, day-care centres, workplace canteens, cafes and petrol stations, restaurants and diners.

The average annual FW was about 23 kg per person and 4–5% of the purchased food amount. The main discarded foodstuffs were vegetables (19%), home cooked food (18%) and milk products (15%). The main reasons for disposing of foodstuffs were spoilage, expiry of the best-before or use-by date and plate leftovers. Almost half of the food waste (40%) was still unspoiled at the time of discarding it.

In food services the amount of FW varied depending on the outlet type and was about one-fifth of all food handled and prepared in the outlets. During the study period the most FW were generated in day-care centres (28%) and workplace and student canteens (25%). The findings also suggest that the significant origin of FW was serving waste because of food overproduction for buffet lines.

In the retail sector about 65–75 million kilograms of FW is produced annually, which is about 1–2 % of the total sales in the sector. In the food industry 75–140 million kilograms of edible food was wasted, this corresponds to roughly 3% of the total production volume of the industry sectors included in the study. According to the results, the total amount of FW in Finland was about 385–485 million of kilograms in a year corresponding to about 15% of the food consumed in Finland.

Suitable and appropriate measurement methods for monitoring FW are necessary for reducing FW amounts and following trends in FW. The most suitable method varies depending the sector and the data requirements. Besides FW data, also data about the food purchased or produced is needed for analyses and discussion. The best options to

make estimations about the amount of FW in households would be a combination of composition analysis and diary studies as they would provide appropriate data, e.g. the amount of total FW, edible and inedible FW, types of FW, reasons for FW and background data. In food services a suitable method must be simple and easy enough for the personnel to carry out daily, the method needs to provide data about the food produced, the number of customers and the origin of FW.

Key words: food waste, households, food services, food supply chain, diary study, Finland

Tiivistelmä

Ruokahävikki tarkoittaa ravinnoksi kelpaavan ruoan joutumista pois ruokaketjusta, jolloin siihen käytetyt raaka-aineet sekä voimavarat on käytetty turhaan. Ruokahävikin määrän, tyypin ja alkuperän arvioinnin tärkeys johtuu ruoantuotannon suuresta vaikutuksesta ympäristöön, talouteen ja sosiaaliseen kestävyyteen. Väitöskirjassa tutkin ruokahävikkiä suomalaisessa ruokaketjussa sekä pohdin keinoja sen vähentämiseen jätehierarkian mukaisesti erityisesti kotitalouksissa ja ravitsemispalveluissa, sekä millaisilla menetelmillä hävikkiä voidaan parhaiten tutkia. Hävikkiä syntyy kaikissa ruokaketjun vaiheissa, mutta ketjun loppupäässä ruoantuotannon vaikutukset ovat suurimmillaan, joten on erityisen tärkeä vähentää ruokahävikkiä näiltä sektoreilta.

Ruokahävikki on määritelty tässä työssä siten että se sisältää alun perin ihmisravinnoksi syömäkelpoista ruokaa ja juomaa, ei esim. kahvinporoja tai kasvisten kuoria. Tutkimus tehtiin kotitalouksissa ja ravitsemispalveluissa päiväkirjatutkimuksella, teollisuudessa ja kaupan alalla käytettiin kyselylomakkeita ja haastatteluita. Kahden viikon tutkimusjaksoon osallistui 380 kotitaloutta ja osallistujat punnitsivat päivittäin kotona syntyneen ruokahävikin. Ravitsemispalveluissa hävikkiä tutkittiin sekä linjasto- että annosravintoloissa 51 toimipisteessä sekä kuntien ruokapalveluissa ja yksityisissä yrityksissä. Hävikkiä seurattiin ruoan valmistuksessa, tarjoilussa ja asiakkaiden lautatähteiden osalta.

Ruokahävikkiä syntyi kotitalouksissa noin 23 kiloa henkeä kohti vuosittain eli noin 4–5 % kotiin ostetusta ruoasta. Eniten hävikkiä syntyi tuoretuotteista kuten vihanneksista ja juureksista (19 %), valmistetusta kotiruoasta (18 %) ja maitotuotteista (15 %). Suurimmat syyt hävikkiin olivat ruoan pilaantuminen, päiväysmerkintöjen umpeutuminen ja lautastähteet. Melkein puolet (40 %) poisheitetystä ruoasta oli edelleen syömäkelpoista poisheittohetkellä.

Ravitsemispalveluissa hävikkiä syntyi keskimäärin noin viidennes valmistetusta ruoasta. Eniten hävikkiä syntyi lastentarhoissa (28 %) ja työpaikka- sekä opiskelijaravintoloissa (25 %). Hävikin syyt ravitsemispalveluissa johtuivat usein ruoan ylivalmistuksesta linjastoravintoloissa mutta myös asiakkaiden lautastähteistä annosravintoloissa.

Kaupoissa hävikkiä syntyi 65–75 miljoona kiloa vuodessa, noin 1–2 % myydyistä ruokatuotteista. Eniten hävikiksi joutui tuoretuotteita kuten vihanneksia, hedelmiä ja leipää. Elintarviketeollisuudessa ruokahävikkiä syntyi 75–140 miljoonaa kiloa, noin kolme prosenttia teollisuudessa valmistetusta ruoasta. Tulosten perusteella Suomessa syntyy vuosittain ruokahävikkiä yhteensä noin 385–485 miljoona kiloa ja määrää vastaa noin 15% kulutetusta ruoasta.

Hävikin määrän seuranta ja vähentäminen vaativat säännöllistä mittausta ja siihen soveltuvia menetelmiä. Sopivat menetelmät riippuvat ruokaketjun osasta ja tarvittavien hävikkitietojen laadusta. Hävikin määrän lisäksi on tärkeää saada tietoja ostetusta tai

valmistetusta ruokamäärästä, joihin hävikin määriä voidaan verrata. Kotitalouksissa paras menetelmä on yhdistelmä, jossa hävikkiä mitataan sekä lajittelututkimuksella ja päiväkirjatutkimuksella, jolloin saadaan tarvittavat tiedot sekä hävikin määrästä, laadusta, syistä sekä lisäksi taustatietoja esim. perhetyyppi jne. Ravitsemispalveluissa hävikinmittausmenetelmän pitää olla tarpeeksi yksinkertainen ja helppokäyttöinen että henkilökunta pystyy vaivattomasti kirjaamaan tarvittavat tiedot päivittäin. Tarvittavia tietoja ovat valmistettu ruokamäärä, hävikin määrä ja asiakkaiden määrä.

Asiasanat: ruokahävikki, kotitaloudet, ravitsemispalvelut, ruokaketju, päiväkirjatutkimus

List of original publications

I Koivupuro, H.-K., Hartikainen, H., Silvennoinen, K., Katajajuuri, J.-M., Heikintalo, N., Reinikainen, A. and Jalkanen, L. 2012. Influence of socio-demographical, behavioural and attitudinal factors on the amount of avoidable food waste generated in Finnish households. International Journal of Consumer Studies, Vol. 36 Iss 2: 183–191.

II Silvennoinen, K., Katajajuuri, J.-M., Hartikainen, H., Heikkilä, L. and Reinikainen, A. 2014. Food waste volume and composition in Finnish households. British Food Journal, Vol. 116 Iss: 6, 1058–1068.

III Silvennoinen, K., Heikkilä, L., Katajajuuri, J-M., Reinikainen, A. 2015. Food waste volume and origin: case studies in the Finnish food service sector. Waste Management, Vol. 46: 140–145.

IV Katajajuuri, J.-M., Silvennoinen, K., Hartikainen, H., Heikkilä, L. and Reinikainen, A. 2014. Food waste in the Finnish food chain. In: Towards eco-efficient agriculture and food systems: selected papers from the Life Cycle Assessment (LCA) Food Conference, 2012, in Saint Malo, France. Journal of Cleaner Production 73: 322–329.

Contributions

Contribution to the papers in this thesis

	I	II	III	IV
Planning and developing the study design and methodology	H-KK, HH, KS, J-MK, NH, AR, LJ	KS, J-MK, HH, LH, AR	KS, LH, J-MK, AR	J-MK, KS, HH, LH, AR
Performing the study and sampling	H-KK, HH, KS, J-MK, NH, AR, LJ	KS, J-MK, HH, LH, AR	KS, LH, J-MK, AR	J-MK, KS, HH, LH, AR
Data analysis	HH	KS, J-MK, HH	KS, LH, J-MK, AR	J-MK, KS, HH, LH, AR
Writing the paper	H-KK, HH	KS, J-MK	KS	J-MK, KS, HH, LH, AR

Koivupuro, H.-K. (H-KK), Hartikainen, H. (HH), Silvennoinen, K. (KS), Katajajuuri, J.-M. (J-MK), Heikintalo, N. (NH), Reinikainen, A. (AR) and Jalkanen, L (LJ), Heikkilä, L. (LH)

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Glossary

Food	All products and raw materials suitable for human nutrition.
Food waste (FW)	Food waste is any food, and inedible parts of food, removed from the food supply chain, to be recovered or disposed of (Östergren et al. 2014).
Originally edible/inedible FW	FW can include parts that are originally edible for humans or parts that are inedible for humans, e.g. coffee grounds or peelings.
Separately collected bio waste (bio waste)	Bio-degradable waste collected from households (kitchen and garden waste), food services, food industry and retailers (Finnish Association for Biological Waste Treatment 2018).
Waste hierarchy	An approach to waste management which sets the following priority order when shaping waste policy and managing waste at the operational level: prevention, (preparing for) reuse, recycling, recovery, disposal (EU 2010).
Household	A household is formed of all those persons who live together and have meals together or otherwise use their income together (Statistics Finland).
Food service sector	All companies serving food (profit and non-profit).
Food service subsector	Segments according to the HORECA register, e.g. schools, workplace canteens, hospitals (HORECA 2015).
Waste management	Organised activity for the purpose of collection, transport, recovery and final treatment or disposal of waste. Activities aimed at the prevention of waste generation are also regarded as waste management. (Statistics Finland 2018)
Luke	Natural Resources Institute Finland (formerly MTT).
FOODSPILL	A project that studied FW in Finland during 2010–2012.

FUSIONS	FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) was a project about reducing food waste in Europe (2012 – 2016). It was funded by the European Commission Framework Programme 7.
WASTESTIMATOR	A project that studied FW in households and food services in Finland during 2016–2017.
HSY	The Helsinki Region Environmental Services Authority

Contents

1. Introduction

1.1. The significance of food waste globally and locally

The significance of food waste (FW) arises from its large environmental, economic and social impacts. Furthermore, it impacts food security and is a matter of resource efficiency for sustainable food production (Coleman-Jensen et al. 2014, Parfitt et al. 2010, FAO 2011, Buzby et al. 2011). Globally, one-third of the food produced is lost or wasted, which amounts to about 1.3 billion tons per year (FAO 2011). For example, in the United States consumers discard 124 kilograms per capita per year of edible food, which is worth $390 per capita per year (Buzby & Hymen 2012). In Europe, the FUSIONS project collected and analyzed FW data that amounted to about 88 million tons of FW, which is about 20% of the total food produced (Stenmarck et al. 2016).

Research and political agendas focusing on the FW issue and aiming to solve the problem have started, but still studies and estimations of food waste amounts have weaknesses in their data accuracy and the extent: e.g. many articles have used the same few secondary data sources from narrow geographical areas (Xue et al. 2017). Additionally, terms and definitions vary causing possible misunderstandings, e.g. the difference between food loss and food waste, avoidable or unavoidable FW, edible or inedible FW, side stream or by-product etc. In 2012 the European Commission launched the FUSIONS project focused on how social innovation can reduce FW and also harmonize monitoring and the definitions used (EU FUSIONS 2016). The EU has also launched the REFRESH research project taking action against food waste (REFRESH 2018).

Despite the challenges and uncertainties, it is obvious that the future food supply chain needs to minimize food waste and loss for food security and environmental reasons. The FAO has stated that the world needs to increase its food production by 60 percent by 2050 (FAO 2016). In a situation where the population is growing and sustainable new areas for agriculture are scare, food loss and waste must be minimised as much as possible (e.g. Hodges et al. 2010, Thi et al. 2015). Improving the efficiency in food production and consumption, as well as changes in the general diet in Western countries are vital to ensuring the future food supply for up to 9 billion people (e.g. Willet et al. 2019, Foley et al. 2011, Godfrey et al. 2010).

In 2015, world leaders adopted 17 Global Goals (Sustainable Development Goals) to fight inequality and climate change (UN 2015). For the next fifteen years these goals aim to end poverty and build sustainable economic growth, while protecting the environment, climate and the planet. When studying these goals in detail, many of them can be connected to food or food waste. Many are connected to food waste directly, e.g. achieving zero hunger, good health or sustainable cities, but many are also connected indirectly, e.g. ensuring clean water or maintaining biodiversity. Goal number 12 is to *ensure sustainable consumption and production patterns* and its third target (12.3) is stated as: "*By 2030, halve*

per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses." The European Union and member states have committed to these goals and have taken food waste prevention as an important part of the *EU Action for the Circular Economy* (EU 2015) to work towards creating a common methodology to measure FW and to clarify legislation.

Finland is also drafting its new *National Waste Plan* and *Waste Act Reform*. The Ministry of the Environment's *National Waste Plan* (ME 2018) has set detailed targets for halving food waste, e.g. by making a roadmap for measuring and studying FW, directing the food system to reduce FW, and increasing education for children and youth. The Ministry of Agriculture and Forestry has published the *Government report on food policy* (MAF 2017), which sets out the policy objectives and key priorities for activities regarding the future food system. The report states actions needed to reduce food waste by enhancing food appreciation and through education. It also outlines improvements needed in measuring and monitoring FW in the food chain.

FW is generated in all stages in the food supply chain (FSC) (e.g. Canali et al. 2017, Parfitt et al. 2010). The later the phase in the FSC in which food is wasted, the more negative the environmental, economic and social impacts. FW arising in the household and consumption phase has been reported to be the main generator of all food wasted in developed countries (Parfitt et al. 2010, FAO 2011, Stenmarck et al. 2016).

The EU 28 produce about 88 million tons of food waste per year (173 kg/pp/year), and about 53% of the total FW is generated from households (92kg/pp/year) (Stenmarck et al. 2016). In the Nordic countries, households generate about 46 kg/pp/year of originally edible FW in Denmark and Norway (Edjabou et al. 2016, Hanssen et al. 2016) and 28 kg/pp/year in Sweden (SMED 2012).

Even though research data on household FW in the Nordic and other countries is available there is notably weak data on the amounts or quality of FW in the food service sector. Instead of the quite uniform amount of waste from households, food services differ largely in terms of the business idea and size (e.g. the HORECA register 2016). FW research has been carried out in e.g. school canteens or by examining customer plate leftovers, however, estimating the FW in the total food service sector or the overall food service sector is rare. Studies using weighing methods for the estimation of FW amounts can be found concerning the public and educational sector, e.g. studies of schools and student canteens (e.g. Engstrom & Carlsson-Kanyama 2004, WRAP 2011, Eriksson et al. 2017), and hospitals (Sonnino & McWilliam 2011, Williams & Walton, 2011, Diaz-Ferreira et al. 2015). Private sector case studies can be found which study restaurants and hotels (Tatono 2017, Kallbekken & Salen 2013, Youngs et al. 1983), as well as catering companies or canteens (Lorenz et al. 2017, Bentz et al. 2015). In the EU's FUSIONS project, the estimated FW generated by the food service sector was 21 kg/person/year and amounted to 12% of the total FW generation in Europe (Stenmarck et al. 2016). In addition, survey methods have been used for understanding personnel and customer behaviour and attitudes (e.g. Principato et al. 2018, Sakaguchi et al. 2018).

In the food service sector, the origin of FW is typically divided into kitchen waste (preparation process), serving waste (surplus food produced but not eaten) and customer plate leftovers (Table 1). In addition, originally edible and inedible FW can be separated to determine the share of batches such as peelings and coffee grounds. The share of these origins varies depending on the subsector type, e.g. when food is served in buffet lines it can easily be overproduced. A case study of hotels showed that the serving waste from a buffet lunch consisted of 20–40% of the produced food (Pirani & Arafat 2016) and in schools serving waste has been found to be a significant part of produced or served food, amounting to about 15% as case studies found in Italy (Falasconi et al. 2015) and in Sweden (Eriksson et al 2017). In hospitals consumers' plate leftovers have been measured to be very high: a case study in Portugal found 953 g of plate waste per patient per day (Diaz-Ferreira et al. 2015) and William & Walton (2011) reported the median plate waste to be about 30% of produced food. The composition of FW depends on the type of subsector, the food assortment and menu options. In the education sector FW has been reported to consist largely of side dishes such as potatoes and rice (Lagorio et al. 2018, Betz 2015, Saputri et al. 2019, WRAP 2013b), main courses (Lagorio et al. 2018) and vegetables, fruit or legumes (Boshini et al. 2018, Derqui et al. 2018). In the restaurant and cafe subsector the main type of FW has been reported to be fruit and vegetables or side dishes (Filimenou et al. 2019, Betz et al. 2015, Wang et al. 2017).

In Finland, FW research started at the Natural Resources Institute (LUKE, formerly MTT) with the first studies reviewing the literature (Koivupuro et al. 2010) and studying how packages cause food waste (Silvenius et al. 2011). The work continued in mapping FW in the Finnish food chain in households (I, II), food services (III), retail and industry (IV). This work is still continuing, and more detailed data is being produced by Luke researchers such as Hartikainen et al. (2014, 2018), Heikkilä et al. (2016) and Harrison et al. (2020). In addition, some recent research projects have been reported on households and food services such as Lahti & Silvennoinen (2020), Silvennoinen et al. (2019c), Silvennoinen et al. (2020), Nisonen & Silvennoinen (2020).

Whereas consumption is a major FW generator in Europe and Finland, in less developed countries FW mostly occurs in primary production (Aggidis et al. 2013, Godfrey et al. 2010, Hodges et al. 2010). Even though the FW per capita is estimated to be lower in developing countries, the total amount is almost the same level as it is in the developed countries due to the size of population (Thi et al. 2015, FAO 2011). FW management and environmental issues are greater challenges for developing countries (Thi et al. 2015). Urbanization is connected significantly to FW generation in both developed and developing countries, however, in this respect the latter can be more problematic due to the weak infrastructure in waste management (Lipinski 2013). There is a need for sustainable food production and consumption all over the world and the negative impacts of FW are happening in all countries.

1.2. The environmental and socio-economic impacts of food waste

Food waste is unsustainable because of all the negative impacts of producing food as a raw material and because the processing of these materials into food is done in vain. Food and food production have an enormous climate impact accounting for about 20–30% of all consumption (e.g. Seppälä et al. 2009, FCRN 2014). In 2013 the United Nations reported (FAO 2013) that FW generated more greenhouse gas (GHG) emissions than any country creates in a year (including other activities that cause GHG, for example, emissions from housing and travelling), except for China and the United States. The report estimated that the carbon footprint of the food produced but not eaten is equivalent to 3.3 billion tonnes of GHG emissions per year. Considering the climate impacts of food waste, the most important issues are the volumes and the types of food wasted. The impact is dependent on the diets and food cultures of each geographical region e.g. how much animal-based food is produced and consumed.

The amount of GHG emissions varies between regions, and according to a United Nations study (FAO 2013), the emissions are highest in Asia, Europe and North America. Asia has high amounts of GHG emissions due to losses during rice production. Very low emissions have been reported from Sub-Saharan Africa where FW consists of roots and tubers that have a low carbon footprint. Europe and North America have high emissions due to food waste which consists of relatively high amounts of cereals and meat, as well as vegetables grown in greenhouses. The European Commission (2010) concluded that the total climate impact of the food waste created by the entire food chain of the EU27 was approximately 170 million tons of GHG emissions per year, which corresponds to about 3% of the total EU27 climate impact. A food waste study in the UK found that the GHG emissions resulting from avoidable food and drink waste arising from UK households accounted for approximately 17 million tonnes of GHG emissions, which corresponds to 1.7% of the UK's domestic GHG emissions (WRAP 2012). The GHG savings that would result from preventing all avoidable food waste in the UK would be equivalent to removing every fourth car from the road in the UK. In Finland, food accounts over one third of the environmental impact from private consumption (Seppälä et al. 2009). The impact of food consumption on the climate is approximately one quarter of the private consumption, whereas, the impact of food consumption on water systems is even more significant due to eutrophication (Seppälä et al. 2009).

The impacts above are partly also social and connected to human welfare, but FW also has other important social dimensions, e.g. there is a link to hunger and malnutrition if food is lost or wasted and it is not used for consumption. Global hunger is on the rise and the proportion of people suffering from chronic hunger amounts to 815 million (FAO 2018), and at the same time, the amount of food wasted would have potential to feed all of them (e.g. Stuart 2019). A high amount of food is lost in low-income countries due to insufficient farming technology, which results in lower incomes and weak access to food for smallholder farmers (FAO 2018, IFPRI 2018). High income countries are also suffering from malnutrition

because the food people consume may be of poor quality or people cannot afford it, e.g. the UN recently estimated that 8.4 million people in the UK lived in food insecure homes and one in five children suffer from food insecurity (Taylor & Loopstra 2016). FW can increase these insecurities and their impact if a share of food in homes is wasted. FW also means lost nutrients and micronutrients such as vitamins and fibre with effects on human health. For example, the amount of vitamin C lost in Europe per day is equivalent to the amount needed for 90 million people for a day (Scherhaufer et al. 2015).

FW affects economics directly through the money, work and other resources lost. Additionally, waste management costs rise in parallel with FW amounts. Project Fusions (Stenmarck et al. 2016) estimated the value being lost amounted to 143 billion euros per year for edible food in the EU-28 food supply chain. The value per ton is highest for household waste because it is mainly originally edible (definitions Table 1, p. 16) and the costs are accumulated further along the food supply chain. Reducing FW means direct monetary savings for food sector actors, which would avoid unnecessary purchases and make intermediate savings (in labour, energy etc.). These savings would be free to use for other goods and services, economic activities, and for creating employment (Campoy-Munoz et al. 2017).

These environmental and socio-economic impacts could be minimized and avoided by preventing and managing FW according to a waste hierarchy. Waste management focuses on the collection, logistics, recycling, disposal and monitoring of waste and aims to avoid the negative effects of waste on people and the environment. A proper and regularly updated waste management plan would provide a framework for waste policy and target achievement (EU 2012).

1.3. Waste hierarchy and food waste hierarchy

In the EU Waste Framework Directive (WFD) (EU 2016) the concepts for waste management and the hierarchy for reuse and recycling are laid out. The directive sets out the basic principles for how EU member states should manage waste to achieve no negative impacts on people or the environment, and the goal is for the EU *to become a society that seeks to avoid waste and uses waste as a resource*. The WFD also specifies that member states need to meet a range of binding targets on the collection, recovery, recycling and landfilling of different waste streams, and need to provide data on waste management.

The waste hierarchy is a tool or procedure referring to five steps from the most preferable aspect, prevention, to least favourable choice, disposal. Member states' waste legislation and policies should follow this hierarchy (EU 2016) (Figure 1). However, the waste hierarchy has limitations, and it has been criticized that it does not necessarily guarantee the best environmental outcomes (Van Ewijk & Stegemann 2016, Eriksson et al. 2015), that it lacks clarity in some respects and that there is some overlap between measures (Gharfalkar et al. 2015). Furthermore, it has further been pointed out that the best options may be different when considering food, garden or wood waste (Defra 2011). Compared to other

materials, food has regulations that can affect how the hierarchy can be followed. For example, there are regulations concerning animal by-products (EU 2008). Food has special characteristics because of food safety: commonly spoiling quickly, and also becoming potentially dangerous once spoiling has occurred. Other aspects include food security ensuring adequate amounts of food daily (which can be enhanced, e.g., via redistribution), and the environmental effects that food has.

Papargyropoulou et al. (2014) have presented the *food waste hierarchy* and WRAP (2013a) *food and drink material hierarchy* which are modifications of the waste hierarchy. These modifications consider features of the food and food chain, and goals towards achieving a sustainable food system and food security. They also take account of environmental, social and economic issues related to FW and favour food use for human consumption over animal feed or its use for energy recovery (Papargyropoulou et al. 2014, Defra 2011, WRAP 2012). In the waste hierarchy (EU 2016), a product becomes waste when it is not in original use anymore. There are differences between hierarchies according to when materials become waste, in the waste hierarchy waste means any substance or object which the holder discards or intends or is required to discard (EU 2016) and in the food waste hierarchy a food product is not considered waste if it is still fit for human consumption (Papargyropoulou et al. 2014) (Figure 1).

Definitions for the waste hierarchy according WFD (EC 2008, EU 2016)		Examples of the food waste and food waste hierarchy
'Prevention' means measures taken before a substance, material or product has become waste.	Prevention **Product**	Preventing the generation of any surplus and over-production of food in the food chain. (Papargyropoulou et al. 2014, Defra 2011). E.g. buying and cooking smaller amounts of food at home or in restaurants.
'Preparing for re-use' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.	**Waste** Preparing for re-use **Food product**	Using surplus or overproduced food for human consumption, even at reduced prices or free of charge (redistribution). (Papargyropoulou et al. 2014)
'Recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. This includes the reprocessing of organic material but does not include energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations	**Food waste** Recycling	Recycling into animal feed (Papargyropoulou et al. 2014). Recycling via composting (Papargyropoulou et al. 2014, Defra 2011).
'Recovery' means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in a plant or in the wider economy.	Recovery	Recovery of energy: anaerobic digestion, gas, heat, biodiesel (Papargyropoulou et al. 2014, Defra 2011).
'Disposal' means any operation which is not recovery, even when the operation has as a secondary consequence the reclamation of substances or energy	Disposal	Food or drink going into sewers or landfills (Defra 2011).

Figure 1. A comparison of the waste hierarchy and food waste hierarchy with priority examples. There are differences between these two hierarchies when materials become waste. In the waste hierarchy, a product is considered waste when the holder discards it and in the food waste hierarchy a food product is not considered to be waste if it is still fit for human consumption.

1.4. Definition of food waste

The definition of FW is critical for estimating the amount and type of FW. There is no common established terminology, although some suggestions have been made (e.g. EU-FUSIONS 2014). The term *food* is usually defined as edible material for human consumption and therefore usually feed material for domestic animals or pet food is not considered to be food. The FAO uses two terms defining *food loss* as food which is spoiled or spilled in the post-harvest and production stage before it reaches its final product stage, and *food waste* which is generated in later stages during retail and consumption (FAO 2019).

Critical to the definition is whether the waste was originally edible or not, or whether it also includes peelings, bones, and other parts that cannot be eaten or are not usually eaten by people. The European FUSIONS project (2014) has defined food waste as: "*Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal in sewer, landfill or discarded to sea).*" (Östergren et al.2014). This definition does not include pre-harvest production or harvested products to be used as animal feed. The FUSIONS definition provides a methodological framework and helps to produce a uniform dataset on FW. It also suggests one term *Food waste* that can be defined in more detail if needed, e.g. with other terms such as edibles.

1.5. Food waste management and monitoring

In Europe different kinds of management systems and treatment methods for bio waste exist. They also differ depending on the country and even on the city. Some countries, e.g. Austria, Switzerland, have had a separately collected bio waste system for a long time, while other countries collect bio waste partly or in a limited fashion (ECN 2018). Because of the different statistical methods used in different states and regions, comparisons are difficult. Even if bio waste is separately collected, there are a large numbers of bio waste streams that remain in residual waste streams and some areas may be without separate collection. In addition, in some regions, bio waste collection may cover only garden or park waste, leaving food waste from households or food services out (European Commission 2015). In Europe about half of the municipal waste is recycled, 25% is used for energy and 25% is sent to landfills (Eurostat 2018, Kivo 2018). A new EU directive and the Circular Economy Package are changing waste legislation regarding bio waste, e.g. it must be separately collected (or composted at home) by 2024 (EU 2017).

In Finland, according to the Waste Act (2011), the responsibility for municipal waste management from households and communal activities belongs to the local municipal authorities. Other parts of the responsibility for waste belongs to the waste generators and producers. *The Finnish Solid Waste Association* represents Finnish regional and municipal waste management companies. In recent years developments in waste management have

been progressive and almost all municipal waste is treated in power plants or recycled (OFS 2016). Household residual waste is collected differently in different regions, and local waste management companies organize the collection and transportation. Depending on the region, bio waste is collected from apartment buildings (e.g. building with over 9 apartments) and sometimes from terraced or detached houses (e.g. HSY 2016, Pjhy 2017). Bio waste includes food-based waste, but also things such as soft tissue paper and garden waste, e.g. leaves. Food waste can be found in mixed waste and separately collected bio waste. Moreover, households can dispose of their liquid food waste into the sewer system and can compost organic waste, at least partly. This diversity makes FW research and study challenging because waste management differs from one area to another and there are different methods for waste management depending on the type of housing.

In Finland, waste management authorities monitor waste amounts and conduct compositional studies of waste streams, e.g. by obtaining information about the share of organic material in incinerator power plants (e.g. HSY 2016). Food waste is a part of the mixed and separately collected bio waste and there is no statistical history based on yearly series (OSF 2016). Thus, composition studies are important to help achieve FW data.

The European Union has introduced a new delegated act on food waste measurement for member states in 2019 (EU 2019). Furthermore, this sort of monitoring will be part of a national system (*Monitoring FW in the Finnish Food Chain*) started in 2018 in Finland (Luke 2018). Member states will report on national food waste levels by mid-2022 and the methods to be used in these measurements and estimations for Finnish FW amounts will be defined during 2020 (Luke 2020).

2. Aims of the study

The aim of this thesis was to study the FW amount and type in the Finnish food chain in households, food services, retail sector and food industry. A special focus in the thesis was on households and food services as they were known to be the large and significant generators of FW. In these sectors, in addition to the amount and type of FW, also the reasons for and origins of FW were studied.

The *amount* of FW means the weight of FW in the sector and the *type* of FW means the food category e.g. vegetables, fruit or bread (in the food industry the type refers to the type of the industry e.g. a bakery or dairy). In households the *reason* explains why the food was through away, e.g. due to spoiling or an expired date. The *origin* of FW was studied concerning the food service sector describing the phase of food which was discarded e.g. whether it was serving or plate waste.

Study questions:

1. What are the amounts, types and reasons for FW in households in Finland?
2. What are the amounts, the origin and share of FW from food produced in food services in Finland?
3. What is the amount and type of FW in other sectors (food industry and retail) and what is the total amount of FW in the Finnish food chain?
4. What methods, requirements and quality for data collection would be the most suitable for measuring FW in households and food services for research purposes?
5. How can FW be prevented in households and food services?

This thesis is based on research published in the four main papers (Papers I to IV). Papers I and II cover household FW and paper III handles food services. Paper IV combines the results to estimate FW amounts in the Finnish food chain.

The amount and type of FW in households were identified in Papers I and II. Additionally, in Papers I and II the reasons behind FW were discussed. The amount, type and origin of food waste in the food service sector were measured in Paper III. This included the amount of FW generated in the kitchen, in serving and in consumer plate leftovers. Additionally, Paper III examined the composition of plate leftovers in buffet canteens, e.g. in schools and day-care centres. The total amount of food waste in the Finnish FSC was estimated in Paper IV.

In the thesis, some data which was supplementary to the original research papers has been used to fill in the gaps (see: Material and methods, Discussion). These data were MTT/Luke projects about FW in food industry and primary production (Hartikainen et al. 2014, Franke et al. 2016), reasons for households FW and share of inedible FW in households (Silvennoinen et al. 2013) and preventing FW in food services (Silvennonen et al. 2019a).

3. Materials and methods

3.1. Terms and definitions in this thesis

The definitions and terms related to FW vary slightly in Papers I–IV because at the beginning of this thesis there was no common established terminology and the articles were written before the FUSIONS project defined FW (EU-FUSIONS 2014). In this thesis, the term FW means originally edible food material for human consumption and is the most important measure for the data in Papers I–IV. FW has occasionally been defined differently in other countries and originally edible FW is not always separated from e.g. peelings and bones, which makes comparisons difficult. That is why I have carried out additional studies and publications outside of this thesis, e.g. composition studies to determine the overall amount of FW including originally inedible FW in households (e.g. Silvennoinen et al. 2013, Silvennoinen et al. 2019).

An *amount* of FW means the weight of FW in the sectors and a *type* of FW means the food category e.g. vegetables, fruits or bread (for the food industry *type* means the type of the industry, e.g. a bakery or dairy). In households a *reason* explains why food was thrown away, e.g. due to spoiling or an expired date. The *origin* of FW was studied in the food service sector and it describe the phase of production when food was discarded, e.g. as serving or plate waste.

In this study the fresh weight of FW volumes has been used. This is a common methodology in FW studies and can be used to calculate environmental and economic values but also the water content if needed (Östergren at al. 2014). Food can be valued also as energy and kilocalories can be used as a unit of measurement. When considering food security, this would be also very reasonable. However, the loss of energy is difficult to measure or estimate as it differs between and within food categories. In this thesis, the value of kilocalories lost in households has been estimated, but not in the food service sector because the data did not include information on the composition of recipes to a sufficient level of accuracy. The loss of calories was estimated using data from a household diary study (Paper II) and the energy amounts were estimated from *the National Food Composition Database in Finland* (2019), *Fineli* (2019), and the *Balance Sheet for Food Commodities* (2012). The economic value of household FW was estimated by using FW type results (Paper II) and statistical data from the *Statistics Finland's PxWeb databases* (OSF 2012).

3.1.1. Definition of food waste in households

The household study concentrated on originally edible FW, i.e. all the wasted food and raw materials that could have been eaten if they had been stored or prepared differently (Table 1). Originally inedible FW, such as vegetable scrapings, peelings, coffee grounds, bones or paper tissues were not measured in this study (Table 1). Guidelines were provided on

keeping a diary of household FW and the participants were told how to separate peelings, bones, and other parts that were originally inedible (even if someone could eat them in some situations) (Papers I–II). After weighing and reporting, the participants could put a food waste batches into the waste bin, sewer, compost, or give it to their pet. If a batch was given to a pet it was reported, but other discarding methods were not. For liquid foodstuffs only milk was included because measuring all liquids was deemed too difficult, and liquid milk products are a highly integral part of the food culture in Finland.

3.1.2. Definition of food waste in food services

For weighing and sorting, the FW was divided into two categories so that originally edible (OE) FW was separated from the originally inedible (OIE) FW, such as vegetable peelings and coffee grounds (Table 1, Paper III). In addition, the originally edible FW was sorted into three categories in accordance with its origin as: kitchen waste, serving waste and customer plate waste (Table 1, Paper III). These three waste fractions contained all the wasted food and raw materials that could have been consumed had they been stored or prepared differently and refers to both solid and liquid foodstuff. Kitchen waste consisted of spoiled products and incorrectly prepared food. Service waste refers to food that was cooked and prepared but did not for some reason end up with the customer.

Table 1 Definition and origin of FW and descriptions of how the waste was sorted as kitchen waste, serving waste and plate waste. Inedible FW was only measured for food services.

	Sector	***Kitchen waste*** *Preparing, cooking and storage*	***Serving waste*** *Left from cooked and prepared meals*	***Plate waste***
Food waste (FW) *Originally edible (OE)*	Food services	Spoiled products, incorrectly prepared food, products with expired dates	Overproduction, food left over from buffet	Food left by customers on plate
	Households	Spoiled products, products with expired dates, food does not look spoiled but wasted, risk not taken, not wanted to eat anymore	Overproduction, ood prepared too much	Food left by family members on plate
food waste (OIE) Originally inedible	Food services	Inedible parts of vegetables, coffee grounds and bones	Inedible parts of vegetables, bones	Vegetable peelings, bones

3.2. Household data collection: diary study (Paper I & II)

The research data were collected by carrying out a diary-based study concentrating on mapping the amount, type and reason for FW in Finnish households. In addition, the respondents' demographic backgrounds were charted, such as family type. The participants were chosen from an online panel including 16,000 consumers and the invitation to take part was sent to about 3,000 consumers. After receiving details about the study, a total of 420 households participated in the study and of these 380 households (1,054 people) finished the study acceptably. The households were situated in and around four cities: Helsinki (40%), Turku (19%), Tampere (27%), and Jyväskylä (14%). Although the sample size is relatively large, the sample is not representative of all Finnish households. Due to the method of sampling, the sample did not include enough participants from the oldest age groups. There were only two over 65-year-old respondents in the entire sample and only 12 of all the 1,054 persons were over 65 years old. Additionally, the average household size in the sample, 2.79, was markedly higher than that of an average Finnish household (2.08 in 2009, OFS 2010). More details on the characteristics of the participating households and the sample can be found in Publication I, Table 1 and Publication II, Table 1. Prior to the study, the participants filled in an online background questionnaire and were equipped with electronic kitchen scales, as well as a diary (Figures 2 and 3) with detailed instructions on how to weigh and record their waste and the reasons for discarding food.

The households weighed their FW daily every time they disposed of any food for two weeks. The diary had separate entries for each time food was disposed of. The respondents filled in not only the weight and type of the food disposed of, but also the reason for disposing of it, such as whether it was 'spoiled'; 'past the best before date', etc. The diary entries were easy to make, due to headings such as 'bread', 'potatoes and potato products', 'home cooked food', and 'convenience food', so that the respondent needed only needed to tick the corresponding boxes in the form (Figures 2 and 3).

Date

1. **Food or dish that is thrown away. Choose one.** Vegetable or root, potatoes, fruit, berries, bread, rice or pasta, other grain product, milk, cheese, other milk product, pork or beef or meat product, poultry, fish or fish product, home cooked food:_____, Ready to eat food or take away food:_____

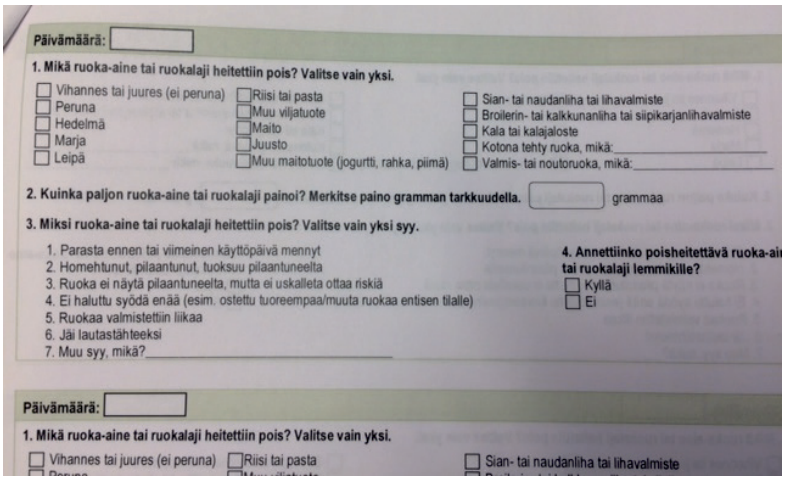
2. Weight of food in grams.

3. Why is the food thrown away?

1. Date expired (best before or used by date)
2. Mouldy, spoiled, smells bad.
3. The food does not look bad, but we did not dare to use it.
4. The food was not wanted for use anymore.
5. The food was cooked too much.
6. Plate waste, leftovers.
7. Other reason, what_____

4. The food or dish thrown away was given to a pet.

□ Yes □ No


Päivämäärä:

1. Mikä ruoka-aine tai ruokalaji heitettiin pois? Valitse vain yksi.

Vihannes tai juures (ei peruna) / Peruna / Hedelmä / Marja / Leipä
Riisi tai pasta / Muu viljatuote / Maito / Juusto / Muu maitotuote (jogurtti, rahka, piimä)
Sian- tai naudanliha tai lihavalmiste / Broilerin- tai kalkkunanliha tai siipikarjanlihavalmiste / Kala tai kalajaloste / Kotona tehty ruoka, mikä:_____ / Valmis- tai noutoruoka, mikä:_____

2. Kuinka paljon ruoka-aine tai ruokalaji painoi? Merkitse paino gramman tarkkuudella. grammaa

3. Miksi ruoka-aine tai ruokalaji heitettiin pois? Valitse vain yksi syy.

1. Parasta ennen tai viimeinen käyttöpäivä mennyt
2. Homehtunut, pilaantunut, tuoksuu pilaantuneelta
3. Ruoka ei näytä pilaantuneelta, mutta ei uskalleta ottaa riskiä
4. Ei haluttu syödä enää (esim. ostettu tuoreempaa/muuta ruokaa entisen tilalle)
5. Ruokaa valmistettiin liikaa
6. Jäi lautastähteeksi
7. Muu syy, mikä?_____

4. Annettiinko poisheitettävä ruoka-ai tai ruokalaji lemmikille?
Kyllä / Ei

Päivämäärä:

1. Mikä ruoka-aine tai ruokalaji heitettiin pois? Valitse vain yksi.

Vihannes tai juures (ei peruna) / Riisi tai pasta / Sian- tai naudanliha tai lihavalmiste

Figure 2. Example of a diary booklet page for one batch of food waste.

Figure 3. Diary booklet and kitchen scales for weighing food waste.

3.3. Food service data collection (Paper III)

The FW amount and type were measured together in 51 outlets in different food service subsectors (Table 2). The sample is not statistically representative, and some subsectors are missing, e.g. fast food restaurants. However, it does give an overview of food services in Finland, e.g. communal food services are a significant part of the Finnish food service sector and food culture as they provide up to half of the meals consumed outside the home. For

these reasons, the study concentrated on such types of outlets to obtain an accurate view of the largest food service types.

Study cases included both profit and non-profit companies and they varied with buffet line set ups or ala carte type menus. The companies were asked to carry out FW measurements as many of them were partners in the FOODSPILL project that studies FW in the sector. To get an estimation of the total FW amount (kg) in the sector and different subsectors the HORECA register (2008) including the number of portions served in subsectors was used for the calculations.

Most of the case study outlets were communal services such as schools and day-care centres, or workplace and student canteens serving buffet line lunches (35 together). Other types of food service included restaurants and catering businesses, such as diners, restaurants, cafes, petrol stations and similar outlets serving food (Table 2). The communal food services, workplace and student canteens served lunches and the amounts of food prepared and wasted were measured from lunchtimes only. Restaurants, diners, cafes and petrol stations included all types of meals prepared throughout the entire day, ranging from breakfast to lunch, sandwiches, snacks and dinners.

The food waste was measured by establishing the amount of food served and weighing the FW generated during cooking and serving and from customer plate waste. The personnel filled in diary forms on a daily basis, indicating the amount of food prepared and served (kg). The diary forms included information on various components of the meals, e.g. main courses, salads, bread, drinks and special diets. In the communal food services, the study was generally carried out at lunchtime, with the exception of elderly service centres where dinner was also monitored. In cafes, restaurants and diners the monitoring usually covered the whole day. Furthermore, the researchers studied the contents of plate waste for 26 days in various outlets.

Data concerning the causes of FW and solutions for reducing FW in food services was gathered in interviews and discussions with the personnel and management during the measurement periods. Three participatory workshops were organized with participants representing both kitchen staff and company management. Results from these workshops are reported in an article by Heikkilä et al. (2016).

Table 2 Food services by type participating in the study and the number of research days

Food service subsector	*No. of outlets*	*Study period days/outlet*	*Outlet total no. of research days*	*Days for leftover analysis*	*Type of meals included*
Schools (communal)	23	5	115	8	Lunch/buffet
Day-care centres (communal)	12	5	60	2	Lunch/buffet
Workplace and student canteens	5	5	25	5	Lunch/buffet
Restaurants and diners	7	1	7	7	All/ala carte and buffet
Cafes and petrol stations	4	1	4	4	All/ ala carte and buffet
Total	51		211	26	

3.4. Data collection in other sectors (Paper IV)

The retail sector study was carried out by interviewing various parties in retail chains as part of the FOODSPILL and *Nordic Food Waste project* to prevent FW in the retail and wholesale trade (Silvennoinen et al. 2012, Glossary p. 6, Stenmarck et al. 2011) (Paper IV). Finnish retail companies participated in the study and provided data about amounts of FW, their opinions about the reasons for FW, and information about waste management methods. All the main retail chain stores participated in the study and their representatives were interviewed (S Group, market share 2009 43,2 %, K Alliance 34,2 %, Finland´s local Store 10,2 %, Lidl 5,1%). The total amount of FW for the retail sector was calculated by using data from interviews and reports about the distribution of shops and the market shares (Finnish Grocery Trade 2010–2011). These results were checked and approved with the retail representatives.

The generation of FW in the Finnish food industry was studied by collecting information on the amounts of FW and amounts of food produced from companies taking part in the FOODSPILL project and other companies representing other subsectors. The participating companies represented different kinds of food industries in Finland including large and small businesses. The data collected were used to calculate the total amount of FW for the food industry sector in Finland and for different industry subsectors: the meat and convenience food industry, dairy industry, bakery industry, vegetable greenhouse industry, and other industry sectors including further subsectors, e.g. sugar, sweet, oil and fat industries. The

companies filled in structured data tables about their FW amounts, quality and by-products. FOODSPILL project companies also participated in project meetings, discussions and interviews. Possibly not all of the originally edible FW in the sectors was included in the study because the share of originally edible material in some side-streams could not be evaluated based on the data obtained for the study. The types of side-streams which were excluded from the calculations were the side-streams from the sorting and peeling of vegetables and fruit, husk and bran material from cereal milling, and side-streams from slaughtering (blood, intestinal organs, skins etc.).

4. Results

4.1. Food waste in households: amount, type, and reasons (Papers I and II)

During a two-week study period the average household produced 2321 grams of originally edible FW and the average FW per person was 875 grams (Table 3). A total of 5,870 FW batches were produced during the study period and the daily FW production of each studied household was one food product on average. The majority of households (70%) produsedunder one kilogram of FW per person during the study period, 29 respondents reported over two kilograms and three households reported no FW at all. The FW batches were small, with 80% of them below or equal to 200 g, while only 42 batches over 1 kg were reported. No differences were observed when comparing the two study weeks with each other and FW distributed over all days of the week, although most FW was produced on Sundays.

The results were extrapolated and used to describe FW over a year. The average annual originally edible FW ranged from 0 to 160 kg per person, which was about 23 kg of FW per person and about 60 kg per household per year. Finnish households bought on average 500–600 kg of food per person annually (excluding drinks) (Tike 2010, Viinisalo et al. 2008). When comparing the purchased amount of food to FW, the average waste value was about 4–5 %.

The size of the household directly correlated with the waste produced—the more people there were in the household the more waste was produced. Single households in general produced more FW than the others and single women, in particular, produced the most FW (30 kg/year). Two-adult households and single men produced the least FW per person (21 kg/year) (Fig 4).

Table 3 Food waste amount per person, per household and weight of FW batches during the study period.

	N	***Mean***	***Median***	***Std.dev***	***Min***	***Q1***	***Q3***	***Max***
FW per person, (g)	380	875	669	796	0	356	1152	6184
FW per household, (g)	380	2321	1656	2463	0	865	2961	23357
FW batches, weight (g)	5870	150	90	204	0,5	42	185	5000

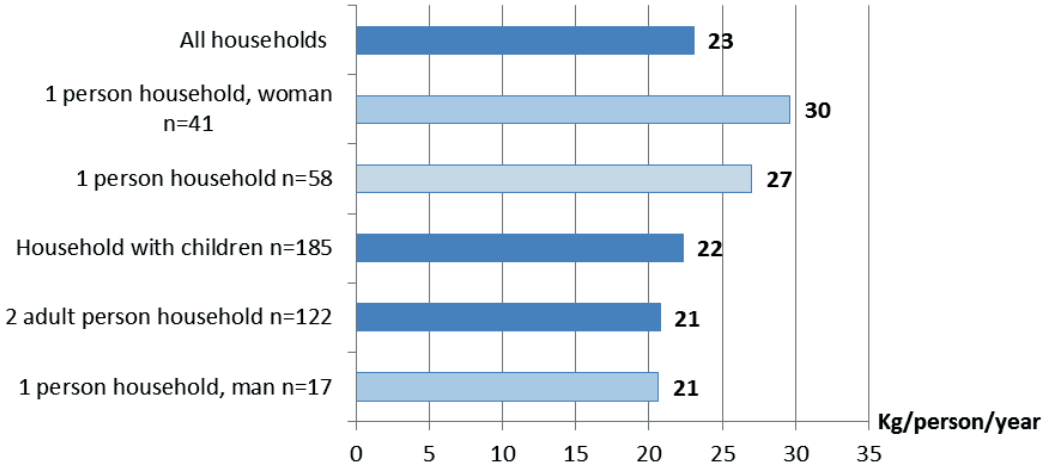


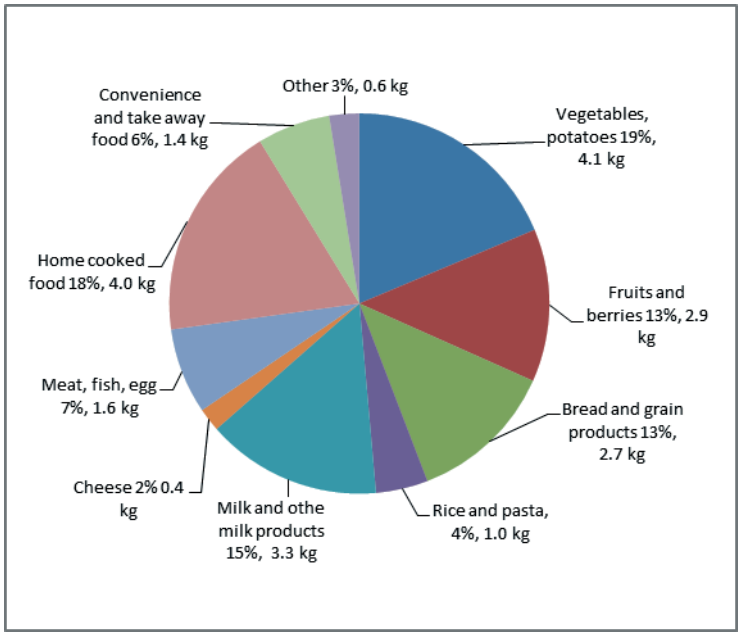
Figure 4. Amounts of FW in different types of households. The single households produced more FW per person than others (light blue).

The most discarded food were fresh and perishable foods (vegetables and potatoes 19%, fruits and berries 13%, bread 13%), home cooked food (18%), milk products (15%), meat, fish and egg (7%), convenience and take away food (6%), rice and pasta (4%) and cheese (2%) (Figure 5a). Home cooked food included various meals prepared at home, such as casseroles, stews, sauces and gravies, porridge, and soups. Convenience foods included ready-made meals, but also hamburgers, pizzas and baby food. The group classified as "other" included the waste of canned goods, and other non-perishable products such as snacks, and accounted for a relatively low (only 3%) amount of the food discarded overall. Together, plant-based FW accounted for 32% of the waste and animal-based FW (meat, fish and eggs, milk products and cheese the value was 24%. The biggest FW batches over one kilogram consisted mostly of vegetables, fruits and dairy products, and the most often discarded FW batch was bread.

The kilocalories lost were about 70 kcal per person per day and 25,500 kcal per person per year. The loss of calories was the largest for bread and grain products (29%), home cooked food (19%) and meat, fish and egg products. These categories contributed a larger share of lost calories as they contributed to the amount of FW in mass, including products with a high energy density. On the other hand, vegetables, fruits and berries accounted for a smaller share as they include products which are low in energy (Figure 5b).

Finnish households consumed about 500–600 kg of food per person per year (Viinisalo et al. 2008, Tike 2010) and thus originally edible FW 23 kg per person was about 4–5% of the food purchased. Households spent on food around 4200 euros per year (OSF 2012) and the value of originally edible FW was thus around 210€ per household and about 100€ per person.

5a



5b

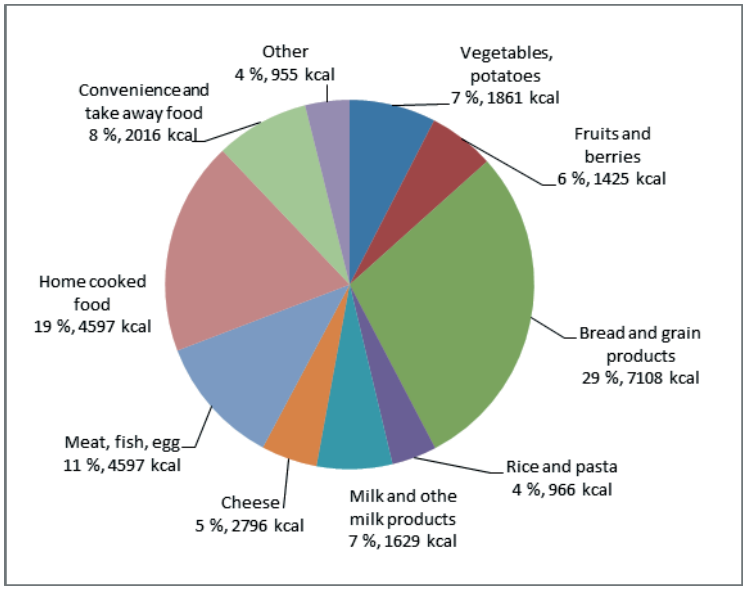


Figure 5 a. Share of FW types in household person/year (average 23 kg/person/year)
5b. Estimation of the loss of calories by type of food per person/year (average 25,000 kcal/year).

The main reasons given for disposing of food were spoilage, e.g. mould (29%), being past the best before or use by date (19%), plate waste (14%), and preparing too much food (13%) (Paper II) (Figure 7). The reasons varied for the food products which were discarded most often. For example, vegetables were discarded because they were spoiled, whereas home

cooked food was discarded as leftovers or due to preparing too much food. For milk products, the reasons were most often due to exceeding the best before or use by dates. Bread, on the other hand, became mouldy or was otherwise undesirable, presumably due to drying out or becoming less tasty. About 40% of the discarded products were not spoilt at the moment they were discarded (shown in green in Figure 6). This food included leftovers, over-prepared food or there was some other reason that the food was not eaten.

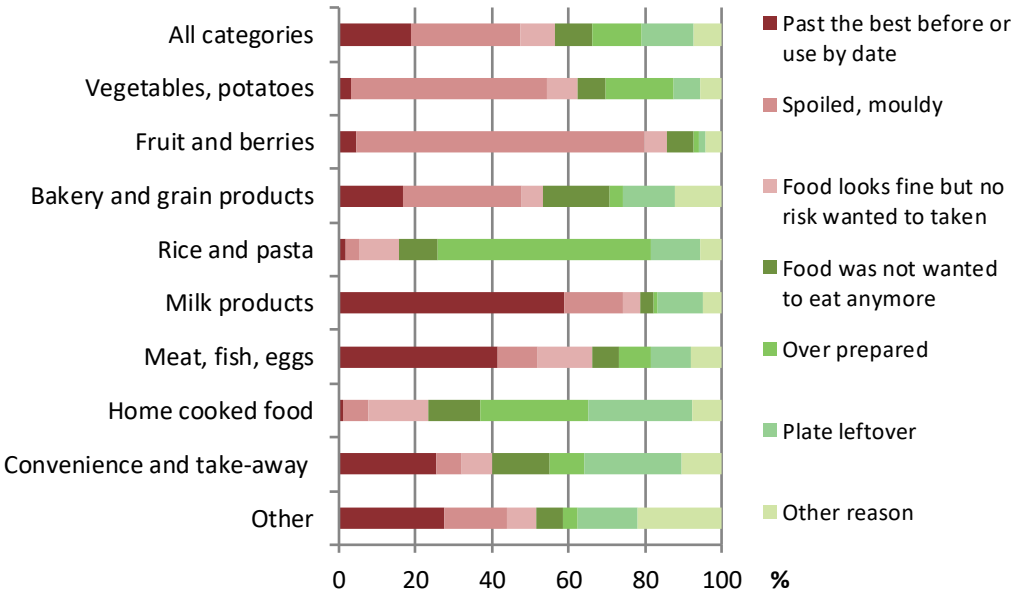


Figure 6. Reasons for food waste in households. Red in a column indicates reasons connected to spoilage and green indicates reasons connected to food thrown away before spoilage.

4.2. Food services (Paper III)

Together 51 outlets in five different food service subsectors participated in the study. The total amount of food prepared was 23,220 kg and together 58,982 food portions were produced during the study period. The amount of food produced per customer varied from schools (343 g) to restaurants and diners (815 g). The amount of originally edible FW during the study was 4396 kg and the amount of FW per customer varied from 58 to 189 g and was the least in schools and highest in workplace canteens (Table 4, Figure 7a).

Table 4 Amounts of food prepared (1.) and originally edible (OE) total food waste from food prepared (2.), total food waste (OE) percentage (3.), food prepared per portion (4.) and food waste volume per portion (5.).

Subsector	*Number of outlets*	*1. Total food prepared kg*	*2. Total FW (OE) kg*	*3. Total FW (OE) %*	*4. Food prepared g/portion*	*5. FW (OE) g/portion*
Schools	23	16117	2727	17	343	58
Day-care centres	12	1569	439	28	384	108
Workplace, student canteens	5	2786	706	25	747	189
Cafes, petrol stations	4	1117	218	20	520	102
Restaurants, diners	7	1631	306	19	815	153

The amount of FW varied from 17% to 28% of the produced food, depending on the type of food service (Figure 7b). The findings show that the main source of originally edible FW was serving waste (buffet serving FW). In day-care centres and workplace canteens the serving waste was as high as 17% of the food produced during the study period. Kitchen waste caused by food preparation and storage was relatively low and varied between 1.5% and 6.4% of the food produced depending on the outlet type. Customer plate waste contributed 4–5%. In restaurants and diners only, the main source of FW was customer plate waste at 9.5% (Figure 7b, definitions in Table 1). FW in restaurants and diners was influenced by the outlet type, and there was a clear difference between à la carte restaurants and diners and buffet type outlets. With self-service buffets, the main cause of food waste was serving waste, i.e. overproduction of food.

Serving waste also constituted the main part of FW when looking at all outlets. Only ala carte restaurants and diners had plate waste amounts higher than the serving waste. However, the amount and type of customer plate waste varied depending on the outlet type. In schools and day-care centres, most of the plate waste consisted of main courses of the day and salads. In ala carte restaurant and diners, the plate waste varied more, and the menus were much more diverse and included more dishes. Most of the plate waste came from side dishes such as potatoes, rice and pasta (29%). Almost as large a share consisted of salads, vegetables and fruit (25%). Main courses such as meat and fish generated less waste, accounting for about 15% overall (Paper III).

This study included only limited numbers of case studies (51) and not all subsectors were covered. For this reason, these results cannot be extrapolated to cover the entire food service sector in Finland. However, a rough estimation according to the FW percentage from different subsectors and data based on a number of portions produced in the HORECA sector (HORECA 2008) can be made. The amount of FW in the Finnish food service sector was about 75 to 85 million kilograms per year and about 14–16 kg per person and this covers about one fifth of all the food handled and prepared in the food service sector (Figure 8).

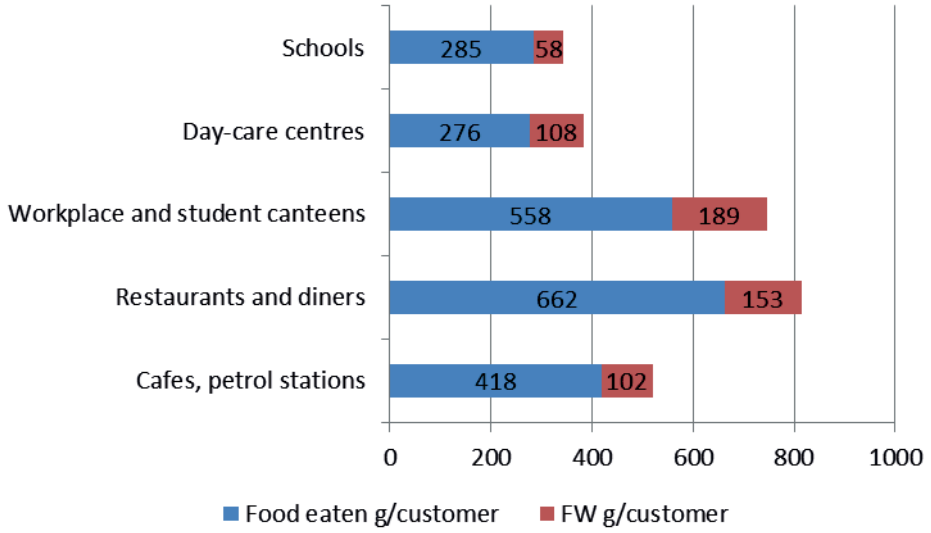


Figure 7a. The amount of food eaten and wasted in food service subsectors. The amount of food produced per customer is a summary of the amounts of food eaten and the FW.

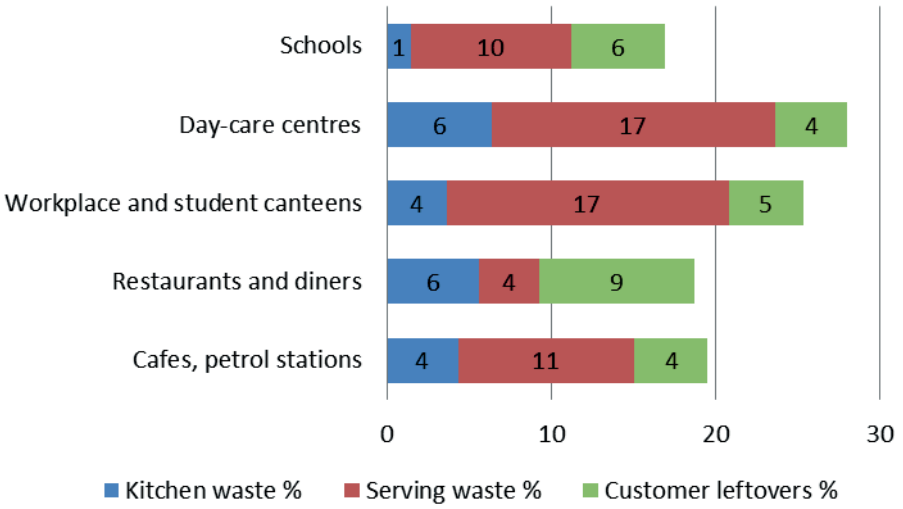


Figure 7b. The origin of FW from the food produced in different food service subsectors.

4.3. Food waste amounts in other sectors and Finnish food supply chain

4.3.1. Retail sector and food industry (Paper IV)

According the data collected from interviews, the estimation of FW from the Finnish retail sector was 1–2% of the total food sales volume and 65–75 million kilograms per year. The main product groups wasted in stores were fresh products, fruits, vegetables, and bread. Other products resulting in FW were dairy products, fresh meat, fish, and convenience food. The least FW was found for canned products, dried or frozen food, and other non-perishable goods. The amount of FW and the number of wasted food products were usually registered very strictly. They were followed at product group level and the reasons for waste was documented in the purchase order system. The data on FW was used for logistics systems planning and other activities in the organization. In the retail sector the food waste mainly generated in the stores and not significantly during transportation or in the warehouses. The respondents stated that consumer behaviour is an important factor: for example, stores are required to supply fresh food e.g. bread throughout the day. The most important reason for throwing away food was the passing of expiration dates on the food batches. The most effective ways of decreasing food waste were prediction, planning, co-operation with suppliers, staff education and internal control. Reduced prices, for food products nearing their expiring dates (discount labelling) and food donations could prevent or decrease food waste generation. The internal control of FW can include improving the accounting system and efficiency of the logistics, better planning, and prediction as well as education of the store staff. The “first in, first out” method and discount pricing principles were implemented in most of the stores. In addition, the ordering systems in the distribution centres and in the stores help with following the pricing and discounting of products.

In the Finnish food industry, the food wasted annually was 75–140 million kilograms and this corresponds to roughly 3% of the total production volume of the industry subsectors which participated in the study (this sum was specified more precisely as 75–105 million kilograms/year in a later study (Hartikainen et al. 2014). The largest FW percentage was in the bakery industry with about 6.5–8% of the total production, meat products and convenience food industry 2–2.5%, dairy industry ~ 3% and other industries 1–4.5%. Not all edible materials and side-streams could be evaluated, the types of side-streams excluded from the calculations include the sorting and peeling of vegetables and fruit, the milling of cereals and the loss of husks and bran material, in addition to side-streams resulting from the slaughter of animals, such as blood, intestinal organs, skin, waste etc. Additionally, FW from primary production was excluded, but a later MTT/Luke study (Hartikainen et al. 2014, Franke et al. 2016) have estimated the FW generated in the primary sector to be about 50–60 million kg/year.

According to the results of this study, the amount of FW in household and the food service sector in Finland is significant and accounted for half of all FW. Together they produced about 220 million kilos of originally edible FW yearly in Finland (Figure 8) and the total amount of FW was about 385–485 million kilograms per year corresponding to about 15% of the food consumed in Finland and about 80 kg per person annually (Figure 9). Compared to other countries, the share of households (32%) was lower than the European estimate (53%) (Stenmarck et al 2016) whereas the shares of food services (18%) and retail (16%) were higher than the European estimates (12% and 5%). However, these differences could have been caused by different FW definitions and variation in study methods, making the comparisong data with other studies difficult.

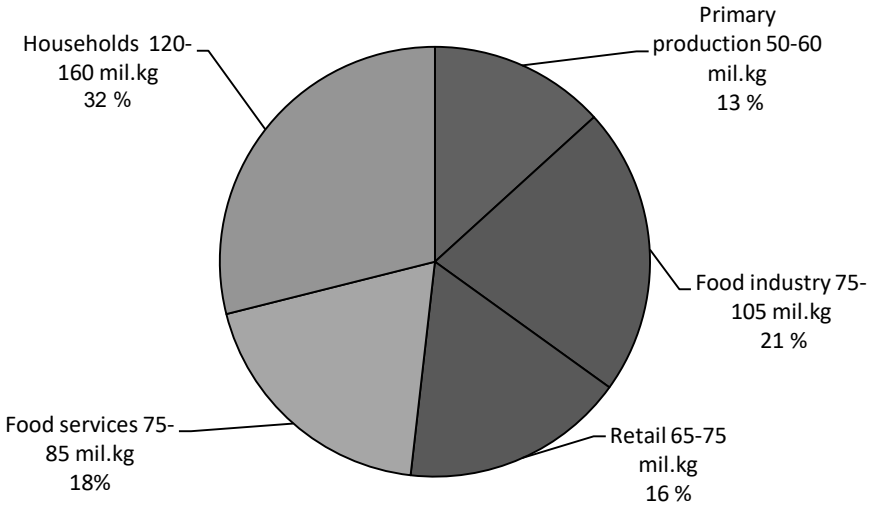


Figure 8. The amounts and percentages of FW in the food supply chain and the share of FW generated in households and food services in Finland. Primary production and food industry according to Hartikainen et al. 2014 and Franke et al. 2016.

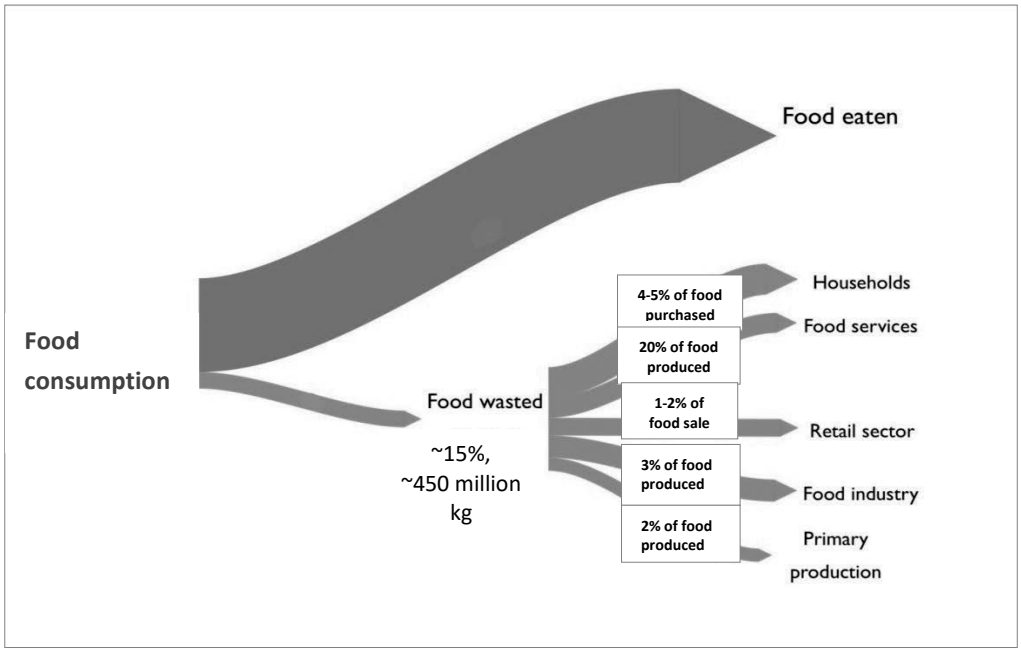


Figure 9. Food wasted together about 450 million kg/year, corresponding about 15% of food consumed in Finland, and the share of FW compared to food purchased, produced or sale (households 4–5%, food services 20%, retail 1–2%, food industry 3% and primary production 2%). Primary production according to Hartikainen et al. 2014 and Franke et al. 2016.

5. Discussion

5.1. Food waste in households

According to the two-week diary study the amount of originally edible FW in households was about 23 kg per person in a year. This means about 65 g per day, and the batches of each discarded pieces of food were small. If extrapolated to the whole of Finland, FW in households amounts to about 124 million kilos a year and about 5% of all food that is bought (Figures 10 and 11).

When comparing the amount of FW to other countries similarities can be found with Sweden (28 kg per person/year), Norway (42 kg per person/year) and Denmark (48 kg per person/year) (Stensgård et al. 2017, Hanssen et al. 2016, Miljøstyrelsen 2014, Edjabou et al. 2016, Naturvårdverket 2013, Figure 11). In the UK the amount of avoidable (originally edible) FW in household was 68 kg per person/year and the total FW including unavoidable and possibly avoidable FW was 112 kg per person/year (Wrap 2015). Comparing data with other, e.g. European, studies is difficult because the definitions and methods differ largely, but estimations can be made after taking the terms avoidable/edible and unavoidable/inedible food waste into account as usually only the total FW is reported. To determine the total FW amount MTT/Luke have carried out several sorting (composition) studies together with waste management companies during 2013–2019 (Silvennoinen & Korhonen 2013, Silvennoinen et al. 2019, Silvennoinen & Nisonen 2020). By examining the results of these sorting studies and the diary study estimation for households in Finland, there was about 50-60 kg of total FW per person in a year (originally edible FW 20-25 kg per person). This could be compared to the average amount of European household food waste of 92 kg per person in a year (Stenmarck et al. 2016).

Compared to other developed countries, European levels seem lower than the USA, whose levels amount to 130 kg per person in a year (Birney et al. 2017). The different results reflect variations between the food consumed and consumer behaviour, but also the different methods for measuring FW and the varying definitions of FW. The EU FUSIONS project defined FW as all food that is wasted including originally inedible parts of food. Differences between countries can vary according to how the terms edible and inedible have been defined and taken into account (Table 2). Furthermore, how the results are reported varies. Usually the amount is measured in kg per person, but sometimes it is measured in kg per household (e.g. Williams et al. 2012). In Finland, sorting studies have shown a large amount of inedible FW of up to 62%, which could be because of the large share of coffee grounds, for example.

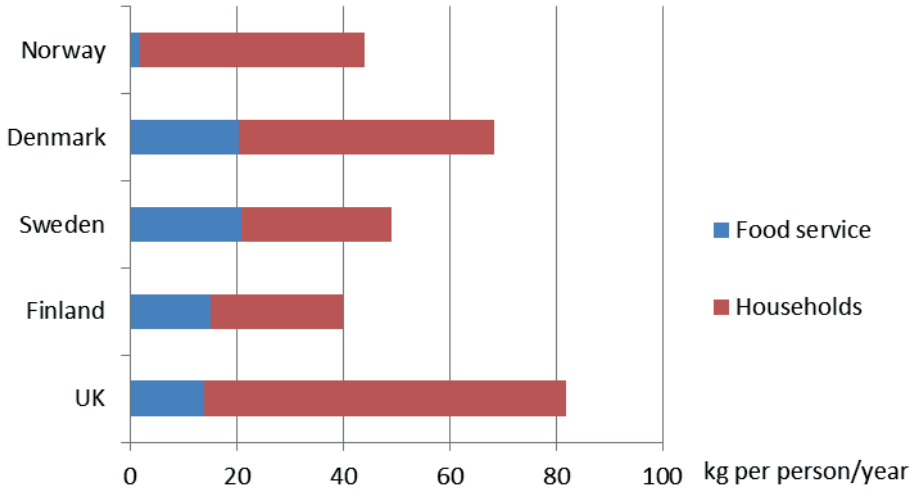


Figure 10. Comparing food waste amounts for the food service sector and households (originally edible) in kg per person/per year (Norway Stensgård et al. 2017, Hanssen et al. 2016, Denmark Miljøstyrelsen 2014, Edjabou et al. 2016, Sweden Naturvårdverket 2013, Finland Katajajuuri et al. 2014 (IV), UK Wrap 2015).

5.1.1. The impacts of FW in households: climate and economic impacts and the loss of calories

The MTT research group (Katajajuuri et al. 2012, Paper IV) estimated the climate impact by using data from a household diary study and the target was to identify acceptable and relevant GHG estimates for different FW categories such as vegetables, bread, meat etc. by using numerous data sources (e.g. Katajajuuri, 2009, Kauppinen et al., 2010; Pulkkinen et al., 2011; Saarinen et al., 2012). For some FW categories, the average GHG impact was used, e.g. for convenience and home cooked food, which included products such as casseroles and other meals, hamburgers and pizzas, all of which include many different types of raw materials. The climate impact of household sector FW was about 350 million kg CO2-eq per year or about 70 kg CO2-eq per person. Thus the climate impact of FW was about 3% of the total climate impact of the typical Finnish diet (2190 kg CO2-eq/person, Saarinen et al. 2019). Animal products account for a relatively large climate impact in comparison to other products. For example, beef and pork products disposed of as FW amounted to only 4% of the total FW, but the climate impactt was one of the highest alongside convenience food and snacks.

Finnish households consumed about 500–600 kg of food per person per year (Viinisalo et al. 2008, Tike 2010) and thus originally edible FW 23 kg per person was about 4–5% of the food purchased. Households spent on food products around 4200 euros per year (OSF 2012) and the value of originally edible FW was thus around 210€ per household and about 100€

per person. This estimation is only rough estimation based on statistic and the MTT research group made also a more accurate estimation based on FW categories and receipts data collected during the diary study (Hartikainen et al. 2013, paper IV). These studies calculated households FW value about 70–80€ per year.

The kilocalories lost were about 70 kcal per person per day and 25,500 kcal per person per year, this means 136 billion kcal in a year together in Finland. *National FINDIET 2012 Survey* showed that the the daily energy consumed was about 2,000 kcal per day (Heldan et al. 2012) and thus the calories lost in households was about 3–4% of total consumption of calories and would feed about 180,000 Finnish people for a year.

5.1.2. Types of FW in households

The most discarded type of FW consisted of fresh and perishable food or home cooked food. The product groups associated with the most FW were vegetables and milk products (Table 5). About half the volume consisted of vegetable-based products and the other half animal or partly animal based products. In the study, dairy products accounted for 17% of the total food waste and about half of this was liquid milk. The reason for the high amount of disposal vegetables was mainly due to spoilage, but these products are also relatively low in price and risk being over-purchased. In other countries similar results have been found in Sweden where same three groups were the most discarded products (Table 5). In the UK vegetables also formed the largest share of FW (Table 5). However, different categories make direct comparisons difficult.

Table 5. Type and reasons for FW in households in Finland, Sweden and the United Kingdom.

Households	FI (this study, Paper II)	SWE (Williams et al. 2011)	UK (WRAP 2012, 2014)
Type of avoidable FW	• Vegetables 19% • Home cooked food 18% • Milk products 17% • Bread and baked goods 13% • Fruits and berries 13% • Meat 7%	• Fruits and vegetables • Dairy • Prepared food	• Fresh vegetables and salads 19% • Other 18% • Drink 17% • Baked goods 11% • Meals 10%
Reasons for FW	• Spoiled, mouldy • Best before or used by date expired • Plate waste • Over prepared • Food not wanted to eat anymore • Food suspected to be past its best for consumption • Other	• Food gone bad • Too much food prepared • Past best before date • Packaging	• Not used in time (e.g. date label) • Other reasons, such as ‘looking’ or ‘smelling off´ • Too much food cooked, prepared or served • Personal preferences

5.1.3. Reasons for waste

The reasons for food waste can divided into two main categories: 1. *Spoiled food* or 2. *Food discarded from the cooking or eating process before spoiling.* These categories have been divided further into two subcategories (Figure 11).

Category 1 *Spoiled food*

This could be connected to the consumer's habit of buying and storing too much food. Food and food products are often highly perishable, can be spoiled, suffer from mould easily and lose their attractiveness. This category especially included vegetables, fruit, and cheese. Food products also reach their expiry date and examples of these foods include milk, meat or fish products. Food can also just lose its quality or look doubtful to eat. These kinds of food included e.g. bread. A Finnish consumer FW survey (Silvennoinen et al. 2013) found that food spoiling happened due to unplanned shopping and food products being forgotten in the fridge.

Category 2 *Food discarded from the storing, cooking or the eating process*

Planning and management are connected to household cooking skills and the ability to estimate the number of people eating and the amount of food they will eat. Home cooked food is often wasted because the household does not want to eat the same food day after day, or because children's food preferences are unpredictable (Silvennoinen et al. 2013). When food is prepared and cooked, FW can result from overproduction and/or when it is left on the plate after eating. According the diary results in this study, there was overproduction of potatoes, rice, soups and sauces. Plate waste included potatoes, bread, meat, convenience and take away food, as well as home cooked food such as casseroles, soups and porridge.

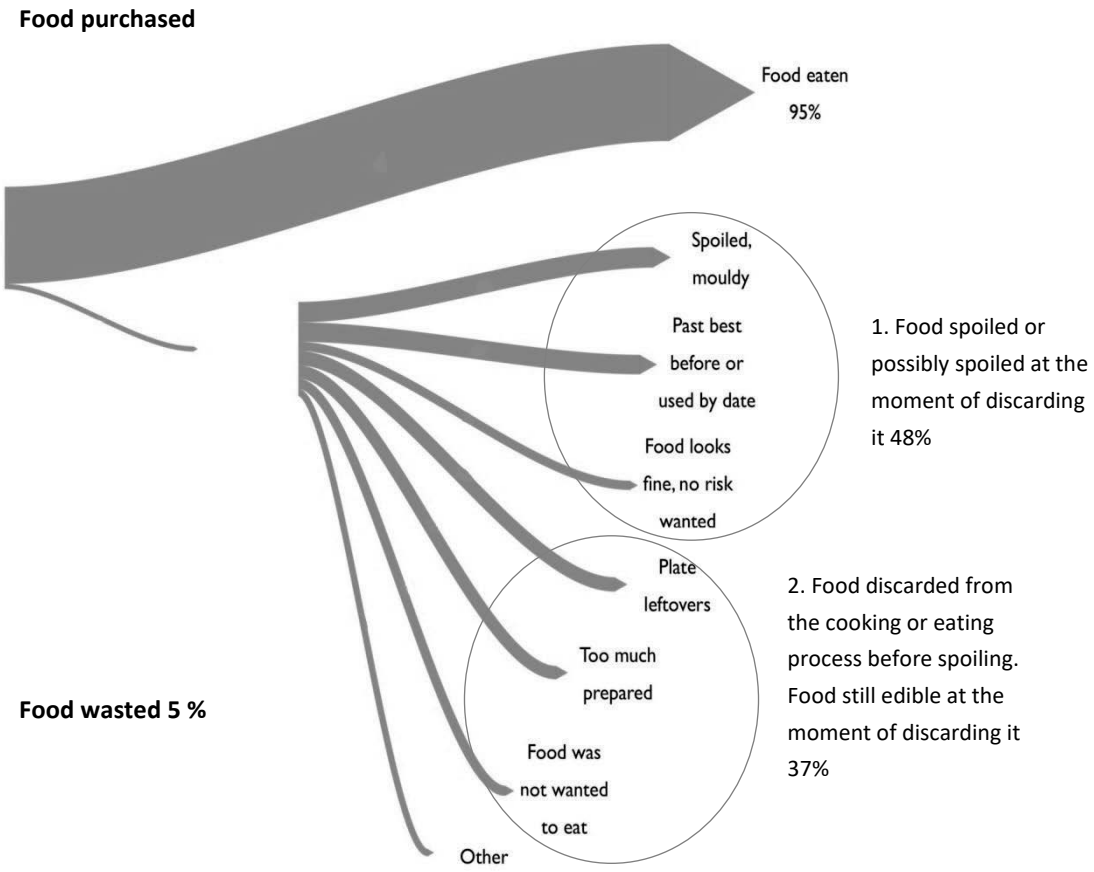


Figure 11. Household FW compared to the food purchased and divided according to the reasons for discarding it. Food spoiled or possibly spoiled accounted for 48%, food discarded during the cooking process or eating came to 37% and other reasons accounted for 15%.

5.2. Food waste in the food service sector

According the results about one-fifth of the food produced was wasted in the food services that participated in the study. This result was similar to those reported in the UK and Sweden, in which about 20% of the food prepared was wasted (WRAP 2013b, Engström and Carlsson-Kanyama 2004, Karlsson 2001, Eriksson et al. 2017). Beretta et al. (2013) reported that avoidable food waste was about 13% in the food service industry in Switzerland.

The estimate for food waste in the Finnish food service sector according the study results is 75–85 million kg per year and this is about 14–16 kg per person per year. The

results were quite similar to the reported amount of food waste generated in the food service sector in a study for the Nordic Council of Ministers, which reported waste of 18 kg per person per year (Martinsen et al. 2012), or results from Sweden and Denmark which reported about 20 kg of food waste per person per year (Naturvårdverket 2013, Miljøstyrelsen 2014).

FW is generated in all stages of the food service business process from storing and cooking to plate waste. The amount of FW generated from different origins (kitchen, serving, or customer plate waste) varied between food service subsectors and individual outlets. The outlets with a buffet line had the largest share of FW, while the serving waste varied, accounting for 10–17% of the food produced depending the subsector. Buffet line outlets with large FW amounts have also been observed in schools in Italy (15%) and Sweden (15%) (Falasconi et al. 2015, Eriksson et al. 2017) and a case study in hotels showed that the serving waste from buffet lunches consisted of 20–40% of the produced food (Pirani & Arafat 2016).

The amount and type of plate waste also varied from one outlet to another, depending on the subsector type. The customer plate waste in communal canteens in schools and day-care centres contained the main courses of the day and salad, and only small amounts of bread or milk. In restaurants and diners, the customer plate waste consisted mainly of side dishes such as potatoes, rice and pasta, and salads. FW from serving was generated when the outlet had difficulties estimating the number of customers and how much food they would eat. FW generated in the kitchen (during the preparing and cooking process) was relatively small. Additionally, the amount of originally inedible FW was quite small, except in cafes and petrol stations (probably due the amount of coffee grounds).

According to the results, the importance of FW research and the minimization of FW in the food service sector in Finland are based on:

- The food service sector's large size and significance in the Finnish food system

In Finland, this sector serves a great number of everyday lunches. Especially large in this regard are communal-based food services, as all school pupils get their lunch at canteens free of charge. Additionally, a great number of people eat their lunch at workplace restaurants or student canteens. (Horeca 2015, Vikstedt et al. 2011).

- The relatively high percentage FW of food produced

About one-fifth of all food prepared in the outlets was wasted in the study period. The largest contribution of FW compared to the food prepared arose at day-care centres in addition to workplace and student canteens. The main source of FW was serving waste due to self-service buffets and overproduction. Only in restaurants and diner type outlets the most FW was produced from plate waste. The most critical aspect in reducing FW in food services is how to prepare the right amount of food. Based on the management interviews and workshops for the participating company representatives (Paper III, Heikkilä et al. 2016), this could be achieved by having a better estimate of the number of diners and careful menu

planning. Solutions to these problems would be to get to know the customers better, interacting with them and cooking in stages. The latter could be difficult to organize due to the limited workforce and would require motivation and commitment from the personnel. Careful planning of the menu and identifying correct portion sizes would also help reduce waste.

- When discarding prepared, cooked and served food in the late phases of the food system the environmental and economic impacts are high.
- Educational elements especially concerning schools and day-care centres.
- Non-standardized FW study methods for weighing and indicators. The food service sector would benefit further research and development to find best methodologies and tools to measure FW.

5.3. Study methods for measuring food waste and requirements for data

To achieve a reduction in FW (Intro 1.1.) the methods to measure and estimate amounts and trends of FW must be evaluated and selected. A different kind of FW measurement methods and possible challenges have been identified and reported (e.g. Koivupuro et al. 2010, Møller et al. 2014, Corrado et al. 2019, Tostivint et al. 2016). The European Union is going to introduce a new reporting obligation for member states to measure FW (EC 2019). This upcoming reporting will include FW amounts from all sectors and instructions describing favourable methods. Specific study demands and data factors affect the choice of the method for food waste estimation. In practice, resources also set limits on how studies can be done.

5.3.1. Methods for measuring household food waste

A commonly used method for measuring household FW have been composition studies, but these are often used together with diaries, surveys or interviews (e.g. WRAP 2012, Koivupuro et al. 2010). The FUSIONS project recommended approaches for FW measurements in households were composition study, diary study and statistics combined with waste composition analysis (Møller et al. 2014). The essential indicators for measuring FW in household is amount of total FW per person, amount of edible FW per person and amount of total FW in household per purchased amount of food (Møller et al. 2014). Additionally, the type and reasons for generating FW are essential to know when determining practices for reducing FW.

Table 6 Features for food waste measurement fulfilling demands for study and prevention purposes.

FW in households, requirements for data collection	Rationale
Amount of FW and contribution of edible and inedible FW	These waste streams differ in their drivers and prevention methods. Essential for obtaining comparable data.
Amount of food waste by type and phase (solid, liquid)	FW types differ in their drivers, prevention and the waste hierarchy principles.
FW reason (driver for discard)	Essential when using data for preventing FW, e.g. dissemination of information about changing to better practices.
Number of persons in household	Essential for obtaining comparable data on the FW per person, not only number of households (which can vary according to the number of family members).
Amount of food purchased per person	Essential to obtain comparable data and indicators for efficiency (this data is usually available from statistics).
A fairly large number of samples from different household and housing types	Households and housing types vary in their amounts and types of FW.
Use of scales and weighing instead of estimations (diary)	To get reliable data.
Sufficiently long measurement period (diary)	For covering FW variation on weekdays, weekends and in different seasons. E.g. apples in the autumn.

Different methods for measuring FW in households are compared in Table 7. A composition study is a method of sorting a certain amount of mixed or organic waste and it is typically carried out by researchers (Figure 12 and 13). The advantage of a composition study is the ability to measure FW from a large number of households. Diary studies are carried out by the study subjects themselves, and that aspect can have an effect on the results because of underestimation of FW (e.g. Quested et al. 2020). In addition, it can be uncertain to find voluntary participants for a random sample. The advantages of a diary study include the possibility for good demographic data on the participants and possibility to also obtain data on FW thrown into the sewer or home compost. Additionally, it is possible to ask about the reasons for each of the FW batch.

Table 7 Comparing different study methods for households.

Households Method	Pros	Cons
Diary, self-reporting method	Exact data on the background, types and origins of FW, amount of liquids thrown into sewers or home compost or used as pet food. Possibility to get data concerning the reasons for discarding FW.	Small sample size, participants might underestimate amounts of FW, weight measurement needs a scale or other instrument, expensive, difficult to get data on inedible parts or packages.
Composition study, sorting study	Large size of sample, possible to obtain data on total FW and data on packages. Data reliable as data is collected by researchers or professionals.	No background information. No data on liquid FW. Demand for samples from mixed and separately collected bio waste. No data if FW is composted at home.
Survey	Relatively easy to conduct for large numbers of people, provides data on background and reasons for FW.	Data on amounts is very uncertain if there is no weighing method.
Workshop, interview	Possible to obtain background data and data concerning opinions, motivations and prevention methods, for example. Data about FW drivers, best practices and possible reduction methods	Data about FW drivers, best practices and possible reduction methods. No data concerning quantities.

Figure 12. Researchers carrying out a sorting study.

Figure 13. Food waste found in household mixed waste.

5.3.2. Study methods to obtain food waste data from the food service sector

In general FW data in food services has been found to have several weaknesses, e.g. the studies have been conducted mainly in a few Western countries and they are often based on secondary data sources (Xue et al. 2017, Stenmarck et al. 2016). In national reports, household FW is often reported, while food services are sometimes only analyzed as a part of the consumer level. Companies may follow and monitor their amounts of FW for their own management purposes, but often they do it only for a limited time and the monitoring may lack parts of FW such as plate waste (Silvennoinen et al. 2019a). Quite often data on the amounts or quality of FW in the food service sector is based on a small number of

measurements and on a limited number of subsectors, e.g. only schools or student canteens. Research, data collection and generalization of the results are complicated and resource demanding because food services differ considerably in terms of their size, location, business concept, menu assortment or even whether they are a non-profit service or not (e.g. HORECA register 2015). In Europe 90% of companies in the food service sector are micro enterprises (HOTREC 2019), which makes it likely that they differ a lot in their practices and management.

An appropriate monitoring system would help services to efficiently follow and utilize FW data. Additionally, management could use a system for developing best practices, menu planning and monitoring amounts and trends in FW. This data could also be used for FW research purposes, e.g. for statistics and reporting for yearly follow-up and achieving targets, e.g. for the upcoming EU *Delegated act on food waste measurement* (EC 2019).

To obtain informative and useful data the most essential indicators are 1. *the percentage of produced food that ends up as waste,* and 2. *the amount of food waste per customer*. Table 8 presents the features that the FW data collection should have to fulfil companies' demands for reducing FW and for study purposes to monitor the FW amount in general. These requirements include amounts, types, drivers and methodological aspects for measurement. Possible methods which could be used in the food service sector include diaries, composition studies, surveys and interviews. These methods are compared in Table 9 and their advantages and disadvantages are discussed. The best method would be to combine diaries and interviews, as then it would be possible to obtain data on the amounts of FW and determine the drivers behind the numbers. Simple and easy to use measurement and result registration forms or tools as well as support from the management are essential for successful measurements.

If the kitchen is very busy, measurements are typically dropped by staff members in favour of more essential tasks. Additionally, the measurement results should be visible to maintain the motivation needed to perform them and the personnel should be able to suggest solutions for reducing FW themselves. Overall a strong commitment to measuring the FW is required from the kitchen personnel, as it does not offer any direct rewards for completed work. Long-term measurements require especially strong commitment, and to succeed, the motivation needs to be kept high with feedback, and the measurements need to be integrated into daily routines as a normal part of the working procedure (Silvennoinen et al 2019a).

Table 8 Features of FW measurement methods applicable to the food service sector, fulfilling demands for study and prevention purposes (in food services).

FW in food services, requirement for data collection	Rationale
Amount of food waste by origin: kitchen, service and customer	FW streams differ according to the drivers, means of prevention and waste hierarchy.
Amount of food waste by type (dish, product, commodity) and phase (solid, liquid)	FW streams differ according to the drivers, means of prevention and waste hierarchy.
Amount of produced food and number of customers	Essential for obtaining comparable data and indicators for efficiency and FW per consumer.
Separate sorting and measurement for edible and inedible FW amounts	Essential for obtaining comparable data, FW amounts vary according to the subsector, outlet and menu, e.g. coffee grounds, bones, peelings.
FW driver (reason for discarding food)	Essential for preventing FW and moving towards better practices.
A fairly large number of samples from every subsector	Subsectors vary a lot and the FW amounts, types and origins are different.
Use of scales and weighing instead of estimations	To get reliable data and results.
Daily records of waste streams and food produced	FW amounts vary significantly by day and menu.
Sufficiently long measurement period	To get a complete picture (e.g. menu cycle).

Table 9 Comparing different study methods for food services.

Food services Method	Pros	Cons
Diary, self-reporting method	Results in precise data about the food produced and discarded, as well as data on liquids thrown into the sewer and the number of clients. Permits data collection on recipes and measures the value of lost calories. Personnel can carry out measurements.	Requires working time. The method needs education and motivation.
Composition study, sorting study	Large size of sample, data on the total amount of food waste, data on packaging. The data is reliable as it is collected by researchers or professionals.	No data on food produced, no possibility to analyse the share of FW of the food produced. Difficult to get separately collected waste samples from food service outlets.
Survey	Relatively easy to conduct for large numbers of professionals. Data about FW drivers, best practices and possible reduction methods.	No data concerning quantities or amounts is very uncertain if there is no weighing method.
Interview, workshop	Data about FW drivers, best practices and possible reduction methods.	No data concerning quantities.

5.4. Following the food waste hierarchy in Finland: options, innovations and practical recommendations

The *food waste hierarchy* (FWH) (see Introduction) can be used for preventing and reducing the quantity of FW, and it can provide guidance for the circular economy and for keeping food and nutrients in the food supply chain. Here the FWH has been used for presenting how FW can be avoided in households and food services in Finland and what kinds of options are available to managers (Figure 14).

The FWH differs from the overall *waste hierarchy* (WH) because when food turns into waste it cannot be used as food for eating once it has spoilt. That is why the most preferable option is to prevent FW by using all food and purchasing the correct amount of food products or raw materials. Originally inedible parts cannot be prevented entirely as not everything is suitable for human consumption, e.g. coffee grounds or bones. Prevention can occur by using more parts that are not usually used, e.g. from vegetable peelings or animal organs. Prevention and re-use are stages that cannot be influenced by waste management actors. However, waste management can involve selecting the most preferable option once food has been thrown away. This is also determined by how households and services sort their waste and FW; e.g. how large a part of the overall waste ends up in bio waste bins or mixed waste bins.

Next, I will present options for different FWH stages in Finland according to the results of this thesis and my other study results (Silvennoinen et al. 2013, 2019). I will also provide examples of initiatives that have been taken during the recent years for preventing and recycling FW in Finland.

5.4.1. Prevention

Household results show that the batches of discarded food are small, which makes the amounts less obvious and leads to difficulties finding good means for improvement or recovery. However, preventing the amount of FW is important in households and plenty of reduction methods can be recommended to avoid food spoiling and better food management: the main thing is to improve the overall planning, storing and cooking skills, meaning that food waste is recognized and noticed. It all begins with carefully planning grocery shopping, using shopping lists and avoiding impulse or extra (overmuch) purchases. For small households, package sizes may be too large and therefore purchasing loose goods could be better than choosing a large package. In Finland, customers can buy almost all vegetables and fruit loose, but also bread and lunch or dinner portions. After coming home, food needs to be stored properly and at the correct temperature. Checking cupboards and fridges regularly would help consumers notice products reaching their expiry date, and vegetables or tubers going off can be avoided by cooking different dishes such as casseroles, soups or stir-fries. Prepared and cooked food causes a great amount of FW; however, this is avoidable by strictly cooking for a certain number of eaters, e.g. calculators or equipment such as spaghetti measures can be useful. It is important to try and use up all the food, e.g. by preparing dishes to be eaten later, instead of discarding it. Plate leftovers are much more difficult to save as they have been on a plate, and possibly mixed with inedible parts of food. For this reason, the size of the serving portion should be considered, because at home it would be easy to have more if needed. According the background survey of diary study the participants prefer storing food correctly, not opening new food packages until the old ones finished and serving smaller portions as the most effective means for decreasing FW at home.

It is also important to pay attention to 1) nutrition, e.g. vegetables and fruit are healthy only when they are consumed; 2) carefully buying vegetables and fruit; 3) expiry dates, although milk or convenience food are often still usable after the given date; 4) carefully planning the amount of cooked potatoes, rice and pasta; 5) carefully planning food amounts, e.g. for children; 6) finding new recipes for using left over food; 7) the option of giving leftovers to pets, although some food and products are possibly dangerous for animals. At home, suitable food can be fed to pets, mainly dogs or cats. A diary study showed that about 40% of discarded *home cooked food* was given to dogs or cats. This could be possibly increased as only 15% of the total amount of discarded FW batches were given to a pet.

5.4.2. Survey of consumer's opinions on preventing FW at home, in retail and in food services

To obtain information about people's opinions on preventive methods, MTT conducted a consumer survey in February 2013 (Silvennoinen et al. 2013). In the survey people aged from 18 to 69 years were invited to an online panel and 1,002 people completed the survey successfully. Of the respondents 50% were females and 50% were males, all age groups were represented, and the sample was nationally representative.

Economic reasons were regarded as the most important motivator for reducing food waste at home. Consumers thought that they could reduce food waste in their households by first eating food that easily get spoiled and by planning their food shopping more carefully. The respondents thought that the means for reducing food waste were simple but challenging in a busy and hectic everyday life. The most important means of reduction were eating the food bought first and perishable foods before others, checking the need for food before purchasing and storing products correctly.

The respondents answered that the most important ways for retail stores to reduce food waste would be to sell products near to the *used by* or *best before* dates at a discounted price and by donating safe but expired products to charity organizations. The price per kilo should be the same for small and larger packages; this would avoid consumers purchasing too large an amount of food. Additionally, the respondents would like to see more package sizes and food sold loose. In restaurants, the two most supported options were *surplus food to be given to charity organizations* and the *possibility to take food home*.

5.4.3. Food services

Kitchen waste from storing, preparing and cooking food was relatively small (1.5–6.5% of the food produced) depending, e.g. on whether or not food is ordered from a central kitchen and thus requiring less preparation. Kitchen FW could be prevented by improving the ingredient check-in and FIFO (first in, first out) cycle, following recipes carefully instead relying on gut feeling, and utilizing all materials creatively. Centralized ordering systems and co-operation with wholesale companies could assist in managing FW by avoiding overly large

packages, ordering and using raw materials efficiently for different menu combinations and using ready-to-use packaging solutions for vegetables for salads.

The largest amount of FW was generated from serving waste, meaning food left over from buffet lines and over-produced food prepared but never served. This serving FW is generated when the staff have difficulties estimating the numbers of customers and how much food they are going to eat. This was the most critical aspect for reducing FW in food services and raised the question of how to prepare the right amount of food that is not finished until the last customer has finished. Prevention was connected to managing and planning, which would be promoted by measuring waste amounts. According to the results from workshops and interviewes (Heikkilä et al. 2016, Silvennoinen et al. 2019a, Silvennoinen et al. 2019b) there were a number of ways to manage waste and reduce amounts:

- By introducing FW monitoring systems for the company: all wasted batches would be weighed and registered. This data could then be used for estimating the number of customers, most popular dishes, and the amount of food produced.
- Careful consideration of the menu each day: buffet lines especially should include the right number of dishes and they should be attractive but should not include too many choices. Deep serving containers could be replaced with shallower ones at the end of the lunch hour.
- Correctly sized product orders and cooking food amounts: the staff could lack the willingness or knowledge to risk the food finishing in a buffet line during a lunch hour. This could be because of using not so experienced personnel, e.g. a large number of extra workers. Additionally, when it is busy, it is more convenient to overproduce food instead of cooking in stages as needed.
- Menu planning based on extensive experience: having food consumption records of the past would help estimate the amount of food needed and help choose preferred meals.
- Estimations of the number of customers: schools and kindergartens have exact numbers of pupils, but excursions, exam dates and illnesses cause uncertainty. This could be avoided by improving the communication between school management and the kitchen personnel.
- Standardized sets of recipes: a continuous menu cycle would improve knowledge of the consumption and sale amounts.
- Factors in attitude and awareness: incompetence, negligence or apparent hurry can lead to a lack of a true will to reduce food waste. One answer would be to change attitudes and increase awareness through orientation and discussions. Furthermore, the visibility of estimates and monetary losses caused by food waste could help staff motivation.

Minimizing food and other waste can be of benefit when marketing food services to customers. In Helsinki the restaurant *Nolla* emphasize their zero-waste concept (Ravintola

Nolla 2018). This restaurant strictly uses seasonal raw materials and composts all the inedible parts. The restaurant's customers can take soil from the restaurant's own compost for houseplants. Another restaurant *Ultima* is experimenting with circular economy methods such as using coffee grounds for growing mushrooms (Ultima 2018).

5.4.4. Preparing for re-use

Households

If all the food purchased is not going to be eaten at home (or taken out, e.g. for lunch) there are some possibilities to give it away, sell or donate it. These are much more difficult options than preventing FW for households because the food must be packed, kept at the correct storage temperatures during transportation, and takes some time and effort. This option must also be planned moderately early, and there must be a time frame for consumption. This could be a good option, for instance, for food surplus from parties, the start of holidays when leaving home for a long time, or for apples or other garden products. In Finland, a new application has been released where a private person can donate food and money paid by the receiver will go to charity (Neighbourfood 2016), and there is also an organization that collects surplus apples (Omenasieppari 2018). Furthermore, a food exchange system and sharing point have been piloted in one housing company (Silvennoinen & Sinkko 2013) and there have been some similar initiatives organized by various associations (e.g. Kalliola Settlement 2018). The aim of the sharing points is to help people share their extra edible food instead of discarding it.

Food services

When food is left over from a buffet line it can be redistributed and donated to charities. It is possible to serve over-produced food in canteens after lunch to local citizens, e.g. this is done in schools in the city of Jyväskylä (Sitra 2013, Kylän kattaus 2018). Another possibility is to donate food to charities that can deliver food to their canteens or directly to the receivers (e.g. Katulähetys 2018, Sitra 2018). The Finnish food safety authorities have published guidelines for donating organizations to secure food safety and have clarified the responsibilities of the receivers and donators (Evira 2017). The European Union has also published guidelines on food donation (EUR-Lex 2017). Guidelines encourage companies to make donations instead of discarding food, but also ensure food safety.

Food redistribution was studied in two areas (Turku and Helsinki) in southern Finland by conducting surveys, questionnaires and interviews for charity organizations redistributing food and nine companies donating food (Hanssen et al. 2014, Silvennoinen & Katajajuuri 2015). The aim of the study was to gain an estimate of volumes, types and numbers of food bags or cooked meals made from donated food, and how the organizations and donating companies operated. The number of cooked food meal portions varied up to 10,000 portions

per year, while the number of redistributed food bags was on most occasions more than 10,000, and up to 270,000 bags per year by one organization. The volume of donated food redistributed by organizations was 3 million kg/year, and this can be cautiously compared to food wasted from the retail sector in the same areas of about 20 million kg/year. It must be remembered that a large part of the donated food comes also from the food industry. The study indicates that there can be a great potential for increasing the amount of food being redistributed in Finland especially in food service sector.

Companies can also sell left-over food to their personnel or customers at a discounted price. Some companies have lower prices after a certain time when the food can be sold as take-away food. When selling outside, applications can be used for managing and advertising (Rescue Club 2018, Lunchie Market 2018). The vocational school Omnia sell their surplus food produced from baking and cooking activities (Omnia 2018). They have established a shop called Frida where students also have the opportunity to learn commercial skills. A new kind of restaurant called *Loop* using discarded food products from retail and industry was established in Helsinki in 2016. This restaurant also makes beer from discarded bread (Loop 2018).

5.4.5. Recycling and recovery

Recycling food in households outside the family is difficult, but it could be possible to recycle FW for animal feed, e.g. bread and vegetables, however, in practice this could be difficult because of the small amounts of material and transportation costs.

Food services could more feasibly recycle FW for animal feed, although this option faces difficulties because of legislation, e.g. on animal products or compulsory registration for feed producers. This option would also require strict sorting to ensure safe and suitable feed materials. There could be possibilities for delivering surplus food, e.g. to dog shelters. It is currently prohibited to supply animal-based food for feeding livestock, but it is permissible for pets.

In 2016, 55% of municipal waste was used for energy and 42% was recycled, e.g. glass, paper, and metal (Kivo 2018). According to sorting studies, the Helsinki metropolitan area produced 65 kg of bio waste per person/year (HSY 2015) and the share of FW was 55 kg of FW per person per year (edible and inedible) (Silvennoinen et al. 2019a). In Finland FW can be found in separately collected bio waste and in the mixed waste (see introduction). Separately collected bio waste is possible to manage in compost or bio energy plants. About two-thirds of bio waste is composted and one-third is digested (SVT 2017). For example, in the Helsinki area a bio-gas plant (e.g. HSY 2018b) saves energy using a process in which bio waste decays to produce soil and gas. Households can also compost organic waste by themselves using various techniques. This could save reduce negative impacts and transportation expenses (Jouhara et al. 2017).

Finland does not locate mixed or bio waste in landfills anymore, but households still direct part of their FW into the drains. The exact amount is not known, but it can be

assumed that coffee and opened milk packages are discarded this way. A diary study indicated that 8% of the total FW is milk, and in the survey (Silvennoinen et al. 2013) 13% of the participants indicated that they throw coffee away daily and 28% at least once a week. When food or drink enters the sewage system it will treated as sludge and biogas. This sludge can be used for composting materials or earthmoving processes and gas for energy purposes (HSY 2018a).

5.4.6. Disposal

In Finland, only a small amount (3% of total municipal waste, OFS 2018) of waste, e.g. slag from incineration processes is directed to landfills (HSY 2018b) anymore.

Table 10 Food waste hierarchy, different stages where FW occurs and how FW can be reduced in households and food services. These stages are explained in the text.

Stage	Households	Food services
Prevention	Saving food from spoiling. Using all food purchased, prepared and stored. Improved storing and cooking skills.	Using all food purchased, prepared and stored. Special attention to overproduction and buffet lines. Selling at discounted prices after lunch. Kitchen: recipes, FIFO Serving: forecasting the number of customers Leftovers: communication, guidance
Preparing for re-use	Difficult outside the family, but possible to give, sell or donate small amounts, e.g. to neighbours, or via software applications, and web pages.	Redistribution and donations to charities or local citizens, selling via software apps, sales personnel.
Recycling	Possible to recycle for animal feed, e.g. bread and vegetables, though there are difficulties because of small quantities, transportation etc.	Possible to recycle for animal feed, e.g. bread and vegetables. Difficulties because of legislation, e.g. compulsory registration for feed producers.

Recovery	Separately collected bio waste is composted or refined for biogas. Households could have their own compost. Mixed waste is incinerated. Food and drinks that are thrown into the sewer and wastewaters are treated in plants producing by-products sludge and biogas.	Separately collected bio waste is composted or refined for biogas. Possible to use compost for growing herbs etc. Liquids are used for sludge and biogas.
Disposal	FW is not disposed of in landfills in Finland.	FW is not disposed of in landfills in Finland.

6. Conclusions

According to the results, the total amount of FW in Finland was about 385–485 million of kilograms in a year. The amount of FW in households and the food service sector is significant and accounts for half of all WF produced yearly in Finland. The amount of household FW was about 23 kilograms per person/year and about 60 kg per household/year. The most discarded types of FW were vegetables, home cooked food and milk products, and the main reasons for FW were spoiling and expired by or best before dates. The kilocalories lost were about 70 kcal per person/day and 25,500 kcal per person/year. The economic value of FW from households was estimated to be around 100€ per person/year.

The amount of FW in the food service sector was together 75–85 million kilograms and about 14–16 kg per person per year. The results show that the share of FW in the food service sector is relatively high and is approximately one fifth of all the food produced. The main source of FW arising from food services was serving waste from buffets and producing too much food, only a la carte restaurants produced more food waste from customer plate leftovers.

The total amounts of FW in households were high because of the sector's relatively large size, even though households only waste about 5% of the food they purchase. More than 40% of food was unspoiled when discarded. It is important, according to the waste hierarchy, to be able to find a way to use food and food products when they are still edible. The most important means to reduce FW in the consumer sector are connected to the capability to purchase the correct amount of food (households) and prepare the right amount of food (food service sector). In households, planning of purchases, awareness and education would help to reduce FW and the food service sector solutions would be more various as there are extensive differences in their business idea, size and type.

In the food industry 75–140 million kilograms of edible food was wasted annually, this corresponds to roughly 3% of the total production volume of the industry sectors included in the study and 14–20 kilograms per person in Finland (this sum was specified more precisely as 75–105 million kilograms/year in a later study Hartikainen et al. 2014). In the retail sector about 65–75 million kilograms of FW is produced annually which is 12–14 kilograms per person.

Suitable and appropriate measurement methods for monitoring FW would be crucial to follow trends and targets for reducing FW in food service companies. A suitable method needs to be simple and easy for personnel to carry out daily, and the method should provide data about the food produced, the numbers of customers and origin of FW. The best options to made estimations about amount of FW in households would be the combination of a composition analysis and diary study as these methods would fulfilling the data demands e.g. amount of total FW, edible and inedible FW, types of FW, drivers and background data of FW.

The European Commission has established a common methodology to measure and report FW levels in the EU. Member states will start collecting data in 2020 and report their national FW levels by 2022. This common methodology includes many options for data collection in different food supply sectors and member states will choose the best ones for their conditions. The results in this thesis include only the first estimates of FW amounts in Finland and research in this field have been continued since with more accurate results from the different food supply sectors. In the future, FW research will work to conduct EU obligatory FW measurements and develop the best approach for each food supply chain sectors for Finnish conditions. This research will present updated FW results and study new methods for regular yearly data collection. In households and food services special research is needed to develop methods that would monitor and collect statistically sufficient data required which would not be too complex or resource demanding.

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