Waste Management 34 (2014) 1911–1919

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Food loss rates at the food retail, influencing factors and reasons as a basis for waste prevention measures

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ARTICLE INFO

Article history:
Received 5 February 2014
Accepted 17 June 2014
Available online 22 July 2014

Keywords:
Food waste
Retail
Food loss rates
Reasons
Waste prevention
Donations

ABSTRACT

This paper quantifies food loss rates for fruit & vegetables, dairy products and bread & pastry as well as donations to social services. In addition potential influencing factors and reasons for food losses are investigated in order to provide a basis for the development of waste prevention measures. Detailed data from 612 retail outlets all over Austria, which covered the period of one year, were analysed and sorting analyses of discarded food were carried out in a small sample of retail outlets. Food loss amounts to 1.3% of the sales of dairy products, 2.8% for bread & pastry and 4.2% for fruit & vegetables. Returned bread amounts to additional 9.7% of the sales of bread & pastry. The food loss rates are similar to the results of previous publications. At present, 7% of the food loss is donated to social services, 38% of retail outlets do not donate any articles at all. Food loss rates are declining with increasing sales areas, increasing numbers of purchases per year and increasing sales of the retail outlet, but explain only 33% or less of the variation of food loss rates. Large differences between retail outlets of comparable structure indicate potential for reduction. More than a quarter of discarded food articles did not show any flaws besides the expiration of the best before or sell-by date. Waste prevention approaches should focus on avoiding returns, transfer of best practices, information and education of employees and customers as well as strengthening the donation to social services.

1. Introduction

In the media and public discussion about food waste and food waste prevention, retail is often blamed for being one of the main contributors (cf. Hölzl, 2014; Schneider and Lebersorger, 2009). However, literature data indicate that only a small percentage of the overall amount of food waste along the supply chain is produced by retail. Excluding agriculture, estimates range between 5% in the food supply chain in Germany (Kranert et al., 2012) 6.5% in the Swedish supply chain (Stare et al., 2013) and 7.6% in the food supply chain in the UK (WRAP, 2010). Recently, retail companies have been making a greater effort to reduce food waste and to communicate their efforts to the public, such as Tesco in UK (TESCO, 2013). From a scientific point of view reliable data are needed in order to quantify the contribution of each stage of the supply chain (e.g. agriculture, production and processing, retail, consumers) to overall food loss quantities, as a basis for planning and evaluation and identification of well-founded waste prevention measures. Although food waste from retail has been investigated in a number of studies, there is still a lack of reliable data (Schneider, 2013b).

This paper is based upon a nationwide sample of 612 retail outlets of different size and type throughout the country. Complete data on the food losses of these outlets and on food donations to social services were provided by an Austrian food retail company which funded the study. Focus was laid on the food losses of fruit & vegetables, dairy products and bread & pastry, which together account for 81% of the company's total food loss in monetary values. In addition, unsold bread & pastry which was returned to the bakeries and which was recorded separately from food loss, was also considered. Results were obtained by a statistical analysis of the provided data and by sorting a small sample of discarded food articles from 6 retail outlets.

The purpose of this paper is to provide a basis for the development of waste prevention measures in food retail, by

- quantifying food loss rates for selected assortment groups,
- investigating correlations between food loss rates and characteristics of the retail outlets,
- and identifying reasons for food loss.

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http://dx.doi.org/10.1016/j.wasman.2014.06.013
0956-053X/

Focus is laid on food loss rates and on donations for which detailed data were available since they were displayed separately in the company's database.

Literature data on food loss from retail are sparse and often limited in scope. Some studies provide only rough estimations on national basis due to data gaps (e.g. Kranert et al., 2012), others were published by retail interest groups for the national retail branch, but without a transparent description of used methodology and data assessment (e.g. EHI, 2011). Published research on detailed data often investigated only a limited number of outlets (e.g. Hogan et al., 2004; Eriksson et al., 2012,2012; Hanssen and Schakenda, 2011; Hanssen and Møller, 2013) or focuses only on individual food product groups (e.g. Eriksson et al., 2014; Eriksson et al., 2012; Hanssen and Schakenda, 2011; Hanssen and Møller, 2013; WRAP, 2011; Buzby et al., 2009). Tesco (2013), a retailer in UK, was the first to publish detailed data on its food losses and reported a total quantity of 28,500 tonnes of food which was wasted in its stores and distribution centers in UK in the first six months of 2013, which is equivalent to 0.87% of the volume of sold products in the same period.

Compared to previous studies, this paper has the advantage that it covers a large sample size (10.7% of the total number of food retail outlets in Austria 2010 (Höbaus et al., 2012)), a complete time series over the period of one year and a very detailed database. Furthermore it combines the statistical analysis of existing data with an on-site survey in a, though small, sample of retail outlets. Limitations are related to the consideration of only the three most important assortment groups (covering 81% of the company's total food loss value) and only one retail company, as well as the small dimension of the sample for the on-site analyses.

2. Materials and methods

2.1. Statistical data analysis

2.1.1. Data base and definitions

Data were provided by an Austrian food retail company in the form of extracts from the company's database. Data on food loss (as sum of depreciation and breakage and amounts donated to social services) were available in units of mass, cost price and sales value. Before starting the detailed analysis, aggregated data on a monthly level from about 700 retail outlets for each assortment group and for the period from January 2009 to July 2012 were screened with the aim to identify a representative period of one year. A statistical analysis of variance and post hoc tests did not indicate significant differences between the years 2010, 2011 and 2012. Therefore the available most current data which covered the period from September 2011 to August 2012 were selected for the in depth analysis. Fig. 1 shows the food loss rates for the screened years.

Food loss rates were used as indicators for food loss, and were calculated as the ratio of food loss in Euros cost price to the sales of the respective assortment in Euros cost price. Food loss is the total quantity of articles which were neither sold nor returned, i.e. the sum of depreciation (due to different reasons such as apparent flaws, damaged packaging, expiration of best before or sell-by date...), breakage of goods and transfer to social services such as food banks or food distribution programs. In the original database the amounts donated to social services were reported separately, while depreciation and breakage had not been differentiated. There is an additional option for unsold bread in Austria. Bread is often taken over in commission from bakeries by retail markets, meaning that unsold bread & pastry can be sent back to the bakery (returned bread) for further treatment (Scherhaufer and Schneider, 2011). These amounts of returned bread are reported separately and are not included in food losses as they do not contribute to a monetary loss from the retailer's point of view. However, the returned bread also contributes to food waste and could be targeted by prevention measures. Therefore the respective amounts are reported in this paper.

For the detailed statistical analysis, data were provided on the basis of articles for each of the about 700 retail outlets per month, from September 2011 to August 2012, which entailed an enormous data volume of about 10 million lines in MS Excel. Each of the about 7300 articles was clearly defined by article number, label, producer name and package size. According to the company's categorization system which was also adopted in the study, each article is assigned to a product group, and each product group to an assortment group such as fruit & vegetables, dairy products or bread & pastry.

2.1.2. Data processing and quality

The statistical data analysis was carried out using the programs Excel 2010 and SPSS 15.0. Some restrictions in data quality have to be taken into account. Due to the huge data volume data could not be checked for all errors and inconsistencies in detail. Data were aggregated and analysed at the level of assortment groups for each retail outlet and per year. Apparent outliers and errors were checked by looking at the underlying data at product group and article level and by consulting the responsible person at the company. If possible, data were corrected or the respective retail outlet was excluded from the further analysis. Also retail outlets which showed missing data for one or more months were excluded.

In total, data from 612 retail outlets could be used for the analysis. The retail outlets cover sales areas between 56 and 2039 m^2 (mean 705 m^2). 26.6% of the outlets were situated in an urban environment, i.e. in cities with more than 190,000 inhabitants, and 73.4% in a rural environment. The retail company differentiates five types of retail outlets with regard to sales area and organisational structure. Table 4 shows the frequency of these types, their mean sales areas and purchases (i.e. number of transactions) per year. The latter were transformed due to data confidentiality, by dividing the mean number per retail outlet by the overall mean.

For the statistical analysis monetary values in cost price were used, i.e. the prices which the company paid for the procurement of the articles. Data by mass were also available, but with lower quality. For some articles, particularly for the assortment of bread & pastry, no mass data were available due to specifics in the accounting system of the company, so that the mass of food loss will be underestimated to different degrees – significantly for bread & pastry, only slightly for fruit & vegetables and for dairy products. For reason of data confidentiality no absolute quantities of food losses will be reported.

Another potential source of data inaccuracy was identified by Eriksson et al. (2012) who found that the recording of wasted fresh fruits & vegetables was quite inaccurate. However, work routines were different in the company investigated in the present study. Packaged fruit and vegetables with a barcode were recorded automatically using a scanner, and unpackaged items were weighed and recorded by mass. In the absence of any other evidence deviations were considered negligible.

The overall food loss rates from all retail outlets (see Table 1) were calculated as the quotient of the sum of food loss from all retail outlets and the sum of the respective sales. The use of arithmetic means would have led to an overrepresentation of smaller retail outlets. Correlations between food loss rates and characteristics of the retail outlets were investigated by using the non-parametric correlation coefficient Kendall's tau-*b*. For differences of food loss rates between different types of retail outlets, analyses of variance and post hoc Tukey tests were used. Differences between retail outlets in urban and rural areas were tested by means of *t*-tests for 2 independent samples. A significance level of 0.05 (two-sided) was used.

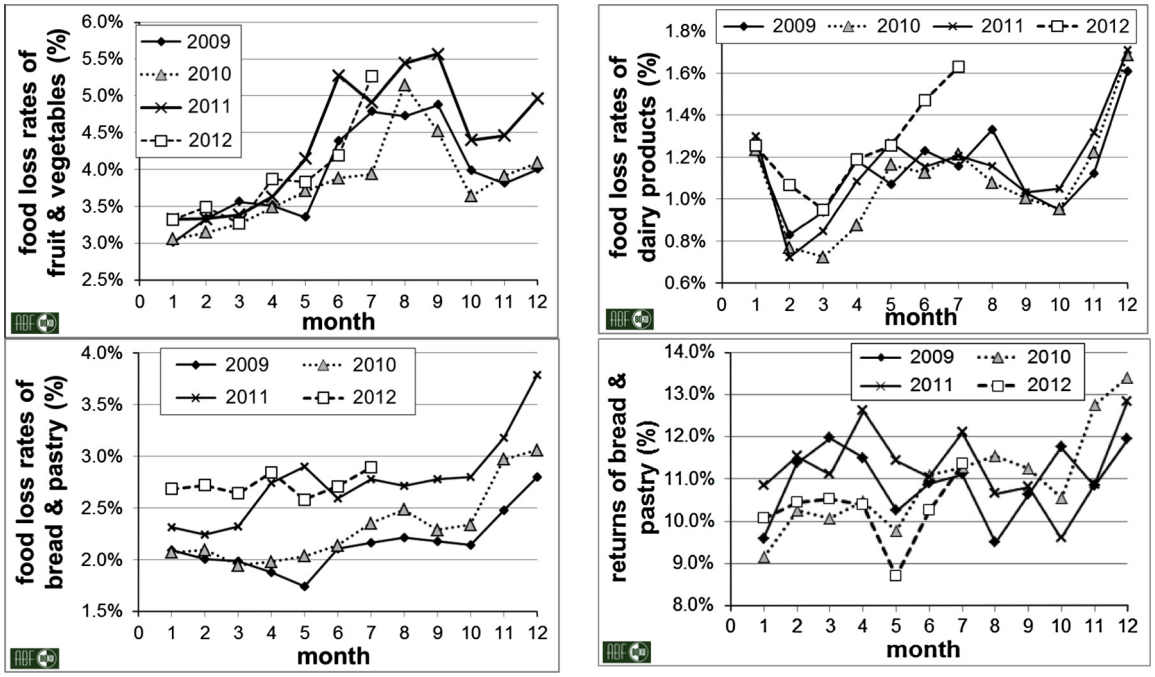

Fig. 1. Monthly variation of food loss rates (loss related to sales, in Euros cost price) for the assortment groups fruit & vegetables (top left), dairy products (top right), bread & pastry (bottom left) and returned bread & pastry (returns related to sales; bottom right) for the years 2009–2012 (data only available until July 2012).

2.1.3. Sorting analysis of food loss in selected retail outlets

The aim of the sorting analysis was to get a first insight into the reasons for food loss in retail outlets by classifying the reasons according to objectively identifiable criteria. It is pointed out that this investigation should provide a basis for identifying starting points for prevention measures and that representativeness was neither intended nor possible. On-site investigations were made in six selected retail outlets in Vienna and its surroundings. The selection covered larger retail outlets with different food loss rates, namely 4 retail outlets of type D with overall food loss rates of fruit & vegetables, dairy products and bread & pastry at 1.8%, 3.1%, 4.1% and 4.2% and two retail outlets of type E with overall food loss rates at 1.4% and 2.1%. A pretest was conducted in retail outlet D on Friday, March 8 in order to test the methodology. The analyses took place twice in each retail outlet, on two different days in April 2013 (Tuesday, April 2; Wednesday, April 3; Thursday, April 11 and Friday April 12). The data from the pretest were also included in the results.

The sorting analysis covered all food articles which had been removed from sale on the same day, not only fruit & vegetables, dairy products and bread & pastry but all assortment groups. Returns of bread & pastry were not included because they were automatically returned if not sold on the same day, assuming that they are only considered fresh on the day of production. In order to not interfere with work routines in the retail outlets, the sorting analyses were scheduled in cooperation with the outlet staff. The personnel of the retail outlets had been instructed not to change the state of the articles during their short storage, by carefully handling and storing them in shallow crates and providing sufficient cooling if necessary. On one day, only articles which were provided for social donation could be analysed in one retail outlet because the other articles had been discarded by mistake.

Each article was weighed with an accuracy of 0.01 kg, a photo was taken, and several criteria were recorded into a spreadsheet. Similar articles with apparently the same reasons were summarized. Article numbers and their classification were taken from already existing lists of removed articles which retail outlets have to keep regularly. Further criteria which were recorded were name and brand of the article, mass, presence of packaging (yes/no), information on net mass and net volume; number of pieces per packaging, best before, use-by or sell-by dates; information if the product had been offered at a reduced price; visual impression (OK, not OK) and detailed information on apparent flaws. The reasons were classified into 6 categories (see Table 6 and Section 3.4).

The number of articles could not be determined unambiguously, due to loose fruits and vegetables and discrepancies between the provided articles and the company's internal lists of removed products. Therefore, the frequency distribution of reasons was based upon net mass.

3. Results

3.1. Food loss rates

The first two columns in Table 1 show the food loss rates for each assortment group and in total by mass and monetary value. The overall loss of fruit & vegetables, dairy products and bread & pastry amounts to 2.8% by mass of the sales of these assortments or to 2.6% by monetary value. There is no great difference between the food loss rates by mass and by monetary value, except for bread & pastry. However, it has to be noted that data by mass, in particular for bread & pastry, are subject to data insecurities (see Section 2.1.2). Further results are therefore only presented in monetary values. The food loss rate of bread & pastry does not include returns of unsold bread to the bakers, which would additionally amount to 9.7% of the sales of bread & pastry. If returned bread is included, the food loss rate of bread & pastry will rise from 2.8% to 12.6% and the overall food loss rate from 2.6% to 4.8%.

In relative quantities, fruit & vegetables account for 53% of the total monetary value of food loss, dairy products account for 22% and bread & pastry for 25%. In addition, the quantity of returns of bread & pastry amounts to another 85% of the total food loss from all three assortment groups.

Table 1
Food loss rates by assortment group as sum of depreciation & breakage and donations (rate = loss related to sales), and the percentage of food loss which was donated to social services, summed up for 612 retail outlets during the period from September 2011 to August 2012.

Assortment	Σ Food loss rate (by mass) (%)	Food loss rate (by value)			Donations (% of food loss by value) (%)
		Σ Depreciation & breakage and donations (%)	Depreciation & breakage (%)	Dona-tions (%)	
Fruit & vegetable	4.19	4.25	4.15	0.10	2.30
Dairy products	1.14	1.27	1.06	0.21	16.32
Bread & pastry	3.99	2.83	2.59	0.24	8.41
Σ Total	2.84	2.57	2.39	0.18	6.97
Returns of bread & pastry	Data gaps	9.69	Not relevant		

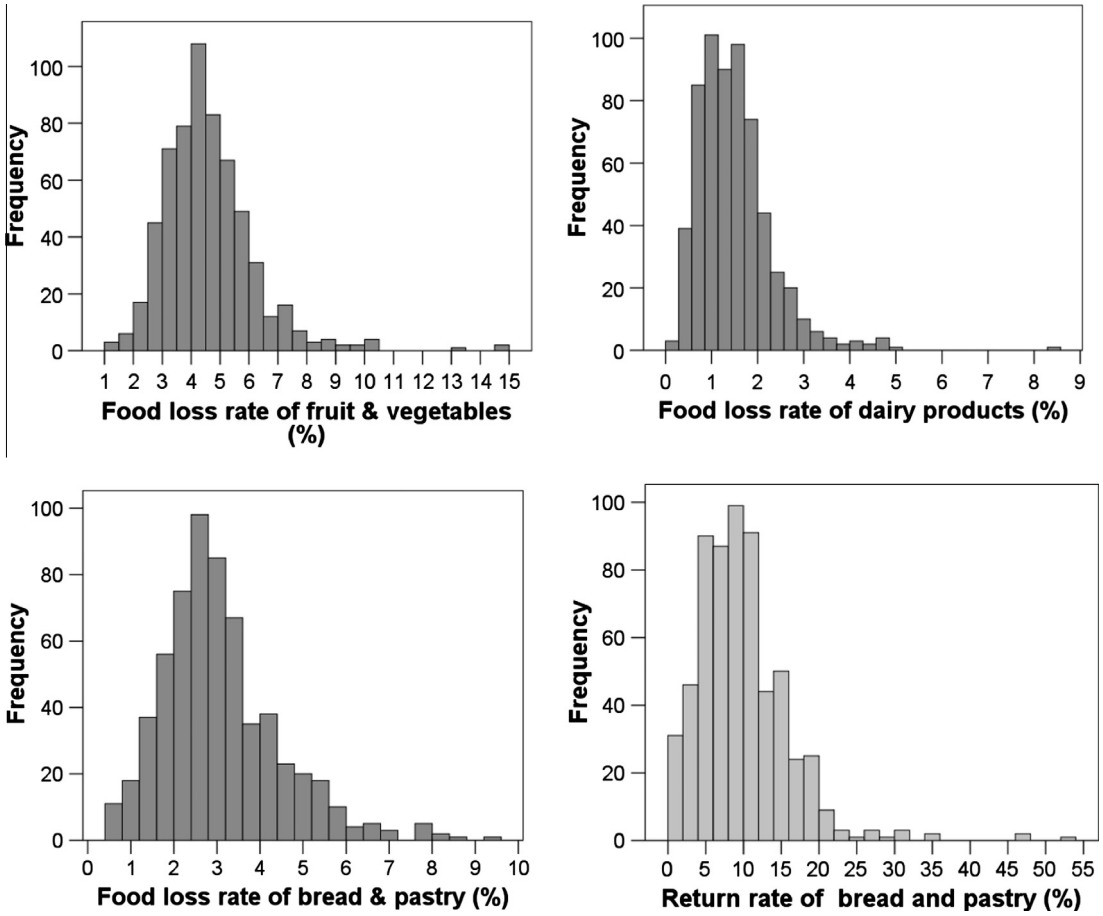

Fig. 2. Frequency distribution (histogram) of annual food loss rates of fruit & vegetables (top left), dairy products (top right), bread & pastry (bottom left) and return rates of bread & pastry (bottom right) in 612 retail outlets, rates by monetary value (cost price).

Food loss rates vary significantly among the individual retail outlets. Fig. 2 illustrates the distribution of the food loss rates for each assortment group and for the returns of bread & pastry. The food loss rates of fruit & vegetables range between 1.2% and 14.7%, those of dairy products between 0.2% and 8.4%, and those of bread & pastry between 0.4% and 9.6%. Altogether food loss rates of these three assortments range between 0.8% and 10.0%. In addition, the individual retail outlets return between 0% and 53% of unsold bread & pastry to the bakers (rate expressed as returned bread in cost price related to sales of bread & pastry in cost price).

Food loss rates exhibit seasonal variations, which is illustrated in Fig. 1. The graphs show similar patterns for each of the four compared years. In general, food loss rates of all assortment groups as well as rates of returns of bread & pastry reach a peak in December, around Christmas. Fruit & vegetables show the maximum food loss rates in the summer months between July and September, and their lowest food loss rates between January and March. Food loss rates of dairy products also increase during the summer months. In 2012 unusual high food loss rates of dairy products were observed in June and July. One possible impact might have been an unusual hot climate, as statistics indicate that June 2012 has been the fifth warmest June ever measured in Austria, and a heat-wave in the first days of July (ZAMG, 2012). The high temperatures may have led to an accelerated spoilage of dairy products and a surplus of certain products because of changed consumption patterns. However, these deviations cannot be clearly interpreted unless data for subsequent months are available.

3.2. Donations to social services

Only a small percentage of food loss is actually donated to social services and thus prevented from becoming waste. Table 1 shows

Table 2
Number of retail outlets (in % of a total of 609) which donated the respective rate of food loss (by monetary value) to social services, by assortment group and in total.

Donated rate of food loss (by value)	Relative number of retail outlets that donate the respective rate of food loss			
	Fruit & vegetables (%)	Dairy products (%)	Bread & pastry (%)	∑ Fruit & vegetables, dairy, bread & pastry (%)
0% (no donations)	53	41	42	38
Less than 5%	37	14	28	22
5–10%	3	4	10	14
10–15%	2	5	5	10
15–20%	2	4	3	6
20–30%	2	7	4	4
30–40%	0	6	3	2
More than 40%	1	17	6	3

Table 3
Kendall's tau-*b* correlation coefficients between food loss rates and characteristics of the retail outlets.

	Fruit & vegetables	Dairy products	Bread & pastry	Σ Fruit & veg., dairy, bread & pastry	Returned bread
Food loss rates (by value)					
Sales area (m^2)	−0.057*	−0.177*	−0.055*	−0.122**	−0.107**
Purchases per year	−0.198**	−0.377**	−0.307**	−0.323**	ns
Total sales° (€)	−0.307**	−0.491**	−0.337**	−0.449**	ns
Sales per assortment (€)	−0.312**	−0.480**	−0.311**		ns

°Sales of fruit & vegetables, dairy products and bread & pastry (in Euros cost price).
* Significance level: $p < 0.05$.
** Significance level: $p < 0.01$.

Table 4
Characteristic of different types of retail outlets and their mean food loss rates (by value) and assortment group.

Type of retail outlet	*n*	Mean sales area (m^2)	Purchases per year transformed[a]	∑ Fruit & veg., dairy, bread & pastry (%)	Fruit & vegetables (%)	Dairy products (%)	Bread & pastry (%)	Returns of bread & pastry (%)
Mean food loss rates								
A	11	243	1.41	3.2	5.1	1.6	3.3	9.6
B	47	486	1.25	2.8	4.4	1.4	2.5	15.1
C	416	539	0.85	2.9	4.7	1.6	3.3	9.7
D	102	1 165	1.28	2.6	4.3	1.2	2.8	8.8
E	36	1 743	1.52	2.3	4.3	1.0	2.2	7.5

[a] Data had to be encrypted due to data confidentiality. Numbers indicate the quotient of the mean per retail outlet and the overall mean, i.e. high numbers indicate above-average numbers of purchases, low numbers below average.

the amounts of food loss which were transferred to social services, expressed as percentage of sales (see last but one column) as well as of food loss (see last column). Overall 7% of the food loss was donated, with significant differences between the assortment groups. The highest percentage, i.e. 16.4%, was recorded for dairy products, the lowest (2.3%) for fruit & vegetables. Dairy products represent 53% of the total monetary value of all donated products, bread% pastry represent 30% and fruit & vegetables 17%.

The majority of retail outlets only donate a very small percentage of their food loss to social services or do not donate any products at all. Table 2 shows the frequency distribution of retail outlets pertaining to the donated rates for each assortment group. 38% of 609 retail outlets did not donate any products of the three assortments and only 25% transferred more than 10% of their food loss to social services. Again, differences between assortment groups are obvious. While 17% of the retail outlets donate more than 40% of the food loss of dairy products, only 1% of retail outlets donate more than 40% of fruit & vegetables.

Donation rates differ by geographic region, size of the retail outlet and urban/rural environment. Larger retail outlets as well as retail outlets in rural environments donate higher percentages of dairy products, bread & pastry and overall to social services than retail outlets in urban environments.

3.3. Correlation between food loss rates and characteristics of the retail outlets

Food loss rates show significant but only very low correlations with selected characteristics of the retail outlets. Sales, number of purchases per year and sales area show significant correlations among themselves, with a moderate correlation between sales and number of purchases (Kendall's tau $b = 0.583$) and low correlations between sales area and number of purchases (Kendall's tau $b = 0.305$) as well as between sales area and sales (0.396). Table 3 shows the values and significance of Kendall's tau-*b* correlation coefficients between food loss rates of the selected assortments on the one hand and sales area, purchases per year and sales on the other hand. Two measures of sales were used: total sales of fruit & vegetables, dairy products plus bread & pastry, and sales of the respective assortment. Food loss rates are declining with increasing sales area, increasing number of purchases per year and increasing sales. However, the correlation with sales area is very low. As for assortment, the food loss rates of dairy products show the highest correlation coefficients, while correlations are lowest for fruit & vegetables. Returned bread does not show significant correlations except for a marginal one with sales area. Group comparisons which used the classification of retail outlets from the original database and distinguished five types according to size (see Table 4) resulted that food loss rates of dairy products and bread & pastry are lower in larger retail outlets (type D and E). No significant differences were found for fruit & vegetables. Table 4 shows the food loss rates per assortment group for each different type of retail outlet.

Linear regression models were calculated in order to investigate the combined effect of the independent variables sales area, sales and number of purchases on the food loss rates of the individual assortments and in total. The regression models explain between

Table 5
Mean food loss rates of retail outlets in rural and urban areas and significance levels of the *t*-test.

	n (Number of retail outlets)	Food loss rates (by value, arithmetic means)				
		Fruit & vegetables (%)	Dairy products (%)	Bread & pastry (%)	Σ Fruit & veg., dairy, bread & pastry (%)	Returned bread (%)
Rural	449	4.6	1.6	3.2	2.9	8.8
Urban	163	4.6	1.4	2.7	2.7	12.5
Significance (*p*)		0.782ns	0.004*	0.000*	0.079ns	0.000*

ns... not significant.
* Significant: $p < 0.05$.

Table 6
Percentage of articles for which the respective reasons could be observed (% of the net mass of the food loss per assortment group), multiple reasons were possible.

Reason	Fruit & vegetables (%)	Dairy products (%)	Bread & pastry (%)	Others/unspecified (%)	∑ All assortment groups (%)
No apparent reason	1	1	2	3	1
Best before/use-by/sell-by date	18	78	98	57	34
Apparent flaws of the product	89	0	3	34	67
Part of the product is lacking	4	0	0	1	3
Damaged packaging	7	3	0	2	5
Breakage	0	18	0	9	3

Table 7
Relative frequencies of observed reasons for products labelled with regular prices and reduced prices (% of the net mass of the food loss per assortment group), sum per column = 100%.

Reason (*single reason, **combi nation of two or more reasons)	Fruit & vegetables		Dairy products		Bread & pastry	
	Reg. (%)	Red. (%)	Reg. (%)	Red. (%)	Reg. (%)	Red. (%)
No apparent reason*	0	3	3	0	2	0
Best before/use-by/sell-by date*	3	25	51	100	97	81
Apparent flaws of the product*	86	45	1	0	0	0
Date expired + apparent flaws**	5	12	0	0	1	19
Damaged packaging + additional reasons*	4	14	6	0	0	0
Breakage + additional reasons*	0	0	39	0	0	0
Others	2	1	0	0	0	0

18% (fruit & vegetables, bread & pastry) and 33% (dairy products) of the variance of the food loss rates per assortment, and 31% for the overall food loss rate. Sales had the highest influence on food loss rates, which had also been found by Eriksson et al. (2014) for meat and dairy. However, the low coefficients of determination indicate that the investigated characteristics of the retail outlets can only explain a small percentage of the variation. Therefore, food loss rates are assumed to be influenced by further factors, such as organizational aspects, individual behavioural aspects of the staff and situation specific aspects. There is evidence that food loss rates of the assortments even differ within a single retail outlet, since food loss rates between assortment groups only show low correlations. The correlation coefficient Kendall's tau-*b* between the food loss rate of fruit & vegetables and dairy products is 0.361, between fruit & vegetables and bread & pastry 0.292, and between dairy products and bread & pastry 0.370. This indicates that a high food loss rate of one assortment group does not necessarily involve a high food loss rate of another assortment group. Returned bread does not correlate significantly with any of the three assortments.

Food loss rates also show significant differences by geographic region and urban/rural environment. Table 5 compares the mean food loss rates for retail outlets in urban and rural environments. Retail outlets in a rural environment have significantly higher food loss rates of dairy products and bread & pastry, but lower rates of returned bread than retail outlets in an urban environment.

3.4. Reasons for food waste – results of the sorting analysis

The list of all sorted articles comprised 451 datasets with a total net mass of 387.1 kg and 1054 individual pieces. Fruit & vegetables represent 68% of the total net mass, dairy products 6%, bread & pastry 7%, and the remaining 19% are accounted for other assortment groups (beverages, meat, instant meals, candies) or products which could not be classified due to unknown article numbers. 78% of all products were available in packaging (71% of fruit & vegetables, 100% of dairy products and bread & pastry, 89% of other products) and 22% had no packaging.

Table 6 shows the reasons for food loss in the different assortment groups. Multiple reasons could have been recorded for one article. Considering all assortment groups, apparent flaws of the product were the most frequent reason, which was observed for two thirds of all products. The best before or sell-by date had been exceeded or reached by one third of all articles. None of the analysed articles had been labelled with a use-by date. Articles usually had been removed from sales the day after the respective date had been exceeded. Only 1.3% of all articles had already been removed on the same day. The other reasons were less important. "Damaged packaging" indicates that the packaging has been damaged, but the product itself has remained intact (e.g. an opened tray of apples), while "breakage" indicates that both the packaging and the product have been damaged (e.g. a smashed cup of yoghurt).

The reasons differ by assortment group (see Table 6). Unlike the other product groups in which every article was labelled with a best before date, 50% of fruit & vegetables did not show any date label. Only 9% of the net mass of discarded fruit & vegetables were labelled with a best before date, 18% had a sell-by date and 23% a packaging date. Therefore the expiration of product dates was a less frequent reason than for other product groups. If only fruit & vegetables which are labelled with a date are considered, 95% of products which had a best before date had exceeded their date, and 51% of the products labelled with a sell-by date. Apparent

Table 8
Comparison of food loss rates of the present study to literature data.

Reference	Country	Reference base	Product group	Food loss rate (%)
Present study	Austria	Sales in cost price	Fruit & vegetables	4.3
Beretta et al. (2013)	Switzerland	Volumes of sales	Fruit & vegetables	8–9
Buzby and Hyman (2012)	US	Food supply value	Fruit	9
			Vegetables	9
		Supply mass per capita	Fruit	9
			Vegetables	8
Hanssen and Schakenda (2011)	Norway	Total turnover	Fruit and vegetables	5.1
EHI (2011)	Germany	Not specified	Fruit and vegetables	3.4–7.0 Average: 5.1
Eriksson et al. (2012)	Sweden	Delivered quantity (mass)	Fruit and vegetables	4.3
WRAP (2011)	U.K.	Total value	Selected fresh produce types	0.5 to 1 (Onion) 2.5 to 5 (Avocado)
Buzby et al. (2009)	U.S.	Supplier shipment data	Fruit	10.7 (2005) 8.4 (2006)
			Vegetables	10.3 (2005) 8.4 (2006)
Present study	Austria	Sales in cost price	Dairy products	1.3
Buzby and Hyman (2012)	US	Food supply value	dairy products	9
		Supply mass per capita	dairy products	11
Eriksson (2012)	Sweden	Mass sold in tons	Dairy	0.3 (2011)
			Cheese	0.5 (2011)
Hanssen and Møller (2013)	Norway	Turnover in economic value	Fresh milk products, fresh cheese	1.6 (2012)
EHI (2011)	Germany	Not specified	Dairy products	0.9–3.4 Average: 1.6
Present study	Austria	Sales in cost price	Bread & pastry	2.8 12.5% (with returns)
Buzby and Hyman (2012)	US	Food supply value	Grain products	12
		Supply mass per capita	Grain products	12
Hanssen and Schakenda (2011)	Norway	Total turnover	Bread & pastry	6.4
EHI (2011)	Germany	Not specified	Bread & pastry from self service	0.8–1.4 average: 1.0
			... From self service with returns	7.9–13.2 average 10.4
			... From in-house bakery	3.8–9.6 average 6.5

flaws were the main reason for fruit & vegetables, while this reason was not relevant for dairy products and bread & pastry. In detail 54% of the removed fruit & vegetables had changed colour, 52% had dents, 39% were overripe, 34% were mouldy, 29% were withered and 18% were moist (multiple criteria were possible here). Bread & pastry were usually not offered for sale any longer when the best-before or sell-by date was reached. This reason was also the most important for dairy products. Breakage is also a relevant reason for the loss of dairy products.

In a further step, each article was also classified based on its combination of reasons. Though multiple reasons were possible, only one reason was identified for the majority of removed articles (87%). Two reasons were identified for 8% of the articles. Considering all assortment groups, 56% of all articles (75% of fruit & vegetables, 0% of dairy products and bread & pastry, 30% of other products) had been removed from sales solely on the ground of apparent flaws, 28% (9% of fruit & vegetables, 78% of dairy products, 96% of bread & pastry, 54% of other products) solely because of exceeding best before or sell-by date. About 7% of all articles (9% of fruit & vegetables, 0% of dairy products, 3% of bread & pastry, 2% of other products) were removed because of exceeding the best before or sell-by date and simultaneously one or more additional reasons.

27% of all products were labelled with reduced prices, or 27% of fruit & vegetables, 55% of dairy products, 8% of bread & pastry and 24% of other products. Table 7 compares the frequencies of observed reasons for discarded products labelled with regular prices and reduced prices for the main assortment groups. Reduced-price fruit & vegetables were less frequently discarded because of apparent flaws and comprised a higher proportion of items in damaged packaging than regular-priced items. All discarded dairy products labelled with reduced prices had exceeded their best before date, whereas breakage and damaged packaging was the reason for nearly half of the discarded regular-priced items.

4. Discussion

Table 8 compares food loss rates of the present study to available literature data. It is important to note that results of different studies usually cannot be exactly compared due to different definitions, methodologies and reference bases (e.g. supplier shipment data or sales data, in terms of mass or monetary value). Furthermore essential methodological details are not always provided. The food loss rate of fruit & vegetables in the present study ranks at the lower end of the range of literature data. Literature data for dairy products and bread & pastry are very diverging. While food loss rates for dairy products in Norway (Hanssen and Møller, 2013) and Germany (EHI, 2011) were similar to the results of the present study, and food loss rates of dairy products in Sweden (Eriksson, 2012) were lower, the study of Buzby and Hyman (2012) in the US found a striking high rate. Food loss rates of bread & pastry in the present study are higher than rates for self-service reported by EHI (2011), but lower than rates for in-house bakery/baking facilities. However, considering that the data of the present study include both food losses from self-service and in-house bakery/baking facilities, food loss rates of both studies can be assumed to be in a similar order of magnitude.

Although returns of bread, i.e. unsold bread & pastry does not constitute any waste or monetary loss from the perspective of the retail outlets, because they are sent back to the bakeries and do not have to be paid for, they are relevant from the perspective of sustainability and waste management due to their high

quantities. Some retailers, like discount shops, have taken care of the disposal of their waste bread themselves (Scherhaufer and Schneider, 2011). If losses have to be discarded at own expense, this will create an incentive for the retail outlet to minimize losses by optimizing demand planning and ordering. Additional measures should be considered such as awareness raising and information of clients or an adaption of the display for sale at the end of the day when stocks are decreasing (Scherhaufer and Schneider, 2011).

Though significant correlations between food loss rates and sales area, number of purchases per year, sales, market type and location of the retail outlet in a rural or urban area could be identified, their low influences indicate that structural characteristics cannot sufficiently explain the differences between retail outlets. Food loss rates show a large variation between individual retail outlets, even within the same market type. These results indicate that food loss rates mainly depend on other influences such as different work routines or demands planning and ordering (cf. Eriksson et al., 2014), which had also been mentioned by regional managers in discussions during the project. Other potential influences discussed in the literature are turnover, shelf-life and wholesale pack size as well as customer preferences or accidental causes (Eriksson et al., 2014; Eriksson, 2012). The large differences of food loss rates suggest that food loss rates could be significantly reduced in several individual outlets (cf. Hanssen and Schakenda, 2011). As a comprehensive database is available, the histograms of food loss rates could be used as basis for a benchmarking within the retail company, by scrutinizing differences in framework conditions and work routines between outlets with low and with high food loss rates. Thus, best practices could be identified and transferred to other outlets (cf. Eriksson et al., 2012). Education and information of employees as well as awareness raising are important aspects in this connection (cf. Scherhaufer and Schneider, 2011).

Donation to social institutions is an option for those articles which are still safe to consume, but have been removed from sales (cf. Schneider, 2013a). The results of the present study show that a high proportion of retail outlets have not yet made use of this possibility at all. Though donated articles represent a loss for the company from a business point of view because of a loss of revenues and potentially additional costs for storage area and working time (Eriksson and Strid, 2013), the donation to social services is beneficial from a waste management point of view. It reduces waste quantities and waste management costs (Alexander and Smaje, 2008; Schneider, 2013a) and can contribute to a positive image of the company, not to mention the social benefits for the clients of these services. In addition, the company saves CO_2-equivalents by donating articles which would otherwise have been wasted. Dairy products require about 3500 g CO_2-equivalents per kilogram for their production, processing, packaging, storage, transport and trading which is higher than for fruit & vegetables (320 g CO_2-equivalents per kg) and bread & pastry (830 g CO_2-equivalents per kg) (Schneider et al., 2013). Hence the current donation of 16% of the food loss of dairy products to social services can be regarded as beneficial for the environment. In practise, existing on-site boundary conditions such as the regional demand for donated products, the logistic effort or the company's costs have to be considered and may reduce the theoretic prevention potential (Salhofer et al., 2008; Schneider, 2013a).

The sorting analysis of the discarded products provided a first insight into the reasons for food waste and into differences between assortment groups. The majority of articles had been removed from sale due to apparent flaws. However, there was even no apparent reason at all for 1% of articles, and 28% did not show any flaws besides the expiration of the best before or sell-by date. That was particularly relevant for dairy products and bread & pastry. One strategy of retail outlets for preventing food waste is to offer products at reduced prices (cf. Hölzl, 2014; Scherhaufer and Schneider, 2011) just before they reach their best before or sell-by date, or when they show minor visual flaws which do not affect product quality. This strategy is also already being used by the investigated retail outlets. The sorting analysis showed that about one quarter of discarded products had been labelled with a reduced-price sticker, more than half of the dairy products, but only 8% of bread & pastry. From these data no conclusions can be drawn about the effect of price-reductions on food waste quantities. Additional information would be required, pertaining to the quantity of articles offered at reduced prices or the exact time when an article was price-reduced (how many days in advance of reaching the best before date). This information was not included in the present study but would be worth considering in future research. However, the fact that retail companies have been using this strategy indicates that it is beneficial and cost-effective, since supermarkets have to be profitable (Eriksson, 2012).

Apparent flaws were the main reason for the discard of fruit & vegetables. Packaged articles such as a tray of apples are often discarded if a single piece of its contents is spoilt. The investigated retail company has been testing a new procedure, in which packages are opened, spoilt items removed and the remaining items are sold loose. Compliance with legal requirements such as product traceability or hygiene standards was clarified and ensured in advance. At present, there is no information about the effect of this measure, as this pilot trial has just started. Dairy products are mainly discarded when their best before date has expired, but also breakage and damages of the packaging are relevant. About one fifth of dairy products are discarded for this reason. It has to be considered that damages are caused both by employees and by customers and that prevention measures such as careful handling routines are primarily aimed at the former.

The overall food loss rate of the included assortment groups fruit & vegetables, dairy products and bread & pastry amounted to 2.6% of the sales of the respective assortment groups, or to 4.8% if returns are included. By comparison, private households spend a higher proportion of their household expenditures for food which is later discarded uneaten. For Germany, Kranert et al. (2012) estimated that the monetary value of food wasted by an average household amounted to 10–14% of the household expenditures for food and non-alcoholic beverages. Though these data are comparable only to a limited degree, they indicate that retail handles food more efficiently than private households. Nonetheless there is still potential for optimization which has been recognized by retail companies (cf Tesco, 2013; Hölzl, 2014).

5. Conclusions

The food loss rates found in the present study are similar to the results of previous publications with the restriction of only limited comparability. Food loss rates vary by assortment group and amounted to 1.3% for dairy products, 2.8% for bread & pastry and 4.2% for fruit & vegetables. Unsold bread & pastry which is returned to the producers amounted to additional 9.7% of the sales of bread & pastry. Shifting the responsibility for unsold bread & pastry from bakeries to the retail company would provide an incentive for the retail outlets to reduce these high quantities of wasted bread, for example by optimizing demand planning and ordering and providing specific information to the supermarket customers.

Food loss rates are declining with increasing sales areas, increasing numbers of purchases per year and increasing sales of the retail outlet. However, correlations are low and these variables explain not more than 33% of the variation of food loss rates, which indicates that food loss rates are rather influenced by other factors

such as human factors. The results also show that a retail outlet with a poor performance in food loss of one assortment group could have a better performance for another assortment group.

From a methodological point of view the large differences even between retail outlets with similar characteristics indicate that extrapolating data obtained from only a small sample may produce biased results. From a practical point of view, the differences between retail outlets could be used for optimizing work routines in less efficient retail outlets by identifying best practices and appropriate training and instructions of the employees. In this context, the high staff turnover in retail represents a major challenge.

More than a quarter of articles which had been removed from sale did not show any flaws besides the expiration of the best before or sell-by date. Such products could be offered at reduced prices, as is already the practice in retail outlets. However, additional research and data are necessary in order to evaluate the effect of this measure on food loss and to determine if there is potential for extending price reductions. Another possibility for articles which are still safe to consume, but have been removed from sales, is their donation to social services. At present, only 7% of the food loss is donated to social services, and 38% of the retail outlets do not use this possibility at all. Cooperation between retail outlets and social services should be expanded wherever reasonable in order to prevent waste and safe CO_2-equivalents.

A comparison of food loss rates from retail to private households indicates that retail is already more effective than private households. However, there is still potential for a further reduction, as the results showed and as also current efforts of retail companies all over Europe indicate. Future prevention approaches should focus on returns of bread & pastry (shifting responsibilities from bakeries/producers to retail companies), internal optimization (benchmarking among retail outlets within a company and application of best practices), training, information and education of employees, awareness raising and information of customers and increasing cooperation with social services. The retail company which was subject of the present study has meanwhile initiated further steps towards food waste prevention.

Further research should enlarge the database by including other assortment groups concerning food (such as meat, beverages, candies, instant meals ...) and further retail companies. A research project which includes all assortment groups and the majority of retail companies in Austria is being carried out in order to quantify the contribution of food retail to overall food waste quantities along the food supply chain. Further research on reasons for food loss should include a larger sample size as well as additional data, for example on price reductions.

Acknowledgements

The authors wish to thank the retail company for funding and supporting the study as well as provision of data, and their colleagues Katharina Böhm and Silvia Scherhaufer who were responsible for the initial screening of the data and identification of the analysed time-span (Ms. Böhm) and for the ecological assessment (Ms. Scherhaufer) in the research project.

References

Alexander, C., Smaje, C., 2008. Surplus retail food redistribution: an analysis of a third sector model. Resour. Conserv. Recycl. 52, 1290–1298.

Beretta, C., Stoessl, F., Baier, U., Hellweg, S., 2013. Quantifying food losses and the potential for reduction in Switzerland. Waste Manage. (Oxford) 33 (2013), 764–773.

Buzby, J.C., Hyman, J., 2012. Total and per capita value of food loss in the United States. Food Policy 37 (2012), 561–570.

Buzby, J.C., Farah Wells, H., Axtman, B., Mickey, J., 2009. Supermarket loss estimates for fresh fruits, vegetables, meat, poultry, and seafood and their use in the ERS loss-adjusted food availability data. Economic Information Bulletin Number 44, United States Department of Agriculture, Economic Research Service, Washington, USA.

EHI, 2011. Nahrungsmittelverluste im Lebensmitteleinzelhandel (food losses in the grocery retail segment). EHI Retail Institute GmbH Köln.

Eriksson, M., 2012. Retail food wastage: a case study approach to quantities and causes [Licentiate thesis 045] Swedish university of Agricultural Science, Uppsala, Sweden). (April 16, 2014) <http://pub.epsilon.slu.se/9264/1/eriksson_m_121126.pdf>.

Eriksson M., Strid I., 2013. Svinnreducerande åtgärder i butik. (April 24, 2014) <http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6594-2.pd>.

Eriksson, M., Strid, I., Hansson, P-A., 2012. Food losses in six Swedish retail stores: wastage of fruit and vegetables in relation to quantities delivered. Resour Conserv Recycl 68, 14–20.

Eriksson, M., Strid, I., Hansson, P.-A., 2014. Waste of organic and conventional meat and dairy products – a case study from Swedish retail. Resour. Conserv. Recycl. 83, 44–52.

Hanssen, O.J., Møller, H., 2013. Food Wastage in Norway 2013. Status and Trends 2009-13. Report No. OR32.13, Comissioned report. http://www.fao.org/fsnforum/cfs-hlpe/sites/cfs-hlpe/files/resources/Food%20Waste%20in%20Norway%202013%20-%20Status%20and%20trends%202009-13.pdf (April 16, 2014).

Hanssen, O.J., Schakenda, V., 2011. Nyttbart matavfall i Norge–status og utviklingstrekk 2010. Østfoldsforskning, Norway, ISBN 978-82-7520-636-5.

Höbaus, E., Michltis, V., Domschitz, J., 2012. Lebensmittel in Österreich Zahlen-Daten-Fakten 2011 (food in Austria, figures – data- facts). Federal Ministry of Agriculture, Forestry, Environment and Water Management (Editor), Vienna. (Dec. 10, 2013) <http://www.lebensministerium.at/publikationen/lebensmittel.html>.

Hogan J., Cunnigham D., Finn J., 2004. Characterisation of Non-Household Municipal Waste in Ireland and the Development of an Approach to Tracking Municipal Waste Composition. Final Report, Environmental Protection Agency, Irland.

Hölzl F., 2014. Umgang mit Lebensmittelabfällen aus der Sicht der Supermärkte (Handling of food waste from the point of view of supermarkets). Presentation at the Innsbrucker Abfall- und Ressourcentag 2014. Österreichischer Wasser- und Abfallwirtschaftsverband. (April 24, 2014) <http://www.oewav.at/Page.aspx?target=171973#show_171973>.

Kranert, M., Hafner, G., Barabosz, J., Schuller, H., Leverenz, D., Kölbig, A., Schneider, F., Lebersorger, S., Scherhaufer, S., 2012. Ermittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur Verminderung der Wegwerfrate bei Lebensmitteln in Deutschland (Determination of discarded food and proposals for a minimization of food wastage in Germany). ISWA, Stuttgart, Germany.

Salhofer, S., Obersteiner, G., Schneider, F., Lebersorger, S., 2008. Potentials for the prevention of municipal solid waste. Waste Manage. (Oxford) 28 (2008), 245–259.

Scherhaufer, S., Schneider, F., 2011. Prevention, recycling and disposal of waste bread in Austria. Proceedings Sardinia 2011, Thirteenth International landfill Symposium, CISA publisher, Cagliari, Abstract, 15–16. Full paper on CD.

Schneider, F., 2013a. The evolution of food donation with respect to waste prevention. Waste Manage. (Oxford) 33, 755–763.

Schneider, F., 2013b. Review of food waste prevention on an international level. Water Resour Manage 166, 187–203.

Schneider F., Lebersorger S, 2009. Households attitudes and behaviour towards wasting food - a case study. In: Cossu R., Diaz L.F., Stegmann R. (Eds.), Sardinia 2009 Twelfth International Waste Management and Landfill Symposium, (5–9 October 2009, S. Margherita di Pula - Cagliari, Sardinia, Italy). Executive Summaries, CISA Environmental Sanitary Engineering Centre. Abstract, pp. 831–832. Full paper on CD.

Schneider, F., Lebersorger, S., Scherhaufer, S., 2013 Food waste at the food retail - statistical approach to identifying influencing factors. In: Cossu, R., He, P., Kjeldsen, P., Matsufuji, Y., Reinhart, D. Stegmann R. (Eds.): Sardinia 2013 – Fourteenth International Waste Management and Landfill Symposium, CISA publisher. Cagliari. Abstract, 59. Full paper on CD.

Stare, M., Johansson, M., Dunsö, O, Stenmarck, A., Jensen, C. (2013). Förbättrade matavfalls-faktorer för verksamheter. (June 12th, 2014) <http://www.smed.se/wp-content/uploads/2013/04/Slutrapport1.pdf>.

TESCO, 2013. Tesco and Society – Using our scale for good. 2013/14 half year update report. (January, 23rd, 2014) www.tescoplc.com/files/pdf/reports/tesco_and_society_2013-14_halfyear_summary.pdf.

WRAP, 2010. Waste arisings in the supply of food and drink to households in the UK. Final report. (March 22nd, 2014) http://www.wrap.org.uk/sites/files/wrap/Waste%20arisings%20in%20the%20supply%20of%20food%20and%20drink%20toUK%20households,%20Nov%202011.pdf.

WRAP, 2011. Fruit and vegetable resource maps. Final report. (May 3, 2013) <http://www.wrap.org.uk/sites/files/wrap/Resource_Map_Fruit_and_Veg_final_6_june_2011.fc479c40.10854.pdf>.

ZAMG, 2012. Zentralanstalt für Meteorologie und Geodynamik. Monatsrückblick. (Central Institute for Meteorology and Geodynamics. Monthly review) Austria. (Dec. 10, 2013) <http://www.zamg.ac.at/cms/de/klima/klima-aktuell/monatsrueckblick>.