Waste and Resource Management
Volume 166 Issue WR4

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Schneider

ice | proceedings

Proceedings of the Institution of Civil Engineers
Waste and Resource Management 166
November 2013 Issue WR4
Pages 187–203 http://dx.doi.org/10.1680/warm.13.00016
Paper 1300016
Received 22/04/2013 Accepted 10/06/2013

Keywords: environment/reviews/waste management & disposal

ice Institution of Civil Engineers
publishing

Review of food waste prevention on an international level

Felicitas Schneider MSc
Research assistant, Institute of Waste Management, BOKU-University of Natural Resources and Life Sciences, Vienna, Austria

Research on food waste is a topic of paramount significance, which is also reflected in a growing number of reports and scientific papers published online as well as in scientific journals. The aim of the present paper is to summarise published, international research on food waste prevention with respect to different countries and segments along the food supply chain to indicate where such information is available. The focus is on papers in English. It was found that a large amount of information is available in regions such as North America, Western Europe and to a lesser extent in Australia and Northern Europe, whereas elsewhere there is a distinct lack of food waste related publishing in English. Agricultural information can be gathered from most developing countries, but household waste is generally investigated within industrialised regions. Some topics have so far not been targeted sufficiently, for example methodology, definitions, logistics, wholesale and redistribution.

1. Introduction

The availability of sufficient healthy food is essential for the survival of the human species. Despite its importance, a large amount of edible food is wasted along the food supply chain owing to overstated expectations, ineffective technical and management systems, and other causes. Besides ethical issues, the wasting of edible food leads to negative economic, environmental and social impacts. In some cases these effects cannot be quantified in detail owing to a lack of relevant data on the interaction of food wastage and socio-economic consequences. That research on food waste is increasing is reflected in an increasing number of studies and scientific papers published online as well as in scientific journals.

One of the first pieces of scientific literature which included information on wasted food from households, albeit from a nutritional point of view, was published by Atwater (1895) at the end of the nineteenth century. Quantitative information on wasted food was given together with an appeal for further research. Later scientific papers dealt mostly with the generation of food waste with respect to its utilisation to biogas or to compost. There was no determination as to whether the food was edible at the time when, or at any time before, it was wasted. In the late 1980s food waste prevention issues arose again tentatively in scientific literature, and since 2005 more information has become available.

The aim of the present paper is to summarise published international research on food waste prevention with respect to different countries and segments along the food supply chain to indicate where such information is available. The aim is not to compare data in detail. Technical terms used to define wasted food have been adopted from original literature. Therefore, within the text the terms 'food loss' as well as 'food waste' are used.

2. Definition and boundary issues with respect to food waste

Although notable research institutions have dealt with the topic of food waste prevention, there is presently no agreement on a consistent definition of food waste with respect to prevention. The problem of definition starts with the description of what 'food' is. For example, when considering the definition in Regulation (EC) No. 178/2002 (European Commission, 2002) on general principles and requirements of food law, 'food' includes

> any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans … and does not include … (b) live animals unless they are prepared for placing on the market for human consumption; (c) plants prior to harvesting …

The following problems are encountered.

- In some countries, cultural mores mean that specific products are not commonly intended to be ingested by humans (e.g. animal lungs or other offal), while in other countries these products are used for human consumption.
- Animals which die or are killed before they are placed on the market are not seen as food. This means that, for

example, male calves which are killed because they cannot be used for milk production, or male chicks which are killed because they cannot be used for egg production are not included as wasted food resources since they also are not intended to be placed on the market for human consumption.
- Plants which are not harvested due to a low market price or because they do not fulfil visual quality standards (e.g. size, colour) could also not be counted as wasted food as they are prior to harvest.

This means that wider definitions for food than existing, official ones have to be created to capture the extent of wasted food. The next challenge is which term to use for the wasted food (which could be prevented). Several terms are used in international literature, such as food loss (e.g. Gustavsson *et al*., 2011; Kummu *et al*., 2012), food waste (e.g. Defra, 2010; Williams and Kelly, 2003), post-harvest loss (e.g. Hodges *et al*., 2011), kitchen waste (e.g. European Commission, 2004; Lebersorger and Salhofer, 2003), food and drink waste (e.g. Griffin *et al*., 2009; Wrap, 2010), spoilage (e.g. Lundqvist *et al*., 2008) and so on. Of course, an additional dimension arises when a term used is translated from one language into another, and particularly from the author's native language into English for international publishing.

A major part of the literature which considers prevention issues subdivides the wasted food into a part that could be targeted through prevention measures and another part that could not be targeted by those measures. In most cases, terms such as 'avoidable/edible' and 'non-avoidable/inedible' food waste are used for these subcategories. But other criteria could equally be applied, such as suitability for separate bio-waste collection, which varies depending on input regulations, because animal products may be excluded. Lebersorger and Schneider (2011) give an overview of different options to classify food waste and discuss the pros and cons.

As well as the food which is thrown away and therefore is not eaten by humans, some researchers also include over-nutrition as food waste. Over-nutrition is defined as the gap between the energy value of food consumed per capita and the energy value of food needed per capita. This approach was introduced by Smil (2004) and several authors mention this issue within their papers (e.g. Blair and Sobal, 2006; Parfitt *et al*., 2010). Although obesity is an increasing health problem, and not only in industrial countries, the consideration of over-eating with respect to food wastage leads to considerable practical implementation problems. First of all, obesity may have medical causes rather than the intake of too many calories. The stigmatisation of overweight people as food wasters seems to be unfair. How should the share of over-eating be targeted in general consumer awareness campaigns against food waste? Where is the balance so as not to induce anorexia by denouncing over-eating? How should people who have higher than average base metabolism rates due to natural constitutions (e.g. hardgainers), illness or sport activities be handled? Are they allowed to eat more than the calculated energy ration? A number of ethically sensitive questions arise with respect to these issues, and in practice the fight against obesity should spotlight the negative impact on human health and resulting economic damage due to increased health-care costs and so on.

However, even if literally the same term is used within the same language, the wasted food which is classified within this term may vary a lot. It may also consider the packaging material in which the food was wasted. It may not be clear if the inedible parts (e.g. banana peel) of wasted edible food (e.g. whole banana) have been subtracted mathematically. Thus, it is necessary to read the definitions very carefully before a comparison of results can be made. Unfortunately, a comprehensive definition of the targeted wasted food can rarely be found in the scientific literature.

Along with the definition of food waste and the avoidable part of food waste, the methodology used is essential for the quantification and qualification of food waste and has an inseparable impact on the results. If the methodology used cannot measure the defined food waste streams, it should be clearly mentioned within the description of the study. Often there is a discrepancy between theoretically defined food waste and the information that can be collected in practice. The generation of detailed food waste data is often limited by financial restrictions, which impact sample sizes or the level of detail (e.g. investigation on wastage at single product level is not possible).

3. Overview of the scientific literature on food waste

The following section highlights the regional scientific literature that can be found with respect to food waste research along the food supply chain. Owing to the increasing number of reports and papers, as well as the multilingual nature of the available literature, a complete list is not feasible. The overview mentions the most important papers and those dealing with special topics or including a good literature summary of the respective region.

3.1 Global and supra-regional studies

Many studies summarise trans-national results of other studies, compare data and conclude which measures should be implemented to change the situation with respect to wasted food (Table 1). According to Parfitt *et al*. (2010), the Food and Agriculture Organisation (FAO) had already included the reduction of food losses in its established mandate. The Special Action Programme for the Prevention of Food Losses was implemented in 1974 to achieve a 50% reduction of post-harvest losses by 1985. There followed an abundance of

literature funded or conducted by the FAO (e.g. FAO, 1980; FAO *et al*., 2012). Sibrián *et al*. (2006) developed a statistical procedure for estimating dietary energy intake based on dietary energy consumption adjusted for household food wastage where data for the equation can be taken from national statistics. The issue of food wastage at European Community level based on existing data and policy options according to different scenarios was highlighted by Monier *et al*. (2010). Gustavsson *et al*. (2011), on behalf of the FAO, estimated food losses and wastes occurring along the entire food chain and identified causes and possible methods of prevention for different regions of the world. Golob *et al*. (2002) criticised the data given by the FAO as too generalised; in their opinion food losses depend strongly on the specific food commodity and local conditions. To support their conclusion, Golob *et al*. (2002) provide information on grain storage losses in different countries such as Kenya, Bangladesh, India, Malawi, Nepal and Turkey.

Table 1 presents the mentioned studies along with information on the covered stages of the food supply chain. Agriculture means primary production of food on the field and also includes aquaculture. The processing step includes processing of primary food products such as packaging, peeling, cooking and so on, while trade summarises wholesale as well as retail. The hospitality sector encompasses hotels, catering, canteens, restaurants, hospitals and so on. The consumer level deals with private households. As space is limited, the table summarises general information, whereas details have to be taken from the reviewed literature.

3.2 Africa

With respect to food waste or food losses along the African food supply chain, research results are generally published by international organisations within in-house reports which can be easily accessed by way of the internet (Table 2). Some of that information is published by the FAO, which raises awareness of the problem as well as providing practical manuals for loss prevention (e.g. Akande and Diei-Ouadi, 2010; FAO and World Bank, 2010). Another example is the World Bank, who introduced the Global Agricultural and Food Security Programme in 2010, dealing with the combat of post-harvest losses. In 2011, an overview of post-harvest grain losses in Sub-Saharan Africa was released by the World Bank, highlighting amounts, reasons, reduction options, barriers for prevention and other issues (World Bank, 2011).

Food waste from the in-flight catering of Egypt air flights was one topic of El-Mobaidh *et al*. (2006), who differentiated according to flight distance and meal type. Tefera *et al*. (2007) studied the effects of inexpensive post-harvest treatment options to minimise post-harvest mango losses in Ethiopia. In 2012, Nahman *et al*. (2012) published an estimate with respect to the costs related to household food waste in South Africa.

3.3 America

3.3.1 North America

Table 3 shows an overview of selected food waste studies from Northern American countries. One of the first remarkable US publications after those of Atwater (1895), as well as Atwater and Bryant (1902), was the study of Kantor *et al*. (1997). It presented amounts of food losses along the food supply chain subdivided into different food commodities, reasons for wastage, potential for prevention, as well as specific prevention measures. One year before Kantor *et al*.'s study, a guideline was published by the US Department of Agriculture (USDA) with the aim of fostering the recovery of food by raising awareness and expanding the knowledge of communities, individuals and companies in practice (USDA, 1996). The guideline highlighted

Source	Agriculture	Processing	Trade	Hospitality	Consumer
FAO (1980)	Detailed analysis of food loss and waste causes, measurement methods				
Golob *et al*. (2002)	Provides information on grain storage losses in different countries (in %); critically discusses FAO extrapolations				
Sibrián *et al*. (2006)					Statistical procedure for estimating dietary energy intake based on dietary energy consumption adjusted for household food wastage
Monier *et al*. (2010)	Food wastage at European Community level based on existing data and policy options according to different scenarios (in t, kg/cap)				
Gustavsson *et al*. (2011)	Estimates food losses and wastes along entire food chain, identifies causes, possible methods of prevention for different regions, in kg/cap year, total tonnes, in % of production per commodity group, region and stage of food supply chain				
FAO *et al*. (2012)	General discussion about food losses and waste, and context to food access and undernourishment				

Table 1. Overview of selected global or supra-regional food waste studies

existing food recovery initiatives and gave information on how to establish new ones. It also should be mentioned that the largest domestic hunger-relief organisation is Feeding America, which is a national network of more than 200 food banks operating within all 50 states as well as the District of Columbia and Puerto Rico. In 2012, it coordinated the distribution of edible food and grocery products with the help of 61 000 agencies, supplying 37 million people in the USA (Schneider, 2013). In 2001, Rathje and Murphy (2001) published the results of their garbage studies in the book *Rubbish*, which included food waste dug out from different US landfills. Plate waste from hospital patients was investigated, for example, by Kandiah *et al*. (2006) in the USA. Nunes *et al*. (2008) as well as Buzby *et al*. (2011) investigated losses of different food items in the trade sector and at household level in more detail, whereas Buzby *et al*. (2009) is limited to the retail sector. Fish *et al*. (2009) focused on the utilisation of unmarketable water melons left in US fields owing to surface blemishes or because they were misshapen, while Castro-Garcia *et al*. (2009) investigated the impact of harvest technology on table olives.

Meanwhile, the USDA regularly publishes data on food waste losses. These are often the basis for studies estimating the environmental impact of food waste in the USA, such as Venkat (2011) or Cuellar and Webber (2010). Hall *et al*. (2009) compared the percentage of available food energy wasted, as calculated by USDA estimates, and predicted food wastage in the USA by using their own mathematical model. Gooch *et al*. (2010) summarised findings with respect to food waste and prevention measures from Canadian studies.

3.3.2 South America

Studies about food waste generation or prevention from South America are seldom published (Table 4). Whether this is due to language barriers or a lack of research on this topic cannot at present be answered.

Fehr *et al*. (2002) estimated the losses and wastage of fruit and vegetables along the food supply chain in Brazil and discussed the separate collection of organic waste. Ulloa *et al*. (2004) highlighted the creation of agricultural residues in Costa Rica, including rejected green bananas, and the different methods of disposal used. Fresh vegetable losses occurring at the retail stage were studied by Tofanelli *et al*. (2009) at Goiás State/Brazil. Lemos *et al*. (2011) investigated the reasons for losses of 15 leafy vegetable crops between harvest and consumption, also in Brazil. Food waste in Brazilian company cafeterias were the main focus of Soares *et al*. (2011), who measured the generation and costs of food waste and suggested prevention measures. Mattoso and Schalch (2001) investigated food wasted in a Brazilian hospital and discussed the results in the context of the local social and legal situation. In 2007, Mancini *et al*. (2007) presented information about household waste from São Paulo/Brazil which contained details about food waste generation, treatment, as well as prevention issues. Marmolejo *et al*. (2010) conducted an analysis of household waste sorting in Colombia to quantify food waste in relation to socio-economic status.

3.4 Asia

Although the share of food waste is relatively high in Asia (e.g. in China on average 58 wet mass-% according to Wang and Nie

Source	Agriculture	Processing	Trade	Hospitality	Consumer
El-Mobaidh *et al*. (2006)				Food waste from in-flight catering of Egypt air flights, in g/meal, in % per meal, in t/year	
Tefera *et al*. (2007)	Effects of post-harvest treatment options (storage, packaging, disinfection) to minimise the post-harvest losses of mangos in Ethiopia, mass loss in %, % marketable mangos, extended shelf life in days				
Akande and Diei-Óuadi, (2010)	Manual for estimation of qualitative and quantitative post-harvest fish losses in five Sub-Saharan African countries (Ghana, Kenya, Mali, United Republic of Tanzania, Uganda), in %, prevention measures				
FAO and World Bank (2010)	Provides information on state of the art, experiences, further approaches				
World Bank (2011)	Summarises post-harvest grain losses, causes, reduction options, barriers for prevention, in mass-%				
Nahmann *et al*. (2012)					Estimates the overall costs for household food wastage in South Africa, including market price for food items and financial and external costs associated with food waste disposal (landfill)

Table 2. Overview of selected food waste studies from Africa

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Atwater (1895)					Food wasted in low-income US households; results in grammes of lost nutrition, calories
Atwater and Bryant (1902)					Nutritional behaviour of poor households in New York, mentioning wastage of food
USDA (1996)	Guide to show communities, individuals and businesses how to support existing food recovery efforts or to begin new programmes; USA				
Kantor *et al*. (1997)	Amounts of food losses (pounds, mass-%) subdivided into at least eight food commodities, reasons for wastage, potential for prevention as well as specific prevention measures; USA				
Rathje and Murphy (2001)					Food waste generation based on excavation from US landfills (ounces, pounds, g, mass and volume-%), context to crisis, diets, socio-economic issues etc.
Kandiah *et al*. (2006)				Plate waste from 346 patients testing influences (diet order, sex, length of stay, diagnosis), in %	
Nunes *et al*. (2008)			Impact of poor temperature and relative humidity management on quality and shelf life of 19 fruits and vegetables; causes for discard in %; USA		Impact of poor temperature and relative humidity management on quality and shelf life of 19 fruits and vegetables; causes for discard in %; USA
Fish *et al*. (2009)	Loss of unmarketable US water melons on the field (t/ha), potential for use in ethanol production				
Castro-Garcia *et al*. (2009)	Evaluation of table olive damage during harvest, comparison hand harvest and mechanical technologies, in %				
Hall *et al*. (2009)	Calculation of energy content of nationwide food waste from difference between US food supply and food consumed by population (estimated using a validated mathematical model of metabolism relating body mass to amount of food eaten), in kcal/cap year, kcal/year				
Buzby *et al*. (2009)			Estimating the value of fruit and vegetable losses at the retail and consumer levels in the USA (mass, dollar)		Estimating the value of fruit and vegetable losses at the retail and consumer levels in the USA (mass, dollar)
Cuellar and Webber (2010)	Estimates of the energy embedded in wasted food annually in the USA in British thermal units (BTU) per year for ten product groups				
Gooch *et al*. (2010)	Estimate of the share of wasted food along the entire food chain (%, Canadian dollars, mass only for retail to consumer), highlights prevention measures				
Buzby *et al*. (2011)			National estimates of food loss at US supermarket level for 24 fresh fruits, 31 vegetables, five meats, two types of poultry, two seafood items; results in % and mass/capita		
Venkat (2011)			Based on loss-adjusted food availability data from USDA estimate of greenhouse gas emissions from food waste for 134 food commodities (CO_2-equ.), amount of wasted food (t/year, %), economic value in dollars		

Table 3. Overview of selected food waste studies from North America

(2001) cited in Cho *et al*. (2010)), cultural attitudes and a paucity of separate organic waste collection mean that relevant literature from this region is scarce (Table 5). This fact could be influenced by the language barrier, as the literature research of the present paper was conducted in English and did not encompass native Asian languages. In 2001, the Korean Waste Movement Network (KWMN, 2001) published a paper summarising information about the generation of food waste in South Korea, contemporary and preferable disposal techniques, and suggestions about the implementation of prevention measures and the separate collection of food waste. In contrast, Allen (2001) focused solely on a comparison of food waste treatment in South Korea to US options. Li *et al*. (2003) investigated the in-flight food waste generated during Cathay Pacific Airways short, medium and long-haul flights, arranged by different flight classes (first, business, or economy class). Households were the focus of two studies conducted in Turkey, one with respect to bread waste (Gül *et al*., 2003) and the other dealing with energy loss due to food wastage (Pekcan *et al*., 2005). The amount and causes of plate waste from a Malaysian district hospital were the focus of Lily Zakiah *et al*. (2005). Watanabe *et al*. (2011) explored the composition and reduction potential of unused food within household waste in Malaysia by conducting waste sorting analyses and a questionnaire. For Japanese case studies, Watanabe (2009) compared the results of three different methods (food supply–intake difference, waste composition analyses, food loss survey) to estimate the food waste creation of households. Matsuda *et al*. (2012) also focused on households by establishing a life-cycle

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Mattoso and Schalch (2001)				Compares food waste generation from hospital wards in Brazil, in kg/day, kg/patient day, % of total waste, discusses context to social and legal situation	
Fehr *et al*. (2002)	Estimates losses and wastage of fruit and vegetables along the food supply chain in Brazil, discusses separate collection and treatment, in t, %				
Ulloa *et al*. (2004)	Compares residue generation (e.g. rejected green bananas) in 1993/1994 with 2001/2002, present and optimal disposal methods, Mt/year				
Mancini *et al*. (2007)					Conducts household waste sorting analysis, socio-economic analysis, moisture content, discusses food waste treatment and prevention options, in mass-%, volume-%, kg
Tofanelli *et al*. (2009)			Amount of fresh vegetables losses occurring at retail market of Mineiros/Goiás State/Brazil, causes, prevention measures, in %		
Marmolejo *et al*. (2010)					Sorting analysis of household waste in context with socio-economic data in Cali/Colombia, mass-% of food waste, discusses cooked food waste share
Lemos *et al*. (2011)	Investigates losses of 15 leafy vegetable crops in Brazil, reasons for losses (e.g. harvest, conservation, handling procedures)				
Soares *et al*. (2011)				Generation and costs of food waste in cafeterias in Brazilian company, suggests prevention measures, in g/cap, kg/month, % of food purchase costs	

Table 4. Overview of selected food waste studies from South America

Source	Agriculture	Processing	Trade	Hospitality	Consumer
KWMN (2001)					Food waste in municipal waste (t/year; %), current and preferable disposal paths; suggests implementation of prevention and separate collection
Allen (2001)					Anaerobic digestion of urban food waste followed by composting in South Korea, comparison with US treatment options of food waste
Li *et al*. (2003)				Generation of food waste from airline catering sorted by flight classes, distances and food type (total mass in kg; %), lost nutrient value (%)	
Lily Zakiah *et al*. (2005)				Generated amounts, product groups and reasons for plate waste from a Malaysian district hospital, in % of served food	
Gül *et al*. (2003)					Bread waste in Adana/ Turkey with respect to different household income levels, in % of bread purchased, shopping patterns, prevention options
Pekcan *et al*. (2005)					Household food wastage in Ankara/ Turkey, in kcal/ household day, kcal/cap d, % of daily energy intake/cap, g/household day, g/cap day
Watanabe (2009)		Compares results of three different methods of food waste generation in Japan, in %, g and g/cap day			
Treeamnuk *et al*. (2010)	Minimising fruit damage by using grading machine for Java apples, damage percentage, average fruit damage, Thailand				
Watanabe *et al*. (2011)					Reduction potential of unused food in Malaysian households investigated by sorting analysis and questionnaire, in mass-% of households waste
Reardon *et al*. (2012)	Performance of Asian staple food supply chains (rice, potatoes) in Dhaka, Beijing and Delhi, wastage in %				
Matsuda *et al*. (2012)					Life-cycle inventory analysis of households waste management scenarios for Kyoto with special emphasis on food waste reduction activities, in Gg CO_2-eq/year

Table 5. Overview of selected food waste studies from Asia

inventory with special emphasis on household food waste reduction activities in Kyoto/Japan. Changing conditions due to increasing exports or the globalisation of local markets have also been targeted by researchers. In 2010, Treeamnuk *et al*. (2010) looked at the development of a grading machine for Java apples from Thailand with the aim of minimising the damage to fruits by manual grading. Reardon *et al*. (2012) recently published the results of a detailed study of how Asian, domestic, value-staples chains are structured and performing after the food price hike in 2007/2008, including information on the food waste situation.

3.5 Australia

Table 6 gives an overview of selected food waste studies from Australia. Some states of Australia (e.g. New South Wales) have adopted the successful 'Love Food Hate Waste' campaign from Wrap (see Section 3.6.2) to reduce business and household food waste in cooperation with corporate, government and non-profit organisations. Surveys were subsequently conducted and documents published, such as the report from the Office of Environment and Heritage (2011).

In 2009, Baker *et al*. (2009) initiated the relaunch of a 2005 study (Hamilton *et al*., 2005) which surveyed Australian household food wastage, economic impact, reasons, food categories, incentives for prevention and other issues with a broad questionnaire. Jean-Baptiste *et al*. (2011) reported on household food waste generation in Sydney's suburbs based on diary records. In 2011, Mason *et al*. (2011) summarised the findings of Australia's 1262 previous food waste studies and found that it was not possible to aggregate the data on a national or even state level owing to

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Hamilton *et al*. (2005)					Estimates Australian household economic impact due to food wastage, socio-economic influences, prevention options by phone poll, in AUD/year
Walton *et al*. (2008)			Surveys energy and protein intake of elderly patients at hospitals with and without support of volunteers during meals, in kcal/cap day, g/cap day		
Baker *et al*. (2009)					Estimates Australian household economic impact due to food wastage, reasons, food cate-gories, incentives for prevention and other issues by online survey, in AUD/year, AUD/cap year, Mt CO_2-e
Ridoutt *et al*. (2010)	Estimate water footprint of fresh mango losses along the food supply chain in Australia excluding food service sector and mangos which seem to be unsaleable on market, in l/kg				
Jean-Baptiste *et al*. (2011)					Record food losses and causes in households in Sydney by keeping diaries, in kg/household day
Mason *et al*. (2011)	Summarises findings of Australia's previous food waste studies, conclude that there should be a common definition, methodology and approach to investigating food waste				
Office of Environment and Heritage (2011)					Online survey of 1200 residents in NSW with respect to food knowledge, attitudes and behaviour, in AUD/year, % of respondents
Manning *et al*. (2012)				Survey energy and protein intake of elderly patients at hospitals with and without support of volunteers during meals, in kJ/cap day, g/cap day	

Table 6. Overview of selected food waste studies from Australia

different definitions, methodologies and targeted waste streams. The authors mention that little information is available with respect to agricultural food waste and that avoidable food waste is comparatively well monitored compared with unavoidable organic waste during food production. In contrast to other papers, Mason *et al.* (2011) also discuss Australian food charities (e.g. food banks), which redistribute food that is edible but not marketable. Not mentioned by Mason *et al.* (2011) are Ridoutt *et al.* (2010), who estimated the water footprint of fresh mango losses along the food supply chain in Australia, excluding the losses of seemingly unsaleable mangos. Manning *et al.* (2012) continued the research of Walton *et al.* (2008), focusing on the effects of voluntary feeding assistance at elderly care wards in hospitals.

3.6 Europe

3.6.1 Northern Europe

In the past 10 years the Nordic countries including Finland, Sweden, Norway and Denmark have conducted a large number of studies, mostly published in their native languages. There are English papers which cover food waste generation and prevention with respect to retail (e.g. Eriksson *et al.*, 2012; Stenmarck *et al.*, 2011), the processing industry (e.g. Møller *et al.*, 2012), packaging issues (e.g. Williams and Wikström, 2011), hospitality (e.g. Engström and Carlsson-Kanyama, 2004; Kallbekken and Sælen, 2013; Marthinsen *et al.*, 2012), consumer level (e.g. Koivupuro *et al.*, 2012; Thögersen, 1996; Williams *et al.*, 2012) and life-cycle assessment (e.g. Davis *et al.*, 2011). Table 7 highlights the main contents of the studies.

3.6.2 Western Europe

Table 8 indicates important information on selected food waste studies from Western European countries. The Waste Resource Action Programme (Wrap), based in the UK, has published a huge number of detailed food waste related studies along the whole food supply chain since 2000. The studies deal with the supply chain (e.g. Wrap, 2011a), retail (e.g. Brook Lyndhurst and Wrap, 2012), packaging techniques (e.g. Wrap, 2009), schools (e.g. Wrap, 2011b), the hospitality sector (e.g. Wrap, 2011c), households (e.g. Wrap, 2011d) as well as prevention programmes (e.g. Wrap, 2012). Food waste research activities have been carried out in the UK for many years. For example, Cathcart and Murray (1939) conducted a study on nutrition throughout the UK, involving 263 households with various social backgrounds. In the discussion in their paper, Cathcart and Murray (1939) stated that accurate measurement of wasted food was difficult, especially in rural areas as the food residues were often fed immediately to animals. Singer (1979) summarised the previous findings of agricultural, processing, catering and household food waste studies in the UK, supported in the main by the UK Food Wastage Study Group. A paper which is often cited by others is Wenlock *et al.* (1980), who executed a household diary study across Britain to survey the amount of edible food waste generated, the energy content, socio-economic influencing factors and amounts fed to animals. Besides Wrap, other UK research organisations have published interesting results, such as Barton *et al.* (2000) on hospital food waste, Evans (2012) on the social behaviour of households or Alexander and Smaje (2008) on the redistribution of donated surplus food. From other Western European countries, literature in English is in short supply.

3.6.3 Central Europe

Within Germany, Switzerland and Austria several food waste related studies can be found, mostly published in German (e.g. Baier and Reinhard, 2007; Frübis and Class, 1994; Part, 2010). Scientific papers in English (Table 9) can be found dealing, among other things, with the history of food waste (e.g. Schneider, 2011), methodological issues (e.g. Lebersorger and Schneider, 2011), quantification and prevention (e.g. Beretta *et al.*, 2013; Kranert *et al.*, 2012; Salhofer *et al.*, 2008), reasons (e.g. Ganglbauer *et al.*, 2013; Glanz, 2009) and the redistribution of donated surplus food (e.g. Schneider, 2013; Von Normann, 2009). Studies from other Central European countries are more or less reports from authorities on their efforts with respect to food waste prevention or summaries of results from other countries.

3.6.4 Southern and Eastern Europe

Studies with respect to food waste from Southern and Eastern European countries are rare (Table 10). Possible reasons for this could be that local researchers focus on basic topics such as the collection with high coverage rate, separate collection or proper disposal of waste – the examination of food waste as a topic can be expected to rise in the coming years.

Malena *et al.* (2007) summarised findings from pre-existing international literature and assessed data with respect to the mortality rate of pigs and cattle during transport for slaughter from 1997 to 2006 according to the Czech Republic's official statistics. In 2006, Jemrić *et al.* (2006) published a paper focusing on the effect of hot water dips at different temperatures on the loss of Granny Smith apples at storage facilities in Croatia. Jemrić and Ilić (2012) highlight the most important reasons for post-harvest losses of fruits and vegetables in Croatia and Serbia. As Schneider and Lebersorger (2011) stated in their paper, the proportion of household expenditure on food and non-alcoholic beverages is highest in Eastern European countries (e.g. 44·2% in Romania) compared to other European countries (e.g. 9·3% in Luxemburg). In these less affluent countries, this higher outlay might be expected to have a greater impact on food waste behaviour, not only with respect to households but along the whole food supply chain. Therefore it would be very interesting to gather reliable data from those countries. Stefan *et al.* (2013) recently published the results

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Thögersen (1996)					Analyses relation of household food waste and consumption style in Denmark and internationally
Engström and Carlsson-Kanyama (2004)				Food losses from two schools plus two restaurants, Sweden, in % of food delivered, g/portion, monetary loss in Swedish krona	
Davis *et al*. (2011)	Calculates greenhouse gas emissions for 17 food products and flowers from Swedish production including retail considers food waste along food supply chain, suggests prevention measures				
Williams and Wikström (2011)	Analyses relations between the environmental impact of changes in packaging along food supply chain and food losses (ketchup, bread, milk, cheese, beef) at consumer stage				
Stenmarck *et al*. (2011)			Analyses amount of food waste at wholesale and retail (kg/turnover, t/week, t/year), causes, prevention measures, recommendations for Sweden, Norway, Finland, Denmark		
Eriksson *et al*. (2012)			Analyses flows of fruit and vegetables at six Swedish retail stores by analysing recorded data and by performing physical measurements, in kg, mass-%		
Marthinsen *et al*. (2012)				Summarises amounts, initiatives and instruments to reduce amount of avoidable food waste within hospitality sector in Denmark, Finland, Norway and Sweden, highlight practical guidelines, in t, kg/cap year	
Williams *et al*. (2012)					Examines reasons for Swedish household food waste and influence of packaging, in kg/household week, g/cap week
Møller *et al*. (2012)		Develops methodology for food loss mapping within Norway food-processing industry			
Koivupuro *et al*. (2012)					Analyses influence of socio-demographical, behavioural and attitudinal factors on amount of avoidable food waste in Finnish households, reasons, in kg/household year, kg/cap year
Kallbekken and Sælen (2013)				Tests impact of two food prevention measures in hotel restaurants in Norway, in kg, mass-%	

Table 7. Overview of selected food waste studies from Northern Europe

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Cathcart and Murray (1939)					Nutritional behaviour of 263 households in UK, average calories loss in %
Singer (1979)	Summarises results from previous UK food waste studies, discusses food waste definition, philosophises about food waste prevention				
Wenlock *et al*. (1980)					Household diary study across Britain to survey amount of edible food waste generated, energy content, socio-economic influencing factors, season, amount fed to animals, in kcal/household week, kcal/cap day, % of energy intake
Barton *et al*. (2000)				Determines wasted food of hospitalised patients for 28 days, in kcal/cap day, % energy, % protein, GBP	
Wrap (2009)		Estimates potential amount of food waste associated with inadequate heat seals generated at food packaging, in t			
Wrap (2011a)	Quantifies the level of loss and waste of 11 selected fruit and vegetables from field to wholesale and retail in UK, reasons, in t, %, recommendations for prevention				
Wrap (2011b)				Quantifies amount and composition of food waste at UK schools, reasons, prevention options, develops toolkit, in t, g/kid d, %	
Wrap (2011c)				Tests method to quantify food waste from UK hospitality sector, provides estimates on amount, in t, %, GBP	
Wrap (2011d)					Updates previous findings on household food and drink waste, disposal route, in t, %, GBP, estimates greenhouse gas emissions and water footprint associated with wasted food
Brook Lyndhurst and Wrap (2012)			Surveys of a range of factors located at retail believed to influence household food waste, updates from 2009, 20 products detected		
Wrap (2012)		Summarises results from Courtauld Commitment 2 introducing measures impacting food waste occurrence at distribution, retail and household level, in %			
Evans (2012)					Sociological analysis of household food waste with focus on routines of food supply, convention of family meal, socio-temporal context of food practices

Table 8. Overview of selected food waste studies from Western Europe

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Salhofer *et al*. (2008)		Analyses food waste from production and retail in Vienna, reasons, in t, kg/cap year, t/shop year, suggests prevention measures			Analyses food waste from Austrian households, reasons, in mass-%, kg/cap year
Glanz (2009)					Analyses causes for wasting food on household level by content analysis
Von Normann (2009)		Introduces German Tafel organisations with respect to demand and structure, success factors, suggestion for further development			
Schneider (2011)	Reviews development of human attitudes concerning food over the different ages from antiquity to World War II; describes history of wasting food and early prevention measures during times of crises				
Lebersorger and Schneider (2011)	Discusses methodological issues, analyses share of packaging mass included in food waste category on household level using Austrian case study, in mass-%, kg/cap year				
Kranert *et al*. (2012)		Summarises and extrapolates international food waste figures for case of Germany, reasons, prevention measures, in t, mass-%			
Beretta *et al*. (2013)	Quantifies food losses in Switzerland along food supply chain, hotspots, reasons, in TJ, % of total calories, t				
Schneider (2013)	Summarises evolution of food donation activities including political, legal, social, logistical barriers and incentives; introduces concept for a food donation network; discusses impact on ecology, economy and society				
Ganglbauer *et al*. (2013)					Investigates practices around food and waste, introduces FridgeCam to support Austrian and UK households when shopping by way of the internet

Table 9. Overview of selected food waste studies from Central Europe

Source	Agriculture	Processing	Trade	Hospitality	Consumer
Jemrić *et al*. (2006)		Effect of hot water dips at different temperatures on Granny Smith apple losses at storage facilities in Croatia			
Malena *et al*. (2007)		Comparison of mortality rate of pigs and cattle during different transport distances for slaughter from 1997 to 2006 in Czech Republic, in %			
Jemrić and Ilić (2012)	Discuss most important facts for post-harvest losses for fruits and vegetables in Croatia and Serbia with focus on apples and satsumas				
Stefan *et al*. (2013)					Survey 244 Romanian households with respect to planning and shopping routines, attitudes towards food waste, by means of a web-based questionnaire

Table 10. Overview of selected food waste studies from Southern and Eastern Europe

from a web-based survey comprising planning and shopping processes as well as food waste attitudes of Romanian households.

4. Conclusion

Recently a large amount of food waste related literature has been published by different stakeholders dealing with various issues along the food supply chain. The overview of selected international literature on food waste prevention presented in this paper shows that there are some regions where a great deal of literature in English can be found, such as North America, Western Europe and, to a lesser degree, Australia and Northern Europe. This is obvious as English is the mother tongue in most of these regions. It is assumed that there is also food waste related literature at a scientific level in other areas, but in regional native languages. This has been confirmed for Northern European countries, Central Europe and Japan. In addition to other methodological and definitional problems, the language barrier hinders the comparison of results from different regions as it is difficult to discover specific literature on food waste prevention for particular regions.

It is also interesting to see that the results of some organisations, such as FAO or Wrap, which publish extensively on food waste, are published solely as in-house reports which can be accessed freely by way of the internet. Other organisations and research institutions, such as universities, often publish their reports on the internet in their native language, but undertake the scientific review process of those papers in English in journals. This process hampers the availability of the latest results for years and sometimes apparently prevents the publishing at all.

An examination of the table content provided within this paper provides the key aspects as well as the gaps within literature. For example, there is a multiplicity of literature published, for example, by the FAO or World Bank dealing with agricultural food losses in developing countries, but this aspect is not commonly covered for industrialised regions. It is also very difficult to find information on food losses or wastage during logistical processes. There is some literature on food waste within hospitals but little about in-flight catering, schools, the military, prisons, catering at events, and many assumptions have to be made when estimating waste from different types of restaurants. Although during recent years some findings have been published concerning retail food waste, facts about wholesale are not common. There is also scant information about the redistribution sector – that is, the distribution of donated surplus food to people in need. Although there are an inordinate number of papers dealing with household food waste, some issues still remained chiefly unexplored. One example is the proportion of different disposal paths for household food waste, since some of them are hard to determine objectively. While solid household waste can be examined very accurately, disposal via the sewer is mostly investigated by questionnaire, which is not as accurate as a method. In the meantime, there are also some life-cycle assessment studies of different food commodities which include the additional burdens of food waste. Papers introducing evaluation methodology or presenting reliable results of evaluating implemented food waste prevention measures are lacking.

The lack of consistent definitions of food waste and investigation methodology mean that it is still very difficult to compare the results of food waste studies worldwide or even within the same country. Nevertheless, increasing awareness of the important topic of food waste worldwide provides essential knowledge for decision makers and generates input to awareness campaigns, induces changes in organisational structures, and improves technology as well as fostering social understanding. It has been a long road from the first food waste related papers to broad public and scientific awareness, but hopefully the effects will soon be realised.

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