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Food Losses in Supply Chains for Fruits, Vegetables and Potatoes between Field and Retail Shelf in North-Rhine Westphalia, Germany

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ABSTRACT

Food losses occur for many reasons at all stages of supply chains for fruits, vegetables and potatoes. They cause immense economic, environmental and social costs – not only in developing countries but also in developed countries. According to the European Commission, about 90 million tonnes of food are wasted annually in Europe alone. However, particularly for the early stages of supply chains for fruits, vegetables and potatoes there is still a lack of reliable data. Thus, one objective of this study is to contribute to the quantification of food losses between field and retail, where the main focus is set on potatoes, apples, carrots, strawberries and asparagus. Furthermore, neither reasons why products are removed from the supply chains nor their alternative uses are fully examined yet. This is why, the study takes a look on those issues, too. Results are based on data from an online survey among producers of fruits, vegetables and potatoes in North-Rhine Westphalia, Germany and on interviews with producers and other supply chain experts. Findings suggest that the products' size and form, their storage capabilities and food safety issues have big impacts on food losses. Despite a small sample size, these findings are in line with recent studies.

Keywords: food losses; supply chain management; sustainable food systems; fruits, vegetables and potatoes

Introduction

There are estimates that by 2050 approximately 9.1 billion people need to be fed. This is why, it is often argued, that the global food production must be increased and intensified accordingly. However, an intensification of food production can have negative effects on soil fertility, levels of erosion, fresh water reserves or biodiversity (FAO, 2009). Furthermore, food production consumes resources like fertilizers, water and energy (FAO, 2011) and it contributes to climate change by generating greenhouse gas emissions (GHG) (e. g. Porter and Reay, 2015, Munesue et al., 2015). In Europe for example the food and drink value chain is estimated to account for 17 % of the GHG and for 28 % of the material resource use (EU, 2011). Food that is not used for consumption still needs resources and causes environmental costs. FAO (2011) uses the term "Food Wastage Footprint" for these costs without corresponding benefit. Against this background the reduction of food losses and food waste is increasingly discussed as a measure to mitigate the negative effects of food production (FAO, 2011, Kranert et al., 2012, Göbel et al., 2015). It is argued that a reduction of food waste is linked to more efficient supply chains and a more efficient use of resources (Parfitt et al., 2010, FAO, 2011, Porter and Reay, 2016). The potential seems promising. From a global perspective approximately one third of food that is intended for human consumption gets lost or wasted along the food supply chain every year. This is equal to an amount of 1.3 billion tons. For fruits and vegetables it is estimated that 50 % of the annual harvest don't reach the consumer (FAO, 2011).

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The European Commission (2011) has issued a "Roadmap to a Resource Efficient Europe". According to this, one of the milestones is to achieve a 20 % reduction in the food chain's resource inputs and a reduction in edible food waste by 50 % by 2020 (EU, 2010). But a quantification of the amount of food that is wasted or lost is difficult, since a decent and reliable data base for quantification is lacking (Parfitt, 2010, Kranert, 2012). Recent studies try to fill this gap, but research in this area is still needed. Göbel et al. (2015) report that in Germany causes for food losses and measures to reduce them are not fully explored yet. And also from neighbouring countries a lack of research and data is reported (e. g. Frieling et al., 2013, Willersinn et al., 2015).

In order to discuss measurements and possible starting points to reduce food losses, an attempt was made to quantify food losses along supply chains for potatoes, carrots, asparagus, apples and strawberries in North-Rhine Westphalia (NRW). Furthermore, reasons for food losses in supply chains of potatoes and fruit and vegetables in general as well as reduction strategies were surveyed.

The research was jointly conducted by the International Centre for Sustainable Development at the University of Applied Science Bonn-Rhein-Sieg and the North Rhine Westphalian State Agency for Nature, Environment and Consumer Protection (LANUV). The cooperation was supported by the Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia which is engaged in food loss reduction policies.

Food waste vs. food loss

Food losses occur at all stages of the supply chain. Reasons for food losses are diverse. They comprise losses due to mechanical damage, sorting, degradation, storing, processing and transportation. In addition to this, aspects that are linked to the market system are also important reasons for food losses (FAO, 2011) as well as legal and private quality standards (Frieling et al., 2013, Willersinn et al., 2015). However, a generally accepted definition of food loss respectively food waste still doesn't exist (Peter et al., 2013, Porter and Reay, 2016), although efforts in this directions are made. FAO (2011) refers to food losses when edible food mass gets lost for human consumption at production, post-harvest and processing stages. Food losses at later stages of the supply chain are termed food waste. In this study the term "food loss" is used for fruit, vegetable and potatoes that are, at the time of harvest, both intended and suitable for human consumption but are finally not consumed by humans. The scope of this study is focused on food loss at production, post-harvest and processing stages.

Data collection and analysis

Product related particularities such as spoilage or perishability of food as well as the particularities of the subsystems of the generic food supply chain play important roles when assessing food losses (Parfitt, 2010, Göbel et al., 2015). Based on this, an online survey was conducted among North-Rhine Westphalian producers and traders of potatoes, apples, carrots, strawberries, asparagus, lettuce and tomatoes in autumn 2016. These products were taken as typical representatives for both perishable and storable products, and because of their importance for the sector in NRW with respect to the cultivated area.

Participants were mainly invited to take part in the survey by e-mail. A reminding e-mail was sent some weeks after the first invitation. Furthermore, the survey was announced in several professional magazines and newsletters related to the fruit, vegetable and potato sector. Since the main focus of the study was set on the situation in NRW, producers not situated in NRW are not considered in the survey.

The questionnaire used in the survey contained closed as well as open questions. It is based on a questionnaire that was developed at the Institute of Waste Management (ABF-BOKU) of University of Natural Resources and Life Sciences, Vienna. Adjustments were made in order to emphasize supply channels and trading processes from "field to retail shelf". The adjustments are in line with Willersinn et al. (2015) and Göbel et al. (2015) who suggest to take a closer look at subsystems of respective food supply chains. The respondents were asked to choose from a list of products, that a.) they actually produce and b.) that they regard as most important with

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regard to food loss. The questionnaire's subsequent questions are related to that particular product. The survey was facilitated with the software EFS Survey (by QuestBack GmbH. Data analysis was done with SPSS (Version 22) and Excel (Excel 2013).

In order to supplement the online survey, 12 in-depth interviews with experts (producers, traders, food retailers, extension services, and official quality control) were conducted. Emphasis was given on reasons for food loss between field and the retail shelf and – existing or possible – measures to reduce these losses. Results of the survey as well as central statements from the interviews were presented in a workshop with producers, traders, scientists and public administration (e.g. quality control) in February 2017. Approaches to reduce food loss of fruit, vegetables and potatoes from field to shelf were discussed.

Results from the online survey

Data presented in this section are drawn from the online survey. It's a subsample based on 83 questionnaires that were answered by producers of fruit, vegetables and potatoes, where 21 questionnaires relate to strawberries, 20 to potatoes, 12 to apples, 12 to asparagus, 9 to carrots, 6 to lettuce and finally 3 questionnaires relate to tomatoes. The total acreage of potatoes covered by the survey represents 0.9 % of the total acreage of potatoes grown in NRW (based on figures from IT.NRW, 2016), whereas the acreage of strawberries covered by the survey represents approximately 12 %, the area for asparagus approx. 11 %, the area for carrots approx. 5 % and the area for apples 9.1 %. For tomatoes and lettuce the number of complete questionnaires was too little for evaluation.

In order to assess the usage of the products that were initially intended for human consumption, it was asked: "What happens with the product after it is harvested – intended or unintended?" In order to answer the questions, producers had to distribute 100 percent of their harvest to a set of different given uses (see Table 1.). Questionnaires where no answers were given, are not included in the underlying sample. The percentages shown in Table 1 are weighed averages. They are calculated by multiplying the respondent's estimate of post-harvest use with the related amount of the product's harvest (in tonnes). In a second step the mean value for each product and post-harvest use is calculated.

Table 1: *What happens with the product after harvest? (Weighed averages)*

	Potatoes	***Apples***	***Carrots*** [1)]	***Strawberries***	***Asparagus***
N	17	12	6	19	10
Fresh produce (unprocessed)	67,2%	82,7%	66,1%	92,9%	83,3%
Food industry	2,2%	10,9%	0,0%	0,3%	0,0%
On-farm processing	2,7%	2,1%	0,0%	0,5%	0,3%
Social facilities	2,1%	1,3%	0,3%	0,4%	0,6%
Non-food use (feed, spoilage etc.)	24,9%	3,0%	20,9%	4,9%	15,7%
Misc.	0,8%	0,0%	12,7%	0,9%	0,2%
Total	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**

[1)] *Respondents in the online survey didn't indicate that carrots were delivered to the food industry. Nevertheless, due to statements of experts it is likely that carrots for juice or mixed salad production are mistakenly indicated as miscellaneous use.*

The calculated estimates show that average "non-food-uses" for potatoes (24.9 %), carrots (20.9 %) asparagus (15.7 %) are relatively high compared to strawberries (4.9 %) and apples (3.0 %). A proportion of potatoes as well as carrots are used as components in animal feed. For carrots another relevant share is probably used for processed products (e. g. juice, see annotation). In contrast, strawberries are mainly marketed as fresh produce

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(92.9 %). The recorded share for apples that is sold to the food industry (10.9 %) is much higher than in the case of the other products in this study. The use as raw material for apple juice could be a reason for this. A relevant share of fresh asparagus as it is indicated by the survey is lost for human consumption (approx. 16 %) due to preparation processes. Much of this share is used for compost and biogas production.

Table 2: *Distribution of food losses by process (in percent)*

	Potatoes	***Apples***	***Carrots***	***Strawberries***	***Asparagus***
Control (size)	35%	32%	48%	19%	29%
Control (food safety)	27%	30%	8%	53%	2%
Preparing / washing	14%	5%	24%	2%	33%
Storing	11%	18%	17%	1%	8%
Transport	7%	2%	1%	21%	6%
Packaging	5%	13%	2%	0%	5%
Misc.	0%	1%	0%	5%	17%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

The online survey also contained questions related to on-farm processes. The respondents had to estimate their enterprise's distribution of food losses (100 %) for a given set of processes. Values in Figure 1 represent the mean values of the estimates per product in percent. For example, it can be shown that quality issues are the main reasons for food losses. With regard to carrots, size control accounts for approx. 48 % of the process related food losses (Potatoes 35 %, Apples 32 %). In contrast, misshaped fruits don't produce high percentages of food losses with regard to strawberries (19 %). In this case food safety issues (53 %) are much more predominant. They are less relevant in terms of asparagus (2 %) or carrots (8 %). Potatoes, apples and carrots are products that can be stored over a longer period of time. This is why the estimates of losses due to storing issues are higher (Potatoes: 11 %, apples: 18 %, carrots: 17 %) than for asparagus (8 %) or strawberries (1 %).

Results from the interviews and the workshop

In the interviews the experts confirmed that food loss between field and retail shelf is a relevant issue for most field grown vegetables and for potatoes. The level of losses varies largely between different cultures and also between years. According to the producers' estimates average losses are often between 20 and 30 % for field grown crops. It is also estimated, that the major part of these losses still could be used for human nutrition and also complies with general EU marketing standards. For some products losses occur already at harvest stage, because they are not fully harvested – this is the case for hand-picked vegetable crops like salad, cauliflower or broccoli. In other crops – e.g. potatoes, carrots, onions, or apples – grading takes place after harvest. In these cultures alternative food- or non-food-uses (see above) for out graded products are more common than for hand-picked crops. According to the experts, the most important reasons for losses of fruit, vegetable and potatoes between field and retail shelf are:

- **Quality and uniformity requirements:** Experts stated that losses due to quality requirements increased in the last years. Most experts said, that retailers' specifications for quality and uniformity usually exceed general marketing standards. They mentioned examples of requirements that are not reasonable in their opinion (e.g. extreme uniformity of Chinese cabbage, appearance of kohlrabi leaves or absence of silver scurf on potatoes).
- **Fluctuations and a mismatch in supply and demand for perishable products:** Harvest dates for field crops cannot be determined exactly in advance. In contrast retailers need a regular supply with fruits, vegetables and potatoes. Another reason was seen in the fact, that retailers plan their marketing campaigns in advance, without sufficient data, about the availability of sufficient quantities.

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- **Weather conditions:** The importance of weather conditions for food loss is eventually increasing due to climate change. Experts stated that the number of extreme weather conditions are likely to increase. Recent years have shown heatwaves as well as heavy rain falls and flooding.

Further reasons that were mentioned, included increased wages which make it more expensive to have several harvest operations for one field, and specific quality requirements of some supermarkets concerning pesticide residues or client-specific packaging. Planning mistakes (of farmers, traders or retailers), logistic problems or interruptions in the cold chain in some cases also lead to food losses, but according to the experts these reasons are less important than a decade ago and much less important than the reasons mentioned above.

In the last part of the interviews experts were asked for – existing or possible – measures to reduce food waste. Enabling consumers to recognize the quality of products and helping them to "have a healthy relationship to food" was seen as a responsibility both of the state (e.g. schools) and the private sector. If purchasers and quality managers of retail companies "*had a better understanding of agricultural practice"* (e.g. through internships on farms), then this could – according to experts – eventually help to reduce food loss due to "*unrealistic quality requirements*". Some experts positively mentioned existing programs of retail companies to sell products with small optical deficiencies. According to producers these programs should be set up as long-term activities that require a special marketing, and they should avoid a reputation of rummage.

Concerning fluctuations and the mismatch of supply (e.g. harvest peaks of salad or cauliflower) and demand, new methods of communication between farmers and retailers and especially between retailers and consumers could avoid losses to some extent. Experts also mentioned some positive examples here, e.g. replacement of printed advertisement by electronic communication. Several experts mentioned a general problem concerning all efforts to reduce food waste: Supply of most fruit and vegetables is in a surplus at the European scale. If significantly less fruit, vegetables or potatoes are lost after harvest (e.g. because more class-2-products are sold) and the amount of consumption does not change, this will require either changes in imports and exports or a reduction of produced quantities.

Discussion and conclusion

Quantification of food loss and food waste can lead to better assessments of wastage footprints (FAO, 2011). However, quantification is a complex task and standard processes are not established yet. Despite this, it is widely agreed to take a system-based approach (e. g. focusing on supply chains) in order to estimate food losses, since food losses occur at all stages of a supply chain (Parfitt et al., 2010, FAO, 2011, Porter and Reay, 2016). Nevertheless, it has to be clear what is regarded as food loss and what is not, i.e. a clear definition of the underlying system's boundaries is needed.

When dealing with food losses in primary production, the particularities of harvest technologies, product characteristics, handling and storing processes as well as marketing channels have an impact on food losses. This is supported by this study that focused on the early stages of the supply chain. It can also be established that quality issues and market requirements have a strong impact on post-harvest loss rates of fruits, vegetables and potatoes, too. This is in line with recent studies (e. g. Frieling et al., 2013, Göbel et al., 2015, Willersinn et al., 2015).

Peter et al. (2013) point out that in producing potatoes losses occur mainly in store. They have estimated that up to 6.4 % of edible potatoes are lost due to fresh mass losses, decay and germination. But apparently this is not the full picture. Willersinn et al. (2015) calculated higher loss rates (approx. 21 % for non-organic products and up to 29 % for organic products) by taking account of aesthetic reasons, storage life and consumer health reasons. The values in this study lie within this range (approx. 25 %).

For apples, Peter et al. (2013) found that post-harvest losses due to fresh mass loss and parasites are as high as approx. 11 %. What is not included in this figure is the amount of apples that is lost for human consumption because of quality requirements such as size and form. This makes it likely that loss rates are indeed higher. However, this study suggests that losses due to size and form requirements are not so much relevant for apples

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as they are for a variety of vegetables and for potatoes, since the "non-food use" of apples in this study is approx. 3 %.

Regarding food loss reduction strategies findings from the online-survey as well as the experts' statements show that next to other things the consumers' attitudes towards fresh food needs to be addressed. Raising awareness for food loss issues and changes in corresponding buying behaviour are seen as important starting points for food loss reduction.

Nevertheless, there are some limitations of this study. One is that only a small number of producers and traders of fruits, vegetables and potatoes took part in the online survey. This is likely due to the fact, that the general motivation for taking part in online surveys is quite low. However, additional expert interviews and a workshop with experts from the sector allowed to supplement the findings from the online survey.

In conclusion, it can be stated that strategies to reduce food losses should take the complexities and particularities of the underlying systems e. g. supply chain into account carefully. Processes and the stream of products as well as the extent of food lost for human consumption differ widely. In order to make further assessment of food loss quantities and the impact of food loss reduction strategies, more in-depth research is still needed.

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References

European Commission (2011). The Roadmap to a Resource Efficient Europe (COM(2011) 571). Communication from the Commission to the European Parliament, the Council and the European Economic and Social Committee and the Committee of the Regions. online: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN [accessed: 26.01.2017]

FAO (2009). How to Feed the World in 2050. Food and Agriculture Organisation of the United Nation, Rome, online: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf [accessed: 20.12.216]

FAO (2011). Global Food Losses and Food Waste – Extent, causes and prevention, Food and Agriculture Organisation of the United Nation, Rome, online: http://www.fao.org/docrep/014/mb060e/mb060e.pdf [accessed: 20.12.2016]

Frieling D., Stricks V., Wildenberg M. Schneider F. (2013). The beauty and the beast – how quality management criteria at supermarkets create food waste. In: CPM - The Swedish Life Cycle Center (Eds.), Perspectives on Managing Life Cycles. 6th International Conference on Life Cycle Management, Gothenburg, Sweden, 25.-28. August, online: http://conferences.chalmers.se/index.php/LCM/LCM2013/paper/viewFile/724/338, [accessed: 19.12.2016]

Göbel, C., Langen, N., Blumenthal, A., Teitscheid, P., Ritter, G. (2015). Cutting Food Waste through Cooperation along the Food Supply Chain, Sustainability, **7**: 1429 - 1445

IT.NRW (2016). Ernteertrag in NRW, https://www.it.nrw.de/statistik/i/daten/eckdaten/r522lw_ernte.html [accessed: 06.01.2017]

Kranert, M., Hafner, G., Barabosz, J., Schneider, S., Lebersorger, S., Scherhaufer, H., Schuller, H., Leverenz, D., Kölbig, A. (2012): Ermittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur Verminderung der Wegwerfrate bei Lebensmitteln in Deutschland. Studie der Universität Stuttgart (gefördert vom BMELV), online:

DOI: http://dx.doi.org/10.18461/pfsd.2017.1704

http://www.bmel.de/SharedDocs/Downloads/Ernaehrung/WvL/Studie_Lebensmittelabfaelle_Kurzfassung.pdf [accessed: 19.12.2016]

Munesue, Y., Masui, T., Fushima, T. (2015). The effects of reducing food losses and food waste on global food insecurity, natural resources, and greenhouse gas emissions. *Environmental Economics and Policy Studies*, **17** (1): 49 -77

Parfitt, J. Barthel, M., Macnaughton, S. (2010). Food Waste within Food Supply Chains: Quantification and potential for Change to 2050, *Phil. Trans. R. Soc., **365**: 3065 – 3081*

Peter, G., Kuhnert, H., Haß, M., Banse, M., Roser, S., Trierweiler, B., Adler, C. (2013). Einschätzung der pflanzlichen Lebensmittelverluste im Bereich der landwirtschaftlichen Urproduktion, Bericht im Auftrag des Bundesministeriums für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), Braunschweig, online: http://literatur.thuenen.de/digbib_extern/dn052055.pdf [accessed: 21.12.2016]

Stephen D. Porter, S. D., Reay, D. S. (2015). Addressing Food Supply Chain and Consumption Inefficiencies: Potential for Climate Change Mitigation, *Regional Environmental Change,* **16** (8): 2279–2290

Willersinn, C., Mack, G., Mouron, P., Keiser, A., Siegrist, M. (2015). Quantity and quality of food losses along the Swiss potato supply chain: Stepwise investigation and the influence of quality standards on losses, *Waste Management*, **46**: 120 - 132

DOI: http://dx.doi.org/10.18461/pfsd.2017.1704