Environmental impacts and abatement costs of food waste reduction: the case of bread

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ABSTRACT

In this study, environmental impacts and abatement costs of reducing food waste in the life cycle of bread were calculated by connecting life cycle assessment with environmental life cycle costing. The life cycle includes production, processing, sale, consumption and disposal of mixed grain bread in Germany. The functional unit (FU) was set as 1 kg bread consumed. Four scenarios were modelled to examine the costs and impacts of different waste reduction measures: (1) a baseline scenario with no actions taken to reduce food waste, (2) reducing food waste at the retail stage by passing on unsold bread to food banks, (3) reducing food waste at the consumption stage by reducing the amount of bread shopped by 50% followed by a higher frequency of shopping and (4) reducing food waste at the consumption stage by freezing 50% of the bread and consume it to a later point in time. For all scenarios a strong and a weak food waste reduction effect was modelled to show the uncertainties. The life cycle inventory data was analyzed according to the impact categories global warming potential, agricultural land occupation, cumulative energy input and process costs. The calculation resulted in 2.51 kg CO_2eq greenhouse gas emissions, 18.04 MJ Energy input, 6.69 € process costs and 1.13 m^2a agricultural land occupation per FU for the baseline scenario. The waste reduction measures (2) and (4) scored better than the baseline scenario in almost all impact categories with a strong and also a weak waste reduction effect, while measure (3) had higher greenhouse gas emissions, costs and also energy input (weak effect only) as compared to the baseline scenario. As a conclusion, the assessment of environmental impacts and costs of waste reduction actions should be of high priority when it comes to the choice of food waste reduction measures. Measures should be selected according to their case-specific cost-effectiveness that shows the relation between the abatement costs and resource reductions.

Keywords: food waste reduction measures, life cycle costs, mixed grain bread

1. Introduction

Worldwide, about one third of the food produced for human nutrition goes to waste (Gustavsson et al. 2011). In times of public awareness of food shortage in some parts of the world, resource scarcity and the environmental impact of food production, ambitions to reduce food waste are a prominent political and societal topic. In September 2015 the United Nations decided with the Sustainable Development Goals, target number 12.3 to "halve per capita food waste at the retail and consumer levels and reduce food losses along production and supply chains". With this target in mind, the question about the type and consequences of food waste reduction measures arises.

Several studies have been conducted to examine the environmental impacts of food waste. Gruber et al. 2016 considered unconsumed food portions and concluded that avoiding food waste could reduce the environmental impact significantly. Eberle and Fels 2016 looked at the environmental impact of food waste in Germany along the whole supply chain, based on the average German food basket. According to their findings, losses along the product chains constitute between 13 and 20% of environmental impacts. The FAO (2013a) calculated a food wastage footprint with greenhouse gas (GHG) emissions of 3.3 Gt CO_2equivalents(eq), 30% of the world's agricultural land occupation, and direct economic costs (based on producer prices) of 750 bill USD. Studies specifying the costs of food waste, usually refer to the monetary value consisting of the summed producer or consumer prices of the wasted food (e.g. FAO 2013a, Kranert et al. 2012). Little attention is paid to possible cost of food waste reduction either in monetary terms or also regarding other aspects such as additional time dedicated to reduce food waste. Britz et al. 2014 simulated food waste reduction scenarios and the impact on the different economy-sectors for Finland, using a regional CEG (computable general equlibrium) model. They argue that the use of waste reduction may cause severe loss of competitiveness for agriculture and food production if costs are not taken into account. Equally, Rutten and Kavallari (2013) modelled impacts of food loss reduction in agriculture in the Middle East and North Africa on economic sectors and food security. They rate reduction and thus enhanced food security as more beneficial than manufacturing and service-led growth. However, a macroeconomic view is not in the center of interest of this paper but rather a life cycle approach with the direct environmental impacts and monetary costs of food waste reduction measures. Few studies have yet examined life cycle costs of food, including also food preparation at home (e.g. Hünecke et al. 2005 for Germany) while life-cycle costs of food waste reduction actions, have not been conducted at all (Koester 2014). Approaches to prevent food waste range from policy recommendations (especially Waarts et al. 2011, Jepsen et al. 2014) to changes in consumer behavior (Kranert et al. 2012, Göbel et al. 2012, FAO 2013b). Parry et al. (2015) assign the 15% reduction of household food waste in the UK from 2007-2012 to more attentive consumer behavior through e.g. buying appropriate amounts, storing under optimal conditions, using the freezer etc. and technical innovations such as different pack sizes, improved storage and freezing guidance, increased shelf-life, packaging innovations and clearer date labelling. According to Parfitt et al. (2010), the greatest potential to reduce food waste in industrialized countries lies within the retailer and consumer stage. In this study the environmental impacts and abatement costs of food waste reduction measures were calculated, exemplarily for the life cycle of bread. By including cost estimates in the assessment, the study offers a comprehensive evaluation of food waste reduction measures.

2. Methods

2.1 Goal and scope definition

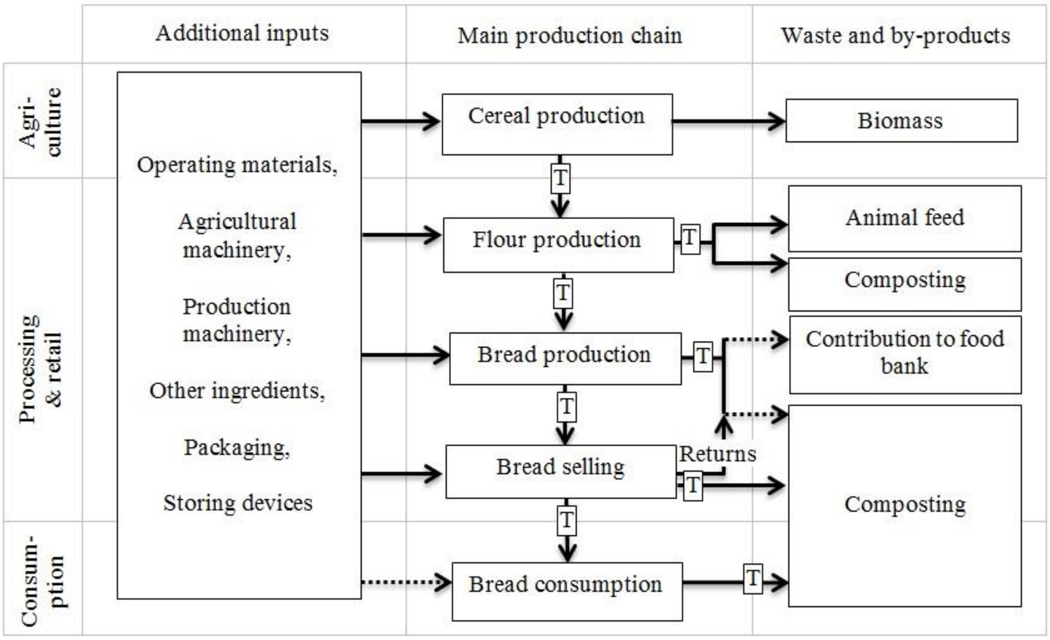
For this study, a standard Life Cycle Assessment according to ISO 14040/44 was connected with an Environmental Life Cycle Costing (LCC), based on the sum of added values (Moreau and Weidema 2015). The product system under study is the life cycle of mixed grain bread in Germany, shown in Figure 1. It comprises the stages agricultural production, milling into flour, baking of bread, selling of bread, bread consumption and disposal during all stages of the supply chain. This operational framework is supposed to display a typical German production and consumption with involvement of medium-sized enterprises during processing and sale. The functional unit is one kilogram of bread consumed. The study is intended to serve as verification for different actions to fight food waste with the main goal to identify the most effective actions for food waste reduction. These actions concern the respective stakeholders at the different points of the supply chain but in addition also researchers and policy-makers for further discussion and application. The actions analyzed are:

1. Baseline scenario with no actions taken to reduce food waste.
2. Reducing food waste at the retail stage by offering food that cannot be sold, but is still edible to food banks.
3. Reducing food waste at the consumption stage by reducing the amount of bread shopped by 50% followed by a higher frequency of shopping.
4. Reducing food waste at the consumption stage by freezing 50% of the bread and consume it to a later point in time.

2.2 System boundaries, assumptions and data origin

A mixed grain bread was chosen as it is with 33.7% the most frequently consumed type of bread in Germany (ZV Bäckerhandwerk 2015a). The main source for the calculation is the ecoinvent database (Weidema et al. 2013). All upstream inputs are based on ecoinvent data through the use of ecoinvent processes. Direct inputs are based on different sources of literature and on estimates for a typical German production chain. All sources of direct inputs used have been summed up in Table 1. Besides direct material and energy inputs, capital goods and tools are included in all ecoinvent processes. Capital goods such as machinery and tools of processes specifically modelled for this supply chain are also included in the calculation while this does not apply for houses and infrastructure. The LCC is conducted as a cursory calculation based on average values for bread production in Germany and exemplary values for additional costs arising within the respective scenarios. The process of agricultural cereal production refers to the production of wheat and rye in Germany within a conventional production system. It includes the inputs of seeds, mineral fertilizers and pesticides as well as the operations soil cultivation, sowing, fertilization, weed, pest and pathogen control, combine-harvest, grain drying and transport from field to farm (4km). Further, it also comprises the machine infrastructure and sheds. Losses during agricultural production refer to mature crop that is or has been edible e.g. not-harvested crops or crop loss at harvest and storage on the farm. The losses of this stage is handled as biomass contribution to the environment while the food waste at all other stages of the supply chain is treated at a composting facility, taking into account the transport to the facility as well as direct inputs and emissions and capital goods.

Figure 1: Overview of the modelled life cycle of bread. Dashed arrows indicate different options considered in the model. “T” stands for transportation.



Source: Own illustration.

Table 1: Data sources for the direct inputs to the life cycle of bread

Processes and additional inputs	Amount	Source of amount used
Wheat and rye production (Germany)		Ecoinvent
Truck transport farm - mill	30 kgkm	Assumption
Production value wheat	0.19 €/kg wheat	BMEL 2015
Production value rye	0.13 €/kg rye	BMEL 2015
Flour production		
Electricity (German energy mix)	0.08 kWh/kg output	Nielsen et al. 2003
Organic chemicals	0.04 g/kg output	Nielsen et al. 2003
Tap water	0.1 l/kg output	Nielsen et al. 2003
Heat (gas)	0.1 kWh/kg output	Nielsen et al. 2003
Machinery	Throughput over whole lifetime 2 Mio. t of grain	Assumption
Paper sacks for transport	140 kg flour per sack	120g paper/m^2
Truck transport mill - bakery	30 kgkm	Assumption
Production value wheat flour	0.34 €/kg wheat flour	BMEL 2015
Production value other flour	0.31 €/kg other flour	BMEL 2015
Bread production		
Bread ingredients	-	Typical German recipe
Electricity (German energy mix)	0.02 kWh/kg output	Nielsen et al. 2003
Heat (gas), industrial furnace	1 MJ/kg output	Nielsen et al. 2003
Plastic baskets for transport	40 t throughput of bread	Assumption
Truck transport from bakery to shop	20 kgkm	Assumption
Production value bread	1.99 €/kg bread	BMEL 2015
Bread sale		
Paper bag as packaging, with print	4.9 g/kg bread	35 g paper/m^2
Consumer price bread	2.32 €/kg bread	ZV Bäckerhandwerk 2015b
Consumption		
Passenger car transport bakery - home	6 km distance	Assumption, (both ways) for shopping 1 kg bread
Transport costs	0.6 €/km	ADAC, medium sized car

The waste portions for each step of the supply chain are shown in Table 2. The flour production takes place in a medium sized production facility in a distance of 20 km to the farm. The milling of the grain results in 80.5% flour, 19% animal feed and 0.5% processing waste. Animal feed is not considered as waste but as by-product. The flour is transported to the bakery in paper sacks with a capacity of 140 kg. At the bakery the mixed grain bread is produced, consisting of 35% wheat flour, 25% rye flour, 39% water and 1% salt. The bread is baked in an industrial gas-driven furnace (no baking pans used). After baking, the bread is transported to a local shop within a distance of 20 km in food transport boxes out of plastic. At the shop, the bread is sold in a paper bag and transported to the consumer's home in a passenger car. The distance between home and shop is assumed to be 3 km. It is further assumed, that shopping takes place for the bread only, therefore, the full distance of 6 km for the forward and back run is assigned to the transport of bread at the consumer stage.

Table 2: Waste portions of bread production at different stages (Jepsen et al. 2014)

	Agriculture	**Postharvest**	**Milling**	**Baking**	**Selling**	**Consumption**
Waste portion	2 %	4.9 %	0.5 %	10 %	2.4 %	11.1 %

The waste reduction scenarios are modelled with different degrees of effectiveness, namely, with a strong, and a weak effect (Table 3). Additional inputs considered for the different scenarios are shown in Table 4. In scenario (2), leftovers from the shop are transported on the return trip of the truck that brings the fresh produce. Therefore, no extra transport is added for this process. However, extra transport is calculated for the transfer of the products to the food bank with a large passenger car. Including forward and back run, the distance amounts to 30 km. For the organization of the donation, an estimated value of 5 seconds per kg bread is used. Additional labor due to donations to food banks is thought to be low, as only little additional logistical work occurs. The main work such as food collection and distribution is conducted by the food banks and staffed with voluntary workers. In scenario (3), only half of the usual amount of bread (0.5 kg) is purchased in connection with the activity of driving by car to the bakery and home, while less bread is wasted at the consumption stage. This also generates additional transport costs and a higher use of paper bags for packaging. Finally, in scenario (4) it is assumed, that half of the bread purchased is put into the freezer for 14 days and afterwards consumed completely (strong effect) or to 94,5% (weak effect). The de-freezing happens by exposing the bread at room temperature. In the freezing scenario, additional costs for the electricity consumed by the freezer and for the purchase of the freezer are accounted for. The freezer was selected as a small sized freezer with a capacity of 30 liters.

Table 3: Effectiveness of waste reduction scenarios at the respective life cycle stages

Scenario	**Strong effect**	**Weak effect**
(2) Contribution to food bank	-70 %	-35 %
(3) More frequent shopping	-100 %	-50 %
(4) Freezing and consuming later	-100 %	-50 %

Table 4: Additional inputs considered for the different food waste reduction measures

Scenario	**Additional inputs**	**Amount**	**Source of amount used**
(2) Contribution to food bank	Passenger car (large size) transport to food bank	30 km distance	Assumption (both ways) Transport capacity 500 kg, 60% utilization
	Transport costs	1 €/km	ADAC, large sized car
	Labor costs	13.78 € per hour	BMEL 2015
	Labor time	5 sec./kg bread	Assumption
(3) More frequent shopping	Paper bag	4.9 g/0.5 kg bread	Size of paper bag 25*15*10 cm, paper weight 35 g/m^2, one bag per 0.5 kg bread
	Passenger car transport from bakery to home	6 km distance	Assumption (both ways) for shopping 0.5 kg bread
	Transport costs	0.6 €/km	ADAC, medium sized car

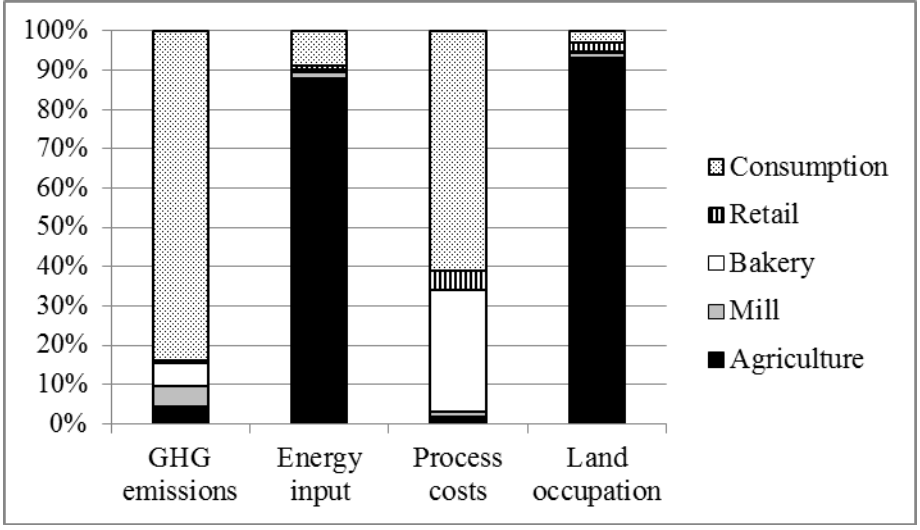
Scenario	Additional inputs	Amount	Source of amount used
(4) Freezing and consuming later	Time in freezer	14 days	Assumption
	Electricity consumption freezer (E_p)	E_p= 1.12 kWh	$E_p=(E_d/SC)*(100\%/u)*V_p*t$ (Nielsen et al. 2003); E_d: electricity consumption of freezer = 0.6 kWh/day, SC: storage capacity of freezer = 30 liters, U: degree of utilization of refrigerator = 50%, V_p=Volume of considered product = 2 liters, t: time of storage = 14 days
	Electricity costs	0.29 €/kWh	strompreise.de
	Purchasing costs freezer	0.00244 €/(l*day)	15 years lifetime, daily degree of utilization 15 liters, purchasing costs 200 €

It is well-known, that costs and prices are very volatile over time. For this study, prices mainly refer to the years 2013 and 2014. Furthermore, the monetary values of by-products or waste have not been considered specifically. Apart from the additional costs from waste reduction scenarios, values are based on averages of German bread production. For the calculation, mass-allocation of environmental impacts was applied to the reference product and by-products. Production and treatment burdens of waste, including food waste, were allocated to the waste producing activity while the output from waste treatment e.g. compost from biowaste treatment becomes available burden free to the market (Ecoinvent 2016). Waste at the agricultural stage is not treated in a composting plant but directly left on the field. The biomass is seen as a by-product and no impacts for the degradation of the biomass were considered. Environmental impacts are not assigned to waste portions as those impacts are thoroughly assigned to the respective output product(s). This implies that compost from food waste composting is available burden free. The life cycle inventory data was analyzed according to the ReCiPe Midpoint impact categories regarding global warming potential and agricultural land referring to a 100 year horizon. In addition to that, the primary energy usage (including renewable and non-renewable energy) and the added monetary value of all processes are summed up, forming the additional impact categories “cumulative energy input” and “process costs”. The software openLCA was used for the calculation (Winter et al. 2015).

3. Results

The share of the different processes on the environmental impacts and costs are shown in Figure 2. Impacts from consumption dominate the GHG emissions (84%) as well as the process costs (61%). The costs of the total supply chain are also significantly influenced by the bakery (31%). Impacts from agriculture determine the land occupation and the energy input, whereby it should be noted that energy input includes the energy content (resp. calorific value) of the grain. The calculation of the whole life cycle of mixed grain bread, including waste portions at each life cycle stage, results in 2.51 kg CO_2eq per kg bread consumed. The largest portion of the emission occurs at consumption due to shopping by car (83% of overall emissions) and waste composting (1% of overall emissions). Besides consumption, 4% of emissions occur at the agricultural production, 5% at flour production, 6% during baking and 1% during selling. The cumulative energy input of the whole life cycle of bread results in a total of 18.04 MJ per kg bread consumed. Around 88% of the primary energy input occurs during agriculture due to biomass input for wheat and rye production. Milling, baking and selling each have an input of 1-2% primary energy, while the shopping trip at consumption accounts for the remaining 9% of energy input. The total life cycle costs amount to 6.69 €. Again, a large portion of the costs, namely 61%, occur during consumption as costs for fuel and the car. Also during baking the added value is comparatively large with 31% of the total costs. Finally, agricultural land amounts to 1.13 m^2a per kg bread consumed. It mainly occurs during agricultural production but partly (around 7% of the total) also during other life cycle stages e.g. in the form of wood production for paper, buildings or energy generation.

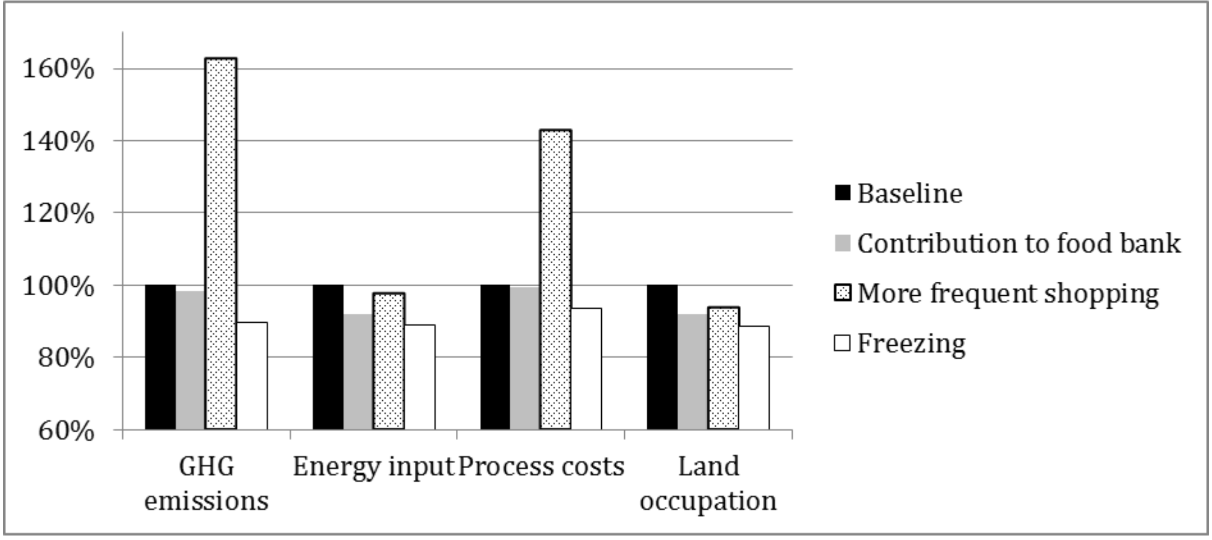
Figure 2: Share of the different processes on impacts and costs



Source: Own calculations.

When comparing the results from the baseline scenario with the three other scenarios under the assumption of a strong waste reduction effect the reduction scenarios score better than the baseline scenario in most categories as shown in Figure 3. However, the more frequent shopping scenario has outstanding more severe impacts with 63% more GHG emissions and 43% higher costs as compared to the baseline. The most effective scenario seems to be the freezing scenario with 90% of GHG emissions, 89% of primary energy use, 88% of land occupation and 94% of costs as compared to the baseline. Also the “contribution to food bank” scenario results in less impact than the baseline scenario, although the difference regarding GHG emissions and costs is marginal.

Figure 3: Results of waste reduction scenarios with a strong effect in relation to the baseline scenario



Source: Own calculations.

When assuming a weak waste reduction effect (Table 5), the impacts of the “frequent shopping scenario” become larger, as compared to the baseline, also regarding energy input while the agricultural land occupation is almost equal. The impacts of the freezing and food bank scenario remain almost all lower than the impacts in the baseline scenario but are largely approximate to the baseline values. An exception here are the process costs of the food bank scenario, they are marginally higher than the baseline costs.

Table 5: Environmental impacts and costs of the life cycle of mixed grain bread

	Scenario	**GHG in kg CO_2eq/FU**	**Energy input in MJ/FU**	**Process costs in €/FU**	**Land occupation in m^2a/FU**
	Baseline	2.51	18.04	6.69	1.13
Strong effect	Food bank	2.47	16.61	6.65	1.04
	Freezing	2.25	16.05	6.27	1.00
	Frequent shopping	4.08	17.62	9.55	1.06
Weak effect	Food bank	2.50	17.31	6.72	1.08
	Freezing	2.39	17.00	6.64	1.06
	Frequent shopping	4.33	18.66	10.11	1.12

4. Discussion

The results show, that waste reduction can also reduce environmental impacts, as it is widely promoted (e.g. Gruber et al. 2016, Eberle and Fels et al. 2016 and FAO 2013). But waste reduction actions do also have an impact on the environment and are also relevant to cost factors. In the presented scenarios, the impacts of freezing a part of the bread, as well as donating the bread to food banks are lower than the impacts of the bread production amount that is wasted in the baseline scenario. In addition, the costs of freezing and donating bread to food banks are lower than the costs of the percentage of bread that is wasted in the baseline scenario. However, the extent of the waste reduction effect is crucial. As seen in the modelling of a weak waste reduction effect in the freezing scenario, the waste reduction action should still be preferred to the baseline scenario even if it goes along with medium success. With the selected waste reduction scenarios of this model, higher life cycle costs occur together with partly higher or almost equal environmental impact as compared to the baseline (frequent shopping – strong/weak effect and food bank - weak effect). Although, this cannot be seen as a rule, high costs of reduction actions may be an indicator of high impact on resource use. At the consumption stage, the consumer is very likely to be unaware of the detailed costs for waste reduction as well as for the bread wasted. The food bank scenario shows that waste reduction can also be beneficial for the producer regarding costs.

It is not very productive to compare the results of the modeled life cycle with results of other studies dealing with the life cycle of bread (comp. Espinoza-Orias et al. 2011, Andersson and Ohlssohn 1999) as results clearly differ due to different system borders, data used or assessment criteria. As it was not the goal of this study to find and establish new data for the life cycle assessment of bread but rather to assess the environmental impacts and costs of waste reduction measures. Therefore, comparison with existing studies is not even necessary and impacts of waste reduction actions have not been assessed, yet.

5. Conclusions

The assessment of environmental impacts and costs of waste reduction actions should be of high priority when it comes to the choice of food waste reduction measures. Measures should be selected according to their efficiency that is expressed as the relation between the abatement costs and resource reductions. It is important to give the consumer detailed information on costs of waste reduction actions as monetary savings can trigger waste reduction at consumption. Under the assumptions of the calculated example the option of freezing a part of the bread and donating the left-over bread to food banks are good approaches for food waste reduction. More frequent shopping is no option to save resources and costs when the shopping trip is done by car and for the single purpose of bread shopping. However, it can be reasonable in a coordinated action. A goal of future studies could be to assess further waste reduction actions that are finely graduated to determine tipping points of food waste reduction actions. Furthermore, the question of direct costs and externalities of resource use should be included in the calculations, as well as estimates about the effect on the national economy.

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6. References

ADAC. ADAC Autokosten-Rechner. [Online] Available from https://www.adac.de/infotestrat/autodatenbank/autokosten/autokosten-rechner/default.aspx/ Accessed 25 May 2016.

Andersson, K., Ohlssohn T. 1999. Life Cycle Assessment of Bread Produced on Different Scales. International Journal of LCA 4 (1). pp. 25-40.

BMEL. 2015. Statistisches Jahrbuch über Ernährung Landwirtschaft und Forsten 2015. 59. Jahrgang. Landwirtschaftsverlag GmbH, Münster-Hiltrup. p 643.

Britz, W., Dudu, H., Ferrari, E. 2014. Economy-wide Impacts of Food Waste Reduction: A General Equilibrium Approach. EAAE 2014 Congress. Ljubljana, Slovenia.

Eberle, U., Fels, J. 2016. Environmental Impacts of German Food Consumption and Food Losses. International Journal of LCA (2016) 21. pp. 759-772.

Ecoinvent. 2016. [Online] Available from http://www.ecoinvent.org/database/system-models-in-ecoinvent-3/cut-off-system-model/allocation-cut-off-by-classification.html/ Accessed 25 May 2016.

Espinoza-Orias N., Stichnothe, H., Azapagic, A. 2011. The Carbon Footprint of Bread. International Journal of LCA (2011) 16. pp. 351-365.

FAO. 2013a. Food Wastage Footprint – Impacts on Natural Resources. FAO, Rome. p 61.

FAO. 2013b. Toolkit – Reducing the Food Wastage Footprint. FAO, Rome. p 119.

Gruber, L.M., Brandstetter, C.P., Bos, U., Lindner, J.P., Albrecht, S. 2016. LCA Study of Unconsumed Food and the Influence of Consumer Behavior. International Journal of LCA (2016) 21. pp. 773-784.

Gustavsson, J., Cederberg, C., Sonesson, U. 2011. Global Food Losses and Food Waste. FAO, Rome. p 38.

Hünecke, K., Fritsche, U. R., Eberle, U. 2005. Lebenszykluskosten für Ernährung. Öko-Institut e.V., Darmstadt/Freiburg. p 40.

Jepsen, D., Vollmer, A., Eberle, U., Fels, J., Schomerus, T. 2014. Entwicklung von Instrumenten zur Vermeidung von Lebensmittelabfällen. Ökopol GmbH, Hamburg. p 23.

Koester, U. 2014. Food Loss and Waste as an Economic and Policy Problem. Intereconomics 6. pp. 348-354.

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 Vermeidung der Wegwerfrate bei Lebensmitteln in Deutschland. Universität Stuttgart, Stuttgart. p 483.

Moreau, V., Weidema, B.P. 2015. The Computational Structure of Environmental Life Cycle Costing. International Journal of LCA (2015) 20. pp. 1359-1363.

Nielsen, P.H., Nielsen, A.M., Weidema, B.P. 2003. LCA Food Database [Online] Available from http://www.lcafood.dk/ Accessed 25 May 2016.

Parfitt, J., Barthel, M., Macnaughton, S. 2010. Food Waste within Food Supply Chains: Quantification and Potential for Change to 2050. Philosophical Transactions of the Royal Society B (2010) 365. pp. 3065-3081.

Parry, A., Bleazard, P., Okawa, K. 2015. Preventing Food Waste: Case Studies of Japan and the United Kingdom. OECD Food, Agriculture and Fisheries Papers No. 76. OECD Publishing. p 51.

Rutten, M., Kavallari, A. 2013. Can Reductions in Agricultural Food Losses Avoid Some of the Trade-offs Involved when Safeguarding Domestic Food Security? 16th Annual Conference on Global Economic Analysis, Shanghai. p 23.

Strompreise DE [Online] Available from www.strompreise.de/ Accessed 25 May 2016.

Waarts, Y., Eppink, M., Oosterkamp, E., Hiller, S., van der Sluis, A., Timmermans, T. 2011. Reducing Food Waste: Obstacles Experienced in Legislation and Regulations. Wageningen UR, The Hague. p 130.

Weidema, B.P., Bauer, Ch., Hischier, R., Mutel, Ch., Nemecek, T., Reinhard, J., Vadenbo, C.O., Wernet, G. 2013. The ecoinvent database: Overview and methodology [Online] Available from www.ecoinvent.org/ Accessed 25 May 2016.

Winter, S., Emara, Y., Ciroth, A., Su, C., Srocka, M. 2015. openLCA 1.4. Comprehensive User Manual, Berlin.

ZV Bäckerhandwerk. 2015a. Brotkorb der Deutschen 2014. [Online] Available from http://www.baeckerhandwerk.de/baeckerhandwerk/zahlen-fakten/brotverbrauch-und-brotkorb-der-deutschen/ Accessed 25 May 2016.

ZV Bäckerhandwerk. 2015b. [Online] Available from http://www.baeckerhandwerk.de/baeckerhandwerk/zahlen-fakten/geschaeftsbericht-20142015/ Accessed 25 May 2016.