Improving the quality and quantity of source-separated household food waste in areas of different socio-economic characteristics: A case study from Lübeck, Germany

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Abstract
A method aiming at improving source-separation performance of household food waste (FW) was investigated in two areas with different socio-economic characteristics in Lübeck, Germany. This included the test of a new FW collection system including the distribution of small collection buckets to each household. In addition, an information event was organized and households were provided with information material including a waste sorting guide. The study also aimed at assessing the FW avoidance potential. A method for waste composition analysis for FW from households was applied for the assessment. Both areas showed an increase of the source-separation of FW from 17.4% to 60.3% (A, *socio-economic low* area) and from 16.6% to 65.7% (B, *socio-economic medium* area) respectively. Compared to the waste composition in the bio-waste (BW) bin prior the investigation, macro-impurities (including paper waste) reduced from around 6.1% to 0.6% (A) and from 13.6% to 1.2% (B). In this respect, the investigated collection system showed a significant improvement to the regular waste collection system.
Keywords: Food waste, Waste composition analysis, Waste valorization, Circular Economy, Socio-economic assessment

1. Introduction

FW became a major concern within the European Union's Bioeconomy Strategy (European Commission 2018). 88 million Mg are wasted per year in the EU-28 with households accounting for more than 50% (Stenmarck et al. 2016, Kranert et al. 2012). At present FW is far from being effectively utilized since a large portion, often up to 70% (Kranert et al. 2012; Richter et al. 2017), is disposed in the residual waste (RW) bin. The average source-separated FW is estimated between 15.8 kg/ inh.&year (Witzenhausen 2017) and 19.1 kg/inh.&year (Kranert 2012) while the potential of FW in the RW is estimated to be around 42.5 kg/inh.&year (Kranert et al. 2012; Richter et al. 2017). Other FW pathways like home-composting were excluded from the present study. Currently, the source-separated BW including FW tends to be contaminated with macro-impurities such as plastic creating difficulties in valorization. Its strict separation at source is the most efficient step in waste collection for the adjustment of BW quality and quantity. Therefore, it is a key step for the valorization.
The goals of this investigation were (i) to investigate areas of different socio-economic characteristics with respect to (ii) an increase of peoples' awareness about source-separation of FW in order to (iii) increase the quantity of source-separated FW by shifting it from the RW output to the BW output and (iv) to decrease macro-impurities in the BW output. In addition, the (v) share of avoidable FW was assessed.

2. Methodology

Households situated in multi-family houses in two districts (37 – area A, 46 – area B) of the city of Lübeck were selected in order to represent socio-economic different neighborhoods. Area A represents a poorer, area B a wealthier neighborhood. The flats in area A are publicly funded which allows for a low rent (5.65 €/m^2) while the flats in area B are not publicly funded (average rent 10 €/m^2). BW bins for mutual collection of green waste (GW) and FW were available in both areas before the investigation.
Before starting the new FW collection system, information material was provided to each household and an information event was organized. Each household was provided with two 5-L buckets for separate FW collection. A collection frequency of three times per week was offered but participants were free to place it into the installed storage facility whenever it was suitable. During the investigation, some of the households were interviewed regarding their habits. The total duration of the intervention was 31 days.
For each area BW including FW and RW were weighed and analyzed for its composition on a wet basis once before and frequently during the intervention. The protocol for analysis was adapted from Bernstad Saraiva Schott et al. (2013) with the sorted fractions shown in Table 1.
During the intervention, FW was weighed and analyzed each time of collection separately for each household. Simultaneously, RW was weighed but as a mix of all

households separately for both areas. Its composition was analyzed once including the generated amount of one week (A) and two weeks (B). A total 634 kg of source-separated FW and 187 kg FW in RW were analyzed.

Table 1. Characterised waste fractions

Main Fraction	Sub-Fraction	Example
Food waste	Unavoidable	Cores, Bones
	Avoidable	Pulp, Meat
	Partly avoidable	Peels
Green waste	-	Leaves
Other kitchen waste	-	Paper towels
Others	-	Paper, plastic

3. Results

The waste composition analysis prior the investigation showed a low source-separation behavior in both areas with area A having an approximately 43% lower performance when compared to area B. Macro-impurities were more abundant in area B, however, with the main fraction being paper (13.1%).

A total of 75% of the households of each area participated in the source separation of FW. 50% of the participants of the accompanying survey stated they begun source-separation of FW with the start of the intervention. During the investigation source-separation increased between 6.5- (A) and 4-fold (B).

Macro-impurities were reduced by around 90% in both areas. The share of avoidable FW was higher in area A and in general the share was higher in source-separated FW than in FW found in RW. A comparison of the results *before* and *during* the intervention is shown in Table 2.

4. Discussion and Outlook

Amounts of source-separated FW prior the intervention were in a range comparable to those reported before (Kranert et al. 2012; Richter et al. 2017). The results show that the new collection system can improve the quality and quantity of source-separated FW significantly. Both areas showed a similar improvement. Source-separation increased to around the double amount found in literature for multi-family houses (Bernstad Saraiva Schott et al., 2013). The amount of avoidable FW was comparable for area B but higher in area A. The reduction of macro-impurities was mainly influenced by the avoidance of plastic bags and undefined fraction (A) and paper (B). Further investigations should include a specific focus on FW avoidance and the evaluation of different transportation units suitable for a decentralized waste management.

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Table 2. Results of FW and RW analysis. SD in parenthesis

	Total generated FW kg (HH[e], week)$^{-1}$	Source-separation (%)[a]	Avoidable FW (%)[a]	Partly avoidable FW (%)[a]	Macro-impurities (%)[b]
Before A[c]	2.3 (-)	9.5	52.7	-[d]	6.1
During A	2.9 (0.2)	61.6	42.9	11.4	0.6
Before B[c]	1.9 (-)	16.6	29.1	-[d]	13.6
During B	2.4 (0.1)	65.9	33.8	12.3	1.2

[a]percentage of total generated FW; [b] in source-separated FW, including paper; [c]one single measurement; [d]not measured *before* intervention, [e]Household

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