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The Meat We Do Not Eat. A Survey of Meat Waste in German Hospitality and Food Service Businesses

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Abstract: Food waste is a global challenge. Detailed information on quantities and drivers is needed to provide tailored recommendations for prevention measures. Current studies on meat waste in the Hospitality and Food Service business (HaFS) sector are rare, often based on small sample sizes, and seldom use comparable reference units. The present study reports meat and meat product waste in the German HaFS business sector based on structured telephone interviews. Purchased fresh meat and meat product quantities, as well as waste during storage, due to preparation and leftovers, are captured for four different market segments. Waste ratios referring to weekly meat purchases are analysed and compared between these segments, as well as on the business-type level. In this context, the authors distinguish total and avoidable meat waste. Absolute meat waste volumes are extrapolated on a weighted base for the entire German HaFS sector. Factors influencing meat waste are identified through regression analysis in order to derive possible food waste prevention measures. The results are discussed to provide recommendations for future national monitoring, policy instruments and research.

Keywords: meat waste; meat product waste; waste ratios; out-of-home market; food waste; away from home (AFH), leftover; plate waste; serving waste

Citation: Thies, A.J.; Schneider, F.; Efken, J. The meat we do not eat. A survey of meat waste in German Hospitality and Food Service businesses. *Sustainability* **2021**, *13*, 5059. https://doi.org/10.3390/su13095059

Academic Editor: Danuta Kołożyn-Krajewska, Beata Bilska and Marzena Tomaszewska

Received: 31 March 2021
Accepted: 28 April 2021
Published: 30 April 2021

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1. Introduction

The limits of planetary resources, combined with a growing world population and a correspondingly increasing demand for food, make more sustainable production and consumption behaviours imperative. The reduction, or even prevention, in food that is wasted along the entire value chain plays a decisive role in this respect [1,2].

This relevance is accounted for in the United Nations Sustainable Development Goal 12.3, which calls for halving the amount of food waste by 2030 and reducing food losses along the entire food supply chain [3].

Following the recommended target–measure–act approach by the World Resource Institute and other leading scientific organisations [2,4], detailed information regarding the emergence of food waste is a fundamental requirement to implement prevention measures and assess their efficiency in a second step. In this context, a comprehensive database would allow for a comparison between product groups, value chains, regions and countries in order to identify influencing factors [5] and derive efficient preventive actions [6,7]. Although the UN member states already committed themselves to SDG 12.3, the European Commission released regulatory instruments for application by the member states in order to further support the achievement of these objectives. As a first step, the European Waste Framework Directive was revised by implementing a common definition of food waste within the European context (Directive (EU) 2018/851). In a second step, reporting of annual food waste quantities to the European statistic office, according to a

defined common methodology with minimum quality requirements, was made compulsory in 2020 to achieve a uniform measurement of food waste and generate a comparable database [8,9]. These specifications also initiated the establishment or adaption of national food waste monitoring systems in European Community countries [10–14].

The aim of associated policy instruments is mainly to reduce the overall amount of food waste. However, with regard to the sustainability of food systems, distinguishing between different product groups is of great relevance [15] as climate effects associated with production vary in terms of resource intensity [16]. This means that food products with lower waste quantities measured in mass might be identified as hot spots, considering alternative indicators such as the global warming potential (GWP), carbon footprint, blue water footprint, land use, biodiversity and ecosystem services [17–21].

The production of animal proteins and especially meat is associated with higher negative external effects on the environment in comparison to plant-based food [22,23]. In addition, there are growing social concerns regarding animal welfare, which is reflected, among other issues, in an increasing number of vegan and vegetarian consumers mostly in Western industrialised countries [24,25]. Researchers at various national or institutional levels conclude that a reduction in meat consumption could have a positive effect on environmental sustainability [16,26,27]. Issues to be considered in this context are land, energy and water use [22,28]; the contribution of greenhouse gas (GHG) emissions; biodiversity loss; and deforestation [26,29]. Beretta and Hellweg conclude in their work on selected hospitality sector case studies that a reduction of two (mass) percent of meat and fish waste in a business canteen, accompanied by a shift to a higher share of fish dishes on offer, could result in the largest environmental benefit of all considered food categories [15]. This underlines the importance of a solid understanding of the magnitude and influencing factors on meat waste along the value chain, which then enables target-oriented measures to lower the environmental footprint and social impact of food systems.

Previous scientific research has focused on the detection and prevention of food waste at the consumer level, especially in industrialised countries [5], as waste volumes appeared to be particularly high compared to other stages of the value chain [30]. However, food is not exclusively prepared and consumed at home. In addition, within the Hospitality and Food Service (HaFS) sector, professional food handling meets individual consumer attitudes, expectations and behaviour. Therefore, food waste accounting and the implementation of prevention measures are especially challenging tasks as two interconnected stakeholder groups with contrasting inherent aims, knowledge and preferences have to be considered and addressed within one stage of the value chain. In addition, each of the various food service business types faces different internal and external framework conditions. The acquisition of information on food waste in the HaFS sector should be prioritised on the research and political agenda. Since the share of meat and meat products purchased by German private households in comparison to meat consumed according to the official meat balance sheets decreased by 7% between 2008 and 2018, it can be assumed that consumption outofhome was gaining importance until the outbreak of the COVID-19 pandemic in March 2020 [31,32]. It remains to be seen how the sector will develop after the lockdown measures are lifted, in connection with the lasting changes in the living and working habits of society.

Available studies on meat waste in the HaFS sector (see Section 2) are often based on small sample sizes and show results in relation to portion sizes, which are hardly comparable. This study therefore reports meat and meat product waste for the German HaFS sector based on structured telephone interviews with HaFS businesses. Purchased fresh meat and meat product quantities, as well as waste during storage, due to preparation and leftovers, are captured, considering four different market segments: Gastronomy, Communal Catering, Accommodation and further HaFS business. Waste ratios referring to weekly meat purchases are analysed and compared between the four different segments and on a business-type level. In this context, the authors distinguish between total and avoidable waste ratios. Absolute waste volumes are extrapolated on a weighted basis

for one year and the total number of HaFS businesses within the four segments. Factors influencing waste ratios are identified through regression analysis in order to derive possible prevention and reduction measures. In addition, the methodological approach is discussed to provide implications for future national monitoring, policy instruments and research.

2. Meat Waste in International Out-of-Home Food Consumption Literature and Data Gaps

The literature references on fresh meat and meat product waste within the out-of-home food consumption sector are generally scarce. A few studies mention meat waste as part of higher aggregated product groups or as part of mixed dishes [33]. However, they do not specifically indicate waste ratios or absolute waste volumes for meat. Other authors provide selected data for specific waste types, such as plate waste [34–37], but do not consider the total quantity purchased.

Table 1 summarises literature references and accompanying information. Among them, only few studies target meat waste in German out-of-home food consumption. Noleppa and Cartsburg [38] give an overview of existing data. In total, meat waste at the consumption level (sum of out-of-home and household levels) is calculated as 16% related to the amount available for consumption, of which 8.3% is classified as unavoidable and 7.7% as avoidable meat waste. Xue et al. [39] analysed the German meat supply chain considering use and disposal paths of meat waste and the use of by-products. At the consumption level (sum of out-of-home and household levels), the authors summed up meat waste at roughly 24%.

In the international literature, the Waste & Resource Action Programme (WRAP) [40] compiled results of several studies in the United Kingdom and found that higher-priced food accounts for a relatively low share of avoidable out-of-home food waste (FW). In sum, 6% of the total avoidable FW was composed of meat and fish.

Schranzhofer et al. [41] analysed FW in the Austrian out-of-home sector, performing a detailed sorting analysis for three different business types: 10 hotels, 8 gastronomy businesses and 11 canteens. For the present paper, unpublished raw data from Schranzhofer et al. was used to recalculate the meat and fish waste quota, which is the amount of avoidable meat and fish waste related to the food output to clients. Waste ratios vary from 1.0% for canteens to up to 4.7% for gastronomy (Table 1). Beretta et al. [17] conducted a mass flow analysis (MFA) based on various waste sorting analyses from Austrian and Swiss literature. The authors provide detailed meat waste figures, considering different meat types and classifying avoidable or unavoidable waste. Papargyropoulou et al. [42] also used an MFA based on primary data of three different out-of-home establishments in Malaysia.

Table 1. Selected national and international data related to meat waste in the HaFS sector.

Reference	Level	Unit	Total meat waste	Avoidable Meat Waste	Unavoidable Meat Waste
Noleppa and Cartsburg [38], Germany	Ooh and Hh	Percentage of production available for consumption stage	16.0	7.7	8.3
Xue et al. [39], Germany	Ooh	Dry matter percentage of meat products available for ooh	ca. 8	-	-
WRAP [40], UK	Ooh	Meat and fish waste in percentage of total FW ooh		6 (including fish)	

Schranzhofer et al. [41], Austria	Ooh	Meat and fish waste in mass percent of total FW ooh	Hotels: 3.7 Gastronomy: 13.8 Canteens: 2.8	-	-
Schranzhofer et al. [41], Austria	Ooh	Meat and fish waste in mass percent of avoidable FW ooh	-	Hotels: 8.9 Gastronomy: 24.7 Canteens: 3.8	-
Own calculation acc. Schranzhofer et al. [41], Austria	Ooh	MW quota (avoidable meat and fish waste related to food mass output to consumers)	-	Hotels: 1.4 Gastronomy: 4.7 Canteens: 1.0	-
Beretta et al. [17], Switzerland	Ooh	Percentage of input to Swiss HaFS sector	-	Pork: 10.3 Poultry: 13.1 Beef, horse, veal: 19.4	Pork: 13.8 Poultry: 25.0 Beef, horse, veal: 13.8
Papargyropoulou et al. [42], Malaysia	Ooh	Percentage of input to establishments	2.1–2.6	-	-

Xue et al. [5] found that available data on food waste is often unrepresentative, is outdated or does not consider different framework conditions. The results of different studies are therefore often not comparable. These issues also emerge when examining the meat product group. Reference parameters (e.g., based on meat input to level or composition of total FW), observation levels (partly including household level), product types (partly fish included), targeted waste streams (partly avoidable meat waste only), origins of data (primary or secondary data) and physical units (dry matter versus fresh matter) differ among the various literature references (Table 1). Furthermore, there is a lack of representativeness as only small-scale pilot studies were used for upscaling.

Thus, the present paper represents a unique primary and representative data source regarding meat waste for the considered segments and associated HaFS businesses, covering all arising points from storage to plate leftovers.

3. Hypothesis, Definitions, Data and Methodological Approach

3.1. Hypothesis

Against the background of a comprehensive literature review, various hypotheses were developed, which were addressed in the course of analysis of the collected data.

Operating conditions of segments and the individual businesses differ greatly from one another. The procurement of meat (quantity, type and degree of processing) as well as the storage and processing in a restaurant is not comparable with a company that hardly processes the meat itself (such as a bakery selling sandwiches to go). This is why an assessment is needed at the business level to make corresponding statements regarding the absolute quantities of meat waste for the entire German HaFS sector.

Hypothesis 1 (H1). *Segments in the HaFS sector report different meat waste quantities due to different framework conditions. Even within the same segments, meat waste varies due to individual characteristics (e.g., size, number and type of meat on offer, suppliers).*

Furthermore, the authors assume that the contribution of different arising points varies between segments. For example, it is known from the literature that in the catering

industry, mainly plate waste occurs. The volume of waste occurring in the course of processing or handling might be low for the majority of businesses, as purchased meat products are likely to be pre-cut or prefabricated. Accordingly, it can be assumed that for different segments, individual arising points have to be identified to derive targeted meat waste prevention measures.

Hypothesis 2 (H2). *The relevance of different arising points of meat waste varies between HaFS segments. Identifying those arising points helps to derive specific reduction measures.*

The authors also assume that internal factors referring to the overall awareness of food waste prevention within each HaFS business affect the level of meat waste. Businesses that have already raised staff awareness on food waste prevention are probably already implementing various prevention measures and, therefore, report lower meat waste. These businesses might also have higher shares of meat leftovers taken home by guests and are more likely to be cooperating with social institutions (food pantries).

Hypothesis 3 (H3). *Businesses that are aware of the food waste issue in general and those that have already implemented prevention measures have lower meat waste ratios compared to businesses that have hardly dealt with the topic.*

3.2. Definition and Data

The products considered in the data collection were fresh meat and meat products (e.g., filets, schnitzel or sliced cold meat), which are purchased and further processed into ready-to-eat dishes within the HaFS sector. All food-grade meat products leaving the food supply chain were defined as meat waste. In addition to the total amount in wet mass, the share of unavoidable meat waste was requested. The classification and definition of unavoidable waste were outlined to the participants at the beginning of the consultation.

As the results have also been used for a mass flow analysis of the entire German meat supply chain, weekly meat purchases in kilograms as well as the share of wasted meat were captured. A reference period of one week was chosen in order to obtain realistic assessments based on the respondents' memory.

A total of 400 companies located in all 16 federal states of Germany were interviewed on the basis of computer-assisted telephone interviews (CATI) by a specialised market research institute (Business Target Group (BTG)) between October and December 2019.

The surveyed businesses were divided into four different segments according to their operating and customer structures: Gastronomy, Communal Catering, Accommodation and further HaFS business. In each segment, a total of 100 companies were interviewed and selected based on random sampling. The number of the individual business types was representative within each segment, based on the total number of HaFS businesses and further available subdivision criteria (such as seating capacity). Due to missing values, the dataset used for the analysis was further reduced to a total of 379 respondents. Accordingly, the final sample structure is shown in Table 2.

Table 2. Sample structure.

Segment and Associated Businesses	*n* (Sample *n* = 379)
Gastronomy	
Bistro	4
Café	13
Pub	16
Home delivery	6
Quick-Service Restaurants (QSRs)	4
Slow food	39
Snack	11
Communal Catering	
Retirement home	10

Disabled facility	1
Business catering	8
University	1
Children and youth facility	39
Hospital	2
School	34
Further care facilities	1
Preventive care and rehabilitation facility	2
Accommodation	
Inn	16
Hotel	35
Hotel Garni	19
Youth hostel	4
Guesthouse	20
Further HaFS business types	
Bakery	49
Butcher	22
Filling station	20
Caterer	3

The questionnaire comprised a total of 15 open and closed questions, which were related to general operation information, meat purchases (meat types and meat-sourcing locations) and estimated meat waste ratios differentiated according to arising points. In addition, participating businesses had to answer several statements regarding their attitudes towards the prevention of food waste in general within a four-point Likert scale. To identify business characteristics that are related to the indicated waste ratios (see Hypotheses 3), the information gathered in this way has been used.

Targeted respondents within each HaFS business were selected according to their ability to assess weekly purchased and wasted meat quantities. The comprehensibility of the questions was ensured through multiple feedback rounds with the market research institute as well as a pretest.

For purposes of comparability, representatives of further HaFS business types were asked to refer to ready-to-eat or takeaway products. The information with regard to meat waste in butcheries therefore refers to waste accruing after early stages of processing, such as trimming or cutting.

The authors distinguished between waste arising during storage, preparation and leftovers (Figure 1). Storage waste occurs during storage on-site, e.g., due to exceeded shelf life. Preparation waste that arises during trimming and cooking processes was categorised as unavoidable waste (inedible components such as bones and tendons) and further waste resulting from cutting of edible material. Leftovers (total of overproduction, remaining from buffet and plate) were also classified as waste and summarised within the questionnaire to not exceed the maximum number of questions at the given financial budget. In contrast, meat taken home in doggy bags by customers was not considered as meat waste in the present study.

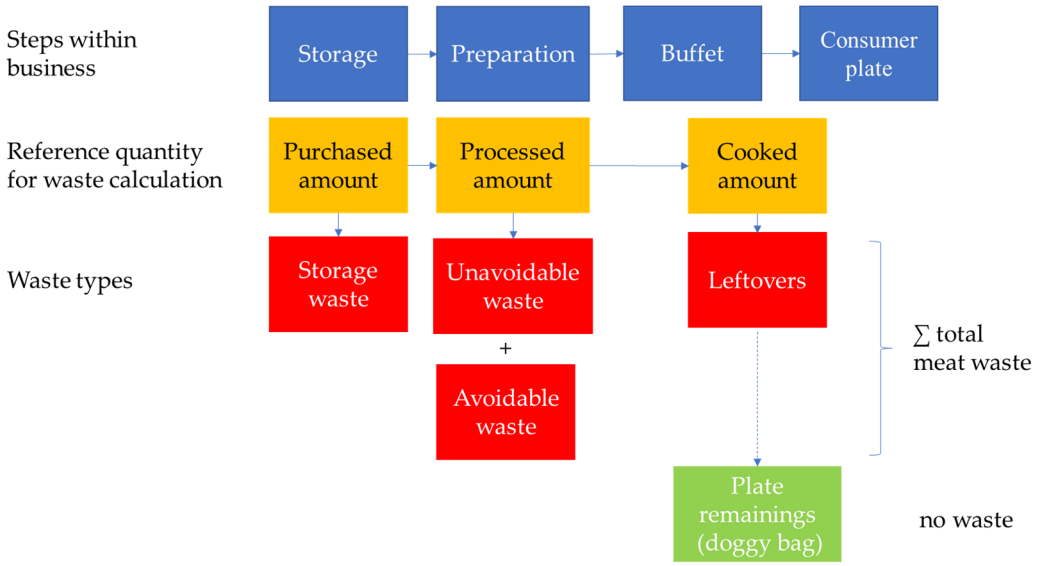

Figure 1. Model for meat waste flows within each assessed HaFS business.

Information on meat waste was given as a share individually related to the meat quantity purchased, processed and cooked, according to Figure 1. Total waste quantities were calculated by adding absolute meat waste quantities at each stage (storage waste, processing waste and leftovers). For reasons of comparability and further analysis, meat waste ratios were determined referring to the purchased meat quantity of each HaFS business. In case a respondent could not estimate single streams, he or she could indicate total waste ratios without distinguishing between different steps.

3.3. Data Analysis

An initial plausibility check of the responses was carried out based on the expertise of the market research institute. The data analysis was carried out in three subsequent steps, using Stata 16.1 for deductive and inductive statistics:

In the first step, waste ratios were compared between the different segments and on the business-type level using various descriptive statistical parameters and explorative analysis (boxplots). Outliers and zero values were not removed, as the indication of zero waste ratios seemed realistic for businesses purchasing ready-to-eat products with only minor processing (such as bakeries or filling stations).

A Kruskal–Wallis H test followed by a post hoc analysis (pairwise comparison) was conducted to test for statistically significant differences in waste ratios between segments [43]. Weighted meat waste for the total German HaFS sector was calculated considering the total number of businesses types for each segment according to the professional business database of the BTG Group.

In the second step, the authors identified driving factors on the level of meat waste ratios. Since the values of the waste ratios (dependent variable) were between 0 and 1, a fractional logistic model was conducted [44]. Average marginal effects were calculated to enable a better interpretation of the estimated coefficients. Goodness of fit was assessed based on the Wald test and McFadden's pseudo-R2 measure [45].

Additionally, in the third step, qualitative statements of 116 respondents given within an additional open question were analysed by qualitative content analysis according to Mayring et al. [46]. Categories defined in the course of the analysis were formed inductively [46].

4. Results

4.1. Descriptive Statistics and Meat Waste Ratios

Information on summary statistics and further characterisation of the participating businesses is presented in Table 3. The interviewees within the HaFS sector were primarily involved as the owner, manager, tenant and/or kitchen manager of a business. The companies with staff reported to have 14 employees, on average.

Participants reported a mean meat purchase of 66 kg per week, whereby the purchased volumes varied noticeably against the backdrop of the standard deviation. Wholesale and butchers were the most frequently mentioned sourcing locations for meat, whereas direct purchases from slaughterhouses or farms were little used. Offered meat types and products were mainly sliced cold meat, poultry, beef and pork. Specialised restaurants offering game or high-priced lamb, however, were rather less prevalent. The variable reflecting the offer of small portions was derived from the open question on further comments.

Table 3. Summary statistics and characterisation of surveyed businesses.

Variables	*n* (Sample *n* = 379)	Mean	SD
Total meat purchase in kg per week	379	66.35	140.83
Number of employees	269	14.97	28.64
Position of the respondent within the company (dummy)			
Owner, management, tenant	208	0.54	0.50
Operational management	26	0.06	0.25
Kitchen management	88	0.23	0.42
Chef	17	0.04	0.21
Purchasing management	2	0.01	0.07
Meat-sourcing location (dummy)			
Butcher	173	0.46	0.50
Farm	21	0.05	0.23
Slaughterhouse	16	0.04	0.20
Wholesale	238	0.63	0.50
Retail	64	0.17	0.37
Purchased meat types (dummy)			
Poultry	253	0.67	0.47
Beef	246	0.65	0.50
Pork	246	0.65	0.50
Lamb	65	0.17	0.40
Game	77	0.20	0.40
Sliced cold meat	260	0.69	0.46
Other	26	0.07	0.25
Offer of small portions (dummy)	4	0.01	0.10

To address Hypothesis 1 (H1), the distribution of the waste ratios in the four different segments was examined descriptively using boxplots (Figure 2). Waste ratios at the business level were investigated using various descriptive statistical indicators (Table 4).

Figure 2 illustrates the distribution of total meat waste ratios related to purchased weekly meat quantities. Due to a relatively large interquartile range, the broadest distribution was found for the Gastronomy segment, followed by Accommodation, Communal Catering and further HaFS business types. Medians of the first three segments were in a similar range, meaning that 4% to 5% of the weekly purchased meat is wasted. However,

the fourth segment deviates visually in this regard. A Kruskal–Wallis H test showed that there was a statistically significant difference in meat waste ratios between the four segments: $\chi 2(3) = 39.370$ and $p = 0.0001$. A post hoc test (Dunn's pairwise comparison with Bonferroni adjustment) confirmed that the fourth segment of further business types has significantly different meat waste ratios compared to the remaining three segments. No statistically verifiable difference could be found between waste ratios of Gastronomy, Communal Catering and Accommodation.

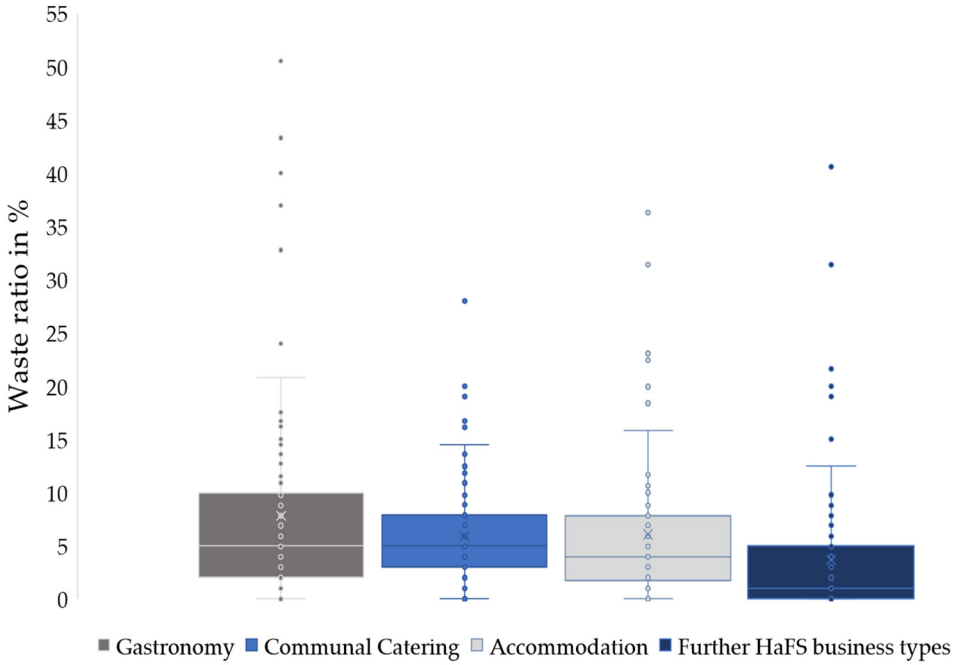

Figure 2. Distribution of total meat waste ratios for the four assessed segments.

Table 4 shows various statistical parameters regarding the total and avoidable meat waste ratios for the four different segments and associated business types. The highest mean total and avoidable waste ratios were found for the Gastronomy segment, including the highest maximum waste ratios. Within this segment, bistros and cafés indicated the highest waste ratios. Communal Catering and Accommodation segments showed comparable mean waste ratios. Within the Communal Catering segment, retirement homes and preventive care and rehabilitation facilities stated the maximum waste ratios. Youth hostels showed the highest waste values within the Accommodation segment. The lowest total and avoidable meat waste rates were calculated for further businesses, including the lowest avoidable waste ratio. Within this segment, the lowest meat waste ratio was found for bakeries, which was not surprising due to the high convenience degree of the meat (e.g., already sliced cold meat to be used in fresh sandwiches).

Table 4. Meat waste ratios for segments and subsegments in percentage of weekly purchased meat and meat product quantity in kilograms.

Segments	*n*	Mean		Median		Min.		Max.		SD	
		Total Waste	Avoidable Waste	Total Waste	Avoidable Waste	Total Waste	Avoidable Waste	Total waste	Avoidable Waste	Total Waste	Avoidable Waste
Gastronomy	93	7.8	5.8	5.0	4.9	0.0	0.0	50.5	34.3	9.7	5.7
Bistro	4	13.4	4.6	8.3	2.0	0.0	0.0	37.0	14.5	17.0	6.7
Café	13	10.1	7.1	5.0	5.0	0.0	0.0	43.3	34.3	14.5	9.4
Pub	16	4.0	4.0	4.0	4.0	0.0	0.0	9.8	9.8	2.8	2.8
Home delivery	6	4.0	2.3	2.0	2.0	0.0	0.0	15.0	5.0	5.7	2.3

Quick-service restaurant	4	4.2	4.2	4.0	4.0	1.0	1.0	7.9	7.8	3.2	3.2
Slow food	39	9.0	6.5	5.0	5.0	0.0	0.0	50.5	25.0	9.9	5.5
Snack	11	8.0	7.1	6.9	6.9	1.0	2.0	24.0	14.5	7.0	5.1
Communal Catering	98	5.9	5.6	5.0	5.0	0.0	0.0	28.0	28.0	4.9	4.7
Retirement home	10	12.2	11.5	12.5	12.3	1.0	1.0	19.0	19.0	5.1	5.4
Disabled facility	1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0		
Business catering	8	6.5	5.9	5.5	5.5	0.0	0.0	13.6	12.6	5.0	4.2
University	1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		
Kindergarten	39	4.1	4.0	3.0	3.0	0.0	0.0	20.0	20.0	3.6	3.6
Hospital	2	8.4	8.4	8.4	8.4	6.0	6.0	10.9	10.9	3.5	3.5
School	34	5.6	5.5	5.0	4.9	0.0	0.0	29.0	28.0	4.8	4.8
Further facilities	1	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9		
Preventive care and rehabilitation facility	2	9.7	7.8	9.7	7.8	6.9	6.9	12.5	8.6	4.0	1.2
Accommodation	94	6.1	4.8	4.0	3.0	0.0	0.0	36.3	20.0	6.9	4.6
Inn	16	5.6	4.1	3.0	3.0	1.0	1.0	31.4	10.0	7.3	3.3
Hotel	35	8.0	6.4	4.9	4.9	0.0	0.0	36.3	20.0	8.5	5.9
Hotel Garni	19	4.0	3.9	3.0	3.0	0.0	0.0	11.8	11.8	3.6	3.5
Youth hostel	4	8.7	6.4	7.5	7.5	0.0	0.0	19.9	19.9	8.5	4.9
Guesthouse	20	4.5	3.3	3.5	2.5	0.0	0.0	11.8	10.0	4.1	3.3
Further HaFS business types	94	3.7	2.5	1.0	1.0	0.0	0.0	40.6	19.0	6.6	3.7
Bakery	49	1.6	1.6	0.0	0.0	0.0	0.0	10.0	10.0	2.5	2.5
Butcher	22	7.2	2.2	2.0	2.0	0.0	0.0	40.6	10.6	11.2	2.6
Filling station	20	4.7	4.7	1.5	1.5	0.0	0.0	19.0	19.0	5.7	5.7
Catering	3	5.0	5.0	5.0	5.0	0.0	0.0	10.0	10.0	5.0	5.0

To test Hypothesis 2 (H2) and verify the relevance of different arising points, the composition of the waste ratios was analysed (Figure 3). According to Figure 1, waste during preparation can be categorised as avoidable or unavoidable. Therefore, Figure 3 shows the percentage shares of storage waste, processing waste (unavoidable), processing waste (avoidable) and leftovers for the segments. The respective shares of the waste types varied between the four segments. However, leftovers made up the greatest waste amount for Gastronomy and Accommodation, with the highest share occurring for Communal Catering. Waste arising during processing (unavoidable and avoidable) as well as storage waste was highest for the Gastronomy segment. Storage waste, avoidable processing waste and unavoidable processing waste had the lowest percentage rate within the Communal Catering segment. Relative figures are given in Figure 3 to support comparisons with other studies and regions, and absolute values are provided within the annex for national focused use (Figure A1).

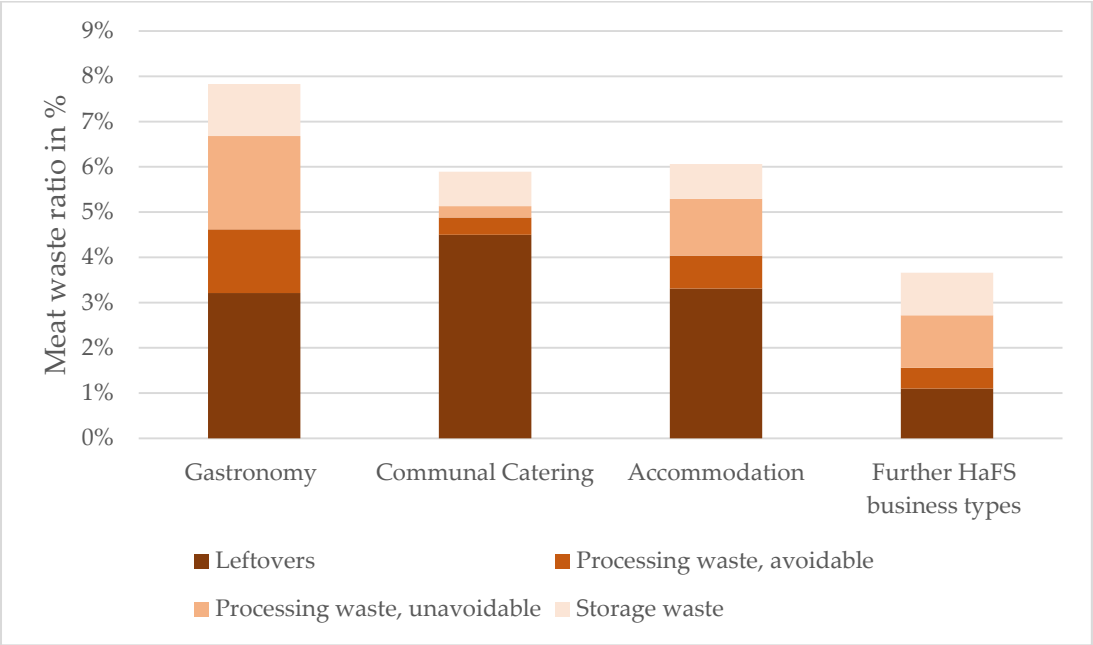

Figure 3. Arising points of meat waste within HaFS segments in percentage.

According to the meat waste definition applied in this paper, the share of uneaten meat that is taken home for later consumption by consumers (doggy bags) is not included (Figure 1).

4.2. Extrapolated National HaFS Meat Waste Amounts

Table 5 shows the average meat purchases and waste amounts extrapolated in tons per year and weighted according to the contribution of each segment to the total HaFS sector. The extrapolation was based on the representative composition of the segments using the average purchase and waste quantity and considering the total number of businesses in Germany.

The highest meat waste quantities arose in Communal Catering (26,500 t), contributing to the total waste volume by 36%. Meat waste in the Gastronomy segment amounted to 23,000 t, followed by further HaFS businesses (22,800 t). The lowest meat waste amount, however, was found for the segment of Accommodation, in addition to the lowest number of establishments.

The annual meat waste amounts to 85,800 tons. However, this extrapolation is limited to the segments under consideration. The recreational sector, correctional facilities and prisons could not be covered on the basis of the sample. In addition, vegetarian and vegan restaurants were excluded from the sample due to the focus on meat but considered regarding the extrapolation of the total meat waste volume, as there was no information regarding the absolute number or share of vegetarian and vegan restaurants within the German HaFS market.

Table 5. Absolute German HaFS annual meat waste in tons.

Segments	Gastronomy	Communal Catering	Accommodation	Further HaFS Business Types
Number of establishments, *n* (Germany)	85,300	88,500	36,800	73,200
Total purchase quantity per year in tons	250,600	402,800	136,600	238,500

Total meat waste per year in tons	23,000	26,500	13,500	22,800
Contribution to total German HaFS meat waste in %	27%	31%	16%	27%

4.3. Regression Results

A fractional logistic regression analysis was carried out to identify influencing factors related to the indicated waste ratios and to verify Hypothesis 1 (H1). Explanatory variables cover purchasing intensity, the respondent's occupation (owner, manager, tenant or kitchen management), the number of different meat types on offer and the number of shopping locations. Additionally, attitudinal statements towards the awareness and prevention of food waste in general were included to examine Hypothesis 3 (H3). The significant coefficients indicate the (decreased or increased) waste ratio in percentage points when multiplied by 100.

Results in Table 6 show that the meat purchases variable was highly significant. This indicates that an increase in the weekly meat purchases by 1 t potentially leads to an increased meat waste ratio of 6.8 percentage points. An increase in the number of meat types on offer also significantly increases the estimated waste ratio by 0.8 percentage points. HaFS businesses offering small portions indicated significantly lower meat waste ratios compared to the ones that did not explicitly pointed out the offer of small servings.

Food service businesses reporting that are sceptical with giving edible surplus food to social institutions for redistribution indicated significantly higher waste ratios compared to the base category (fully agree). Other variables were not statistically significant.

Table 6. Results of regression analysis.

	Meat Waste Ratio
Meat purchase per week in tons	0.052***
	(0.017)
Position of an owner within the business (dummy)	0.010
	(0.009)
Position of a chef within the business (dummy)	0.000
	(0.009)
Number of offered meat types	0.010 ***
	(0.002)
Number of meat-sourcing locations	−0.007
	(0.006)
Offering small portions (dummy)	−0.032 **
	(0.011)
Attitudinal statements	
The avoidance of food waste plays a particularly important role for meat and meat products (e.g., for economic or ethical reasons) (base: fully agree)	
Rather agree	−0.010
	(0.015)
Rather do not agree	0.013
	(0.020)
Training and further education measures for the prevention of food waste are offered/carried out on a regular basis (base: fully agree)	
Rather agree	0.001
	(0.008)
Rather do not agree	0.006

	(0.012)
Do not agree	0.024 *
	(0.013)
Our company participates in a programme to avoid food waste (base: fully agree)	
Rather agree	−0.015
	(0.013)
Rather do not agree	0.027
	(0.027)
Do not agree	0.002
	(0.012)
We regularly measure how much food waste we have (base: fully agree)	
Rather agree	0.007
	(0.013)
Rather do not agree	−0.013
	(0.011)
Do not agree	−0.013
	(0.011)
We give what is still edible to social institutions (food banks, etc.) (base: fully agree)	
Rather agree	0.045 **
	(0.018)
Rather do not agree	0.051**
	(0.020)
Do not agree	0.032 ***
	(0.007)

Notes: Coefficients indicate average marginal effects of multinomial logit regression. Standard errors are reported in parentheses. Test statistic: Wald test: $\chi 2$ (df = 20) = 102.31; McFadden's pseudo-R2 = 0.027. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

4.4. Results of Qualitative Statements of Respondents

Based on the qualitative content analysis, three different categories as well as four sub-categories were established (Table 7). Within the first category, nine respondents stated that they do not donate surplus food to food banks as extensive legal requirements, additional effort and geographical conditions (long distances) have held them back. However, three interview partners stated that they regularly hand over edible surpluses to a food bank.

Within the second category, different measures already implemented to reduce food waste were summarised. Participants described that they give away edible surpluses to employees and customers (children and parents in schools), consume surplus meals themselves or give away meat as pet food. In addition, they further process meat internally into sauces, stocks, soups, pizzas and minced meat. Targeted shopping (including at the butcher's), sourcing of pre-cut products and serving of small portions (also in buffet form) were also described as targeted measures. Regarding the explanation of stated waste rates, the participants linked waste levels to portion sizes, limited storage time due to food safety regulations (under four hours for displayed sandwiches) and seasonality. One participant emphasised that awareness raising among staff is challenging due to language barriers.

Table 7. Results of qualitative content analysis.

Category Code	Category Name	Frequency
C 1	Delivery to food banks	11
C 2	Measures implemented to reduce food waste	50
C 2.1	Handing out surpluses for further consumption	30
C 2.2	Further internal processing of surpluses	8
C 2.3	Targeted purchase, pre-cuts, etc.	6
C 2.4	Portion sizes, legal storage time, etc.	6
C 3	Explanation of stated waste levels	5

5. Discussion and Conclusions

Against the backdrop of planetary boundaries, food systems must be redesigned to be more sustainable. This is particularly necessary for foods with resource-intensive production, such as meat. In this context, political decision makers and scientists often call for a shift in production and consumer diets [22]. However, consumers influence resource demand not only by the meat eaten but also by wasted meat [18]. This is why this paper analyses meat waste ratios, evaluates the German status quo on absolute meat waste quantities and identifies possible future pathways to reduce meat waste in the HaFS market. The following discussion first classifies the calculated total meat waste with regard to quantity, possible environmental effects and the methodological approach. Subsequently, the relevance of different arising points and potential various reduction measures are assessed, also to provide recommendations for future research and towards policy-makers.

5.1. Classification of the Results against the Background of Environmental Effects

The found medians of meat waste ratios varied among the segments between 1% (further businesses) to 5% (Gastronomy, Communal Catering). The total meat waste quantity amounted to 85,800 tons per year, considering four segments and based on a weighted extrapolation. In 2018, waste out of home, therefore, accounted for 2% of the total meat consumption in Germany. Related to meat waste quantities covered by UN food waste segments (food retail, HaFS sector and private households), the avoidable meat waste of German HaFS businesses accounted for 36% (own calculation, based on values taken from [47]).

The actual relevance of meat waste becomes apparent against the background of estimated potential savings in connection with environmental benefits. Although a complete avoidance of wasted meat would certainly be desirable, it nevertheless seems unlikely due to the increasing marginal costs of necessary measures linked to it. SDG 12.3 aims for the ambitious target of a 50% reduction in the total food wasted by 2030. Reducing meat waste by 50% and thus shifting the overall target to a single product group would contribute to saving approximately 840 kt in CO_2 equivalents, an energy expenditure amounting to 17,600 TJ and the avoidance of the use of a land area amounting to more than 1200 km^2 (own calculation based on per kilogram values taken from [48]). Thus, about 1.3% of the total CO_2 equivalents of German agriculture in 2018 [49], 0.8% of the total energy use of German private households in 2018 [50] or 0.7% of the total used agricultural area in Germany in 2017 [51] could potentially be economised. An analysis of the distribution of meat waste within the segments showed both particularly high (bistro, retirement home, youth hostel, butcher) and particularly low (home delivery, kindergarten, hotel garni, bakery) waste ratios (Table 4). Accordingly, some of the participating businesses already reported having relatively good meat waste prevention management. Accepting mean waste ratios of the lower quartile (bottom 25%) of each of the four segments as a feasible benchmark would lead to even greater savings than the realisation of the UN goal: approximately 1300 kt in CO_2 equivalents, an energy expenditure amounting to 27,000 TJ and the avoidance of the use of a land area amounting to more than 1800 km^2.

These absolute results show that reducing meat waste in HaFS alone might not solve issues such as food gaps or climate change. However, it should be an essential part of a bundle of different measures contributing to addressing these challenges. On a strategic and policy level, there are conflicts of objectives that should be mentioned. Pradhan et al. [52] argue that achieving SDG 12 might lead to trade-offs as an improvement of responsible production and consumption (SDG 12) and might, for example, result in reduced availability of food and income and, thus, have negative effects on SDG 2 (hunger), SDG 3 (health and wellbeing) or SDG 10 (reduced inequalities). Reducing meat waste means increasing the quantity of food while resource consumption remains the same. Searchinger et al. [2] rank the reduction in food waste among most promising measures to close the food gap, the land gap and the GHG mitigation gap. Similar results were presented by Gerten et al. [1], who assessed a bundle of measures necessary to feed 10 billion people within four terrestrial planetary boundaries (biosphere integrity, land system change, freshwater use, nitrogen flows). They concluded that reducing food waste is part of four key prerequisites to reach that goal. This is particularly true for meat waste due to the high demand for land and resources.

As stated in Section 2, a comparison of the results of this study with the published literature is hardly possible due to the different reference units used. Looking at the results of Papargyropoulou et al. [42], who focused on food service businesses in Malaysia (see Table 1), the magnitude of total meat waste ratios fit, although a consistent drawing of conclusions is not possible due to the different prevailing frameworks in Germany and Malaysia. In the present study, the segments Gastronomy and Communal Catering contributed most to the overall German meat waste. WRAP [40] identified priority reduction potential for meat and fish waste, especially in restaurants (classification of Gastronomy), QSRs, pubs and services (classification of Communal Catering). Therefore, focussing on the sectors recommended by WRAP and in terms of prevention of absolute waste quantities is also favourable in Germany.

5.2. Limitations with Regard to the Calculated Total Meat Waste

A limitation of the study related to an underestimation of overall meat waste quantities might be a perception-related bias, as reported in the literature mainly for private households [53–55]. Literature references regarding the underestimation of food loss and waste by experts are rare. However, GSARS [56] found underestimated losses for different commodities regarding harvest and on-farm post-harvest activities by farmers compared to objective on-site measurements. Depending on the individual activity, the level of underestimation ranged from approx. 20% to 110%. In the present study, respondents were expected to have a good overview of purchases and waste ratios for economic reasons and to be able to make realistic estimates due to the manageable size of a kitchen in comparison to a farm. The participants were also asked to report weekly values in order to allow for a realistic assessment of the period under consideration. This also meant that seasonal effects were not considered. In addition, vegetarian and vegan restaurants were excluded from the sample due to the focus on meat and meat products. However, they were considered regarding the extrapolation for the total meat waste volume, as there was no information regarding the absolute number or share of vegetarian and vegan restaurants within the German HaFS market. This might have led to a slight overestimation of total meat waste quantities. In contrast, prisons, correctional facilities and the recreational sector could not be covered on the basis of the sample. In addition, meat that was taken home for consumption was out of the scope of consideration.

5.3. Reduction Potential, Practical Implementations and Further Research

In addition to total waste quantities, the authors differentiated between various arising points. In accordance with expectations, leftovers accounted for the largest share of the reported meat waste in the Gastronomy, Accommodation and Communal Catering segments. Leftovers include both overproduction within the kitchen (which was never served) as well as buffet and plate waste. Thus, prevention measures have to generally target kitchen staff and managers as well as consumers or guests. A derivation of tailor-made prevention measures would require a more detailed classification of leftovers, which was not possible in this study due to financial restrictions. In the present study, the share of unavoidable processing waste was particularly high within Gastronomy. This was unexpected, as Kuntscher et al. [57] conclude that the convenience degree of meat and meat products is relatively high within Communal Catering. Thus, inedible parts have already been removed and most meat products come portioned and pre-processed (e.g., battered). The authors assumed that the purchasing approach between Gastronomy and Communal Catering is comparable, even with a slightly lower convenience degree of purchased meat in Gastronomy. In addition, the overall share of processing waste was expected to be lower than the results indicated, which is why there is need for further investigations. In a case study targeting fish suppliers and their HaFS clients, Kuntscher et al. [57] found benefits related to total unavoidable fish waste if only the filets were sourced instead of the entire fish. Fish waste, considered as inedible on the level of HaFS, was then recycled and used for other food products or food ingredients (e.g., fish soup) at the supply level. Further research on meat waste prevention could evaluate the scale and thus the potential of early professional finish of inedible meat fractions (e.g., bones, cartilage).

The share of storage waste was already relatively low for all segments surveyed. A further reduction could possibly be achieved by extending the shelf life of prepared dishes using new preparation and storing methods, especially within businesses offering a wide range of meat types. Głuchowski et al. [58] concluded that the sous-vide method lowered cooking losses and extended the shelf life of analysed chicken breasts in comparison to conventional boiling and steaming. Other research investigates the effect of functional ice, which includes food-grade ingredient solutions within the water matrix and potentially contributes to an improvement of meat shelf life and quality, especially with poultry (e.g., Kataria et al. [59]).

Within further business types, leftovers as well as unavoidable processing meat waste caused the highest waste volumes. The latter seems reasonable as this segment also includes butchers, working with a low level of convenience products compared to other business types. It has to be highlighted again that the interviewed butchers were asked to only consider unavoidable meat processing waste directly linked to offered food products to go.

A number of already established reduction measures could also be derived from the results of this study. Cooperation with redistribution organisations in order to provide edible meat overproduction to people in need is a promising action. The present results showed that increased meat waste ratios tend to be expected due to a lack of cooperation with food banks. As adequate cooling and rapid distribution are required to ensure the best meat safety and quality, food banks must be given as much advance notice as possible of expected surpluses. However, the redistribution of surpluses for social purposes is often experienced as complicated or bears the risk of unlawful practices for donors due to legal hygiene requirements, as indicated by the participating businesses. Policy-makers should therefore develop clear guidelines on donation to lower redistribution barriers. To minimise the effort and ensure efficient information flow, matching of offer and demand can be supported by different mobile applications (Food Cowboy (USA), Food for All (USA), Food Rescue Heroes (USA), Food Rescue US (USA), Goodr (USA) or No Food Waste (India)).

In addition to meat purchases, the number of meat types offered was related to waste ratios according to the regression results. Accordingly, it seems especially challenging for businesses with a wide range of products and a large number of customers to accurately assess the eating behaviour of the guests. The offering small portions variable was derived from an open-ended question. As participants were not explicitly asked whether they offer smaller portions, the effectiveness of this measure should be brought more into focus in future surveys.

Further relevant actions, which, however, could not be fully confirmed based on this study, are the measurement of meat waste and communication and education measures. The engagement with the topic while collecting and weighing food waste supports a positive adaption process within involved staff (e.g., [60]). United Against Waste Germany [60] stresses the importance of communication and motivation not only among the kitchen and service staff but also in cooperation with clients and management. The authors' experience shows that comprehensive inclusion of staff and clients within the HaFS is helpful to realise the full untapped potential.

Further operational conditions could certainly also have an influence on the level of meat waste but could not be considered here due to the restricted length of the questionnaire. Variables with a potential influence on waste ratios are both portion sizes (offering above average portions) and the meat price (the supply of expensive cuts) as owners and managers (should) consider economic aspects. Against this background, a discounted sale of surplus portions directly to customers could be a promising strategy, especially for premium meat cuts. Those activities have recently been supported by mobile app providers such as Too Good to Go (active in multiple European countries), OptiMiam (France), Karma (Sweden), Surplus (Indonesia), Food for All (USA), goMkt (USA) or ResQ (Finland, Sweden, Germany, Poland), offering a digital marketplace for selling last-minute discounted surpluses from restaurants, cafés and other sources.

The effectiveness of a measure and the associated reduction of food waste depend on the accuracy of implementations for each business [60]. Results of this study showed that the use of doggy bags is a measure that can only be implemented effectively for certain business types. The response behaviour of the participants regarding leftovers that are taken home for further consumption varied between the segments. While all participants from the Gastronomy segment answered the corresponding question (100%), only 48% of the respondents assigned to the Community Catering segment provided information in this regard. This could lead to the conclusion that the use of doggy bags could be fostered in the Communal Catering segment, however, presumably to a limited degree, due to different framework conditions (e.g., different consumption situations in canteens, schools and hospitals) compared to the Gastronomy segment. In addition, 71% of the participating Gastronomy businesses indicated that they offer doggy bags. The authors expect further potential in this regard, as the share of German customers who are generally willing to take home plate leftovers increased from 46% in 2015 to 77% in 2017, and 54% of the respondents who are not using this option at present could be retuned if doggy bags were actively offered to them by staff. Apparently, German consumers are ashamed to ask for a doggy bag for fear of being perceived of as miserly [61]. To facilitate a broader establishment, the German Ministry of Food and Agriculture supported the development of an environmentally friendly box for leftovers, which is available wholesale at a reasonable price [62]. Such support at the national or regional policy level is also provided in other European countries such as Austria, Belgium, Luxembourg, the Netherlands and Scotland.

Irrespective of the reduction action, benchmarks are first needed to evaluate the effectiveness of implemented interventions. In this context, the present study has made an important contribution, as it is the first to quantify meat waste in the German HaFS sector on a representative scale. The results can also serve as a basis for further analysis regarding the meat value chain, considering the reference unit used. The approach is an effective way to obtain an overview of waste quantities and could be widened to other areas of the

chain. Data collection within the German HaFS sector could be extended in the near future, e.g., based on a voluntary agreement between HaFS associations, individual companies and the German government, which is expected to be set into force in the course of 2021 as result of the German National Food Waste Strategy [63]. The objective of the agreement is to measure food waste within HaFS businesses on a regular basis by using comparable methodological approaches and reference units as well as implementing a consistent reporting of those values.

An agreement regarding the reduction of meat waste at one level of the FSC is certainly a step in the right direction. In the future, however, policy-makers as well as representatives of associations and industry should encourage the reduction in meat waste in cooperation with clients in later supply chain levels. In June 2020, the UK meat industry in cooperation with other stakeholders, including the HaFS sector, committed itself to developing and implementing targeted practices along the entire value chain [64]. A practical application might also be feasible for the German market. The concrete implementation process could be derived from the results of WRAP [64].

5.4. Concluding Remarks

In conclusion, this study has shown that there is a need for action with regard to the occurrence of meat waste in the German HaFS sector. Segments with the largest meat waste quantities are Gastronomy and Communal Catering, whereby the reduction in unavoidable losses and leftovers should be a particular focus in the future. A future improvement as targeted by SDG 12.3 seems feasible with a view to the data collected in this study, as certain businesses already indicated as having low waste ratios and thus a relatively effective meat waste prevention management. As outlined above, cooperation among different stakeholder groups as well as between upstream and downstream levels within the FSC is essential to achieve the lowest-possible meat waste level. Since comparability is crucial in the course of data collection and subsequent evaluation of measures, the authors recommend using the reference value used in this study to capture future developments. Regarding the assessment of occurring waste quantities and communicating prevention strategies with target groups, environmental effects should be taken into consideration. As meat is only one food product group connected with comparably high environmental effects, dairy products should also be considered in this regard and thus could be the focus of future research.

Author Contributions: Conceptualisation, A.J.T., F.S. and J.E.; methodology, A.J.T.; validation, F.S. and J.E.; formal analysis, A.J.T.; resources, F.S. and J.E.; data curation, A.J.T. and F.S.; writing—original draft preparation, A.J.T. and F.S.; writing—review and editing, all; visualisation, A.J.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

Acknowledgments: The authors would like to thank Sebastian Neuenfeldt for statistical support and Ronja Herzberg for proofreading.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

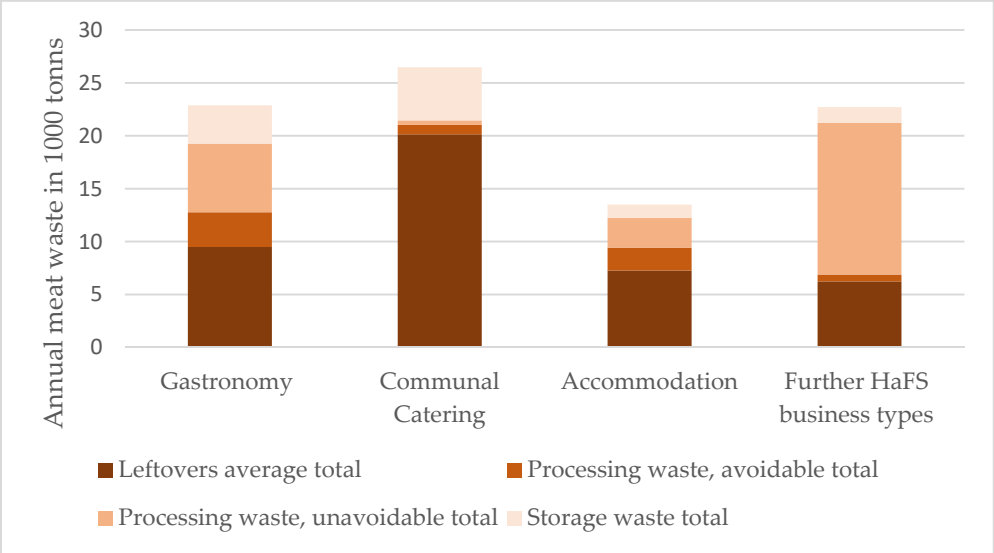

Figure A1. Arising points of meat waste within HaFS segments in 1000 tons.

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