Measuring meat consumption with recommendations towards more sustainability

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Annika Johanna Thies

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1. Referee: PD Dr. Martin Banse, Thünen Institute of Market Analysis, Braunschweig

2. Referee: Prof. Dr. Stephan von Cramon-Taubadel, Department of Agricultural Economics and Rural Development, Georg-August-Universität Göttingen

3. Referee: Prof. Dr. Achim Spiller, Department of Agricultural Economics and Rural Development, Georg-August-Universität Göttingen

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“Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.”

(BAUMUNG and HOFFMANN, 2012)

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List of abbreviations

AICR	The American Institute for Cancer Research
BLE	Bundesanstalt für Landwirtschaft und Ernährung (German Federal Office for Agriculture and Food)
BMEL	Bundesministerium für Ernährung und Landwirtschaft (German Federal Ministry of Food and Agriculture)
BTG	Business Target Group (a market research company)
CA	cluster analysis
CATI	computer-assisted telephone interviews
CN	Combined Nomenclature
CO_2	carbon dioxide
c.w.e.	carcass weight equivalent
DGE	Deutsche Gesellschaft für Ernährung (German Nutrition Society)
e.g.	exempli gratia (for example)
EU	European Union
EVS	Einkommens- und Verbrauchsstichprobe (Sample Survey of Income and Expenditure)
FAO	The Food and Agriculture Organization of the United Nations
FBS	food balance sheets
FLW	food loss and waste
FW	food waste
GfK	Gesellschaft für Konsumforschung (a market research company)
GWP	global warming potential
HaFS	Hospitality and Food Service
HBS	household budget survey
IDS	individual dietary survey
i.e.	id est (namely)
kcal	kilocalorie
KMO	Kaiser-Meyer-Olkin
KNW	Kompetenznetzwerk Nutztierhaltung (Competence Network on Animal Husbandry)
LCA	life cycle assessment
ML	maximum-likelihood
MNL	multinomial logistic regression
NVS II	Nationale Verzehrsstudie II (Second representative National Nutrition Survey)
OECD	The Organisation for Economic Co-operation and Development
p.c.	per capita
PCA	principle component analysis

PPP	personalised price promotions
QMLE	quasi-maximum likelihood estimator
QSRs	Quick Service Restaurants
RQs	research questions
SDGs	Sustainable Development Goals of the United Nations
VAT	value-added tax
WBAE	Wissenschaftliche Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz (German Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection)
WCRF	The World Cancer Research Fund Network
WRAP	Waste & Resources Action Programme
WTP	willingness to pay
ZKL	Zukunftskommission Landwirtschaft (Commission on the Future of Agriculture)

Summary

The broad public calls for a transformation of food systems and addresses a trilemma by emphasising environmental effects, but also referring to health risks associated with meat-heavy diets. In addition, citizens of many EU Member States are raising societal and ethical concerns with regard to livestock farming. Therefore, numerous scientific studies have concluded that a reduction of high meat consumption levels accompanied by more plant-based diets in high-income countries is a prerequisite for a shift towards sustainability. Efforts to achieve more sustainable food systems need to include approaches to lower lost and wasted food quantities along the entire value chain. This is especially relevant with regard to meat, considering the ecological footprint of livestock farming.

Assessing the present situation and subsequently developing targeted strategies to reduce consumed and wasted meat quantities requires a comprehensive information base. Accordingly, this dissertation provides detailed information on average German meat consumption, individual meat consumer groups, and on meat waste within the German Hospitality and Food Service (HaFS) sector in relation to individual arising points. In addition, this thesis deliberates fiscal intervention and targeted marketing to curb meat demand, considering the specific purchasing patterns of individual household segments. It further derives measures for substantial meat waste reduction.

The first article of this dissertation deals with an updated and revised estimation of the annual per capita pork, beef, and poultry consumption in Germany using a market balance approach and following a mass flow analysis. It includes a survey at slaughterhouse level, adjustments to external trade statistics, and assumptions of losses at the processing and wholesale level as well as of waste at food retail level and for at-home and out-of-home consumption. In this manner, an average per capita meat consumption of 64.7 kg is determined for the year 2018, comprising of 34.8 kg pork, 11.5 kg beef, and 15.8 kg poultry. These findings highlight a clear need for action as the identified consumption level is neither compatible with national health guidelines nor with international climate targets. In line with existing literature, results further confirm inconsistencies between per capita meat consumption levels according to food balances and self-reported meat quantities in the course of published surveys. But also, among supply-side approaches, international comparability of meat consumption levels is difficult due to different assumptions on meat utilisation and varying consideration of losses and waste. In order to establish a more consistent calculation of domestic meat supply in the course of food balances, the consideration of different meat types, edible offal, and by-products and the corresponding allocation of commodity codes for international trade statistics would need to be harmonised.

Article (2) comprises an identification and characterisation of German household segments based on meat product purchases using revealed-preference data. A cluster analysis following a previously conducted principal component analysis reveals four different clusters: *pork and beef traditionalists* (59% of the total sample), *convenience-oriented pork buyers* (11%), *poultry lovers* (25%), and *premium red meat lovers* (5%). According to a multinomial logistic regression, there is heterogeneity with regard to the meat purchasing behaviour of these clusters. Therefore, they must be addressed with different priorities when aiming for a dietary shift. Results indicate that *pork and beef traditionalists* , and thus the majority of German households, does not adopt a “less-but-better” meat consumption, but rather exhibits meat-heavy diets. A tax on meat products could generally curb meat demand of these households, whereas more balanced diets of *convenience-oriented pork buyers* could additionally be encouraged by personalised price promotions of plant-based alternatives. Together with *poultry lovers*, they represent younger consumers turning away from high meat consumption levels. Due to the observed consumer heterogeneity, a change in the food environment including effective pricing measures but also a tailored product range accompanied by targeted labelling and communication campaigns could bring about a change in dietary behaviour. Results suggest that marketing strategies considering the meat quality perception of *poultry lovers* and *premium red meat lovers* in particular could promote a qualitative rather than a quantitative shift for these household segments.

The third article determines an annual meat waste of 85,800 tons within the German Hospitality and Food Service (HaFS) sector based on computer-assisted telephone interviews (CATI) and considers different arising points. A comparison of total waste quantities and waste ratios for *gastronomy, communal catering, accommodation*, and *further HaFS businesses* implies that leftovers including overproduction, buffets, and plate waste are a hot spot for meat waste within the HaFS value chain. Among segments, *gastronomy* and *communal catering* are main contributors to total meat waste quantities. There certainly is a potential for meat waste prevention since the prevailing share of waste consists of avoidable meat waste and implementing the waste management of the lower quartile (bottom 25%) of each of the four segments would lead to a waste reduction of 77%. A fractional logit model in addition to qualitative content analysis illustrates that both company-internal and government action might reduce leftover meat. Businesses being sceptical about donating edible food to social institutions reveal significantly higher meat waste ratios. Various companies perceive extensive legal hygiene requirements and organisational efforts as barriers which keep them from entering into long term corresponding cooperations. Communication measures which promote less wasteful behaviour in HaFS businesses need to address staff and guests. They should especially

emphasise environmental effects of food and meat waste. Approximately 1,300 kt or 2% of the total CO_2 equivalents emitted by German agriculture in 2018 could potentially be saved by applying the waste management of the lower quartile of each of the four HaSF segments to all HaFS businesses.

Overall, results of this dissertation demonstrate a need to shift meat demand in Germany into a more sustainable direction. This is especially true, as meat consumption is on average not compliant with environmental and nutritional recommendations; the majority of German households has not yet turned away from traditional meat purchasing habits; and leftovers that are still edible in most cases are a hotspot for out-of-home meat waste.

The three articles provide an important contribution to an improved database on meat consumption and meat waste. In the course of more comprehensive national nutrition monitoring, a regular collection of revealed-preference data covering out-of-home in addition to at-home consumption would make it possible in the first place to analyse the directive effect of legislative intervention towards meat demand management in more detail. A more comprehensive data collection should also be strived for in the course of the German National Strategy for Food Waste Reduction in order to assess the effectiveness of corresponding reduction and prevention measures. According to the Delegated Decision 2019/1597 of the European Commission, national authorities need to declare total food waste quantities without distinguishing between product categories or unavoidable and avoidable waste.

With regard to meat consumption, future research needs to clarify whether there is a sufficient rational for more far-reaching legislative interventions from the perspective of behavioural, environmental, and welfare economics. Considering the individual household segments, studies should additionally examine the influence of a mix of instruments and look at the substitution between meat and alternative food products to assess possible rebound effects. In terms of food waste reduction, an evaluation of waste quantities with an ecological focus and an economic assessment of targeted measures could contribute to specify the declared reduction goals.

This dissertation is among a growing number of scientific publications that draw attention to the issue of meat demand in the context of more sustainable diets. However, this topic is notoriously multifaceted and dietary strategies must balance national and international conflicts of objectives, e.g., environmental, health or animal welfare goals. Moreover, demand-sided concepts for industrialised countries can only be part of a superior solution since meat demand trends in developing countries give new urgency to the need for holistic concepts.

Zusammenfassung

Die breite Öffentlichkeit fordert eine Transformation von Ernährungssystemen und spricht ein Trilemma an, indem sie die Auswirkungen einer fleischlastigen Ernährung auf die Umwelt hervorhebt und gleichzeitig auf die damit verbundenen Gesundheitsrisiken hinweist. Darüber hinaus stellt die Bevölkerung in vielen europäischen Ländern vermehrt gesellschaftliche und ethische Anforderungen an die Haltung von Nutztieren. Zahlreiche wissenschaftliche Studien sind daher zu dem Schluss gekommen, dass eine Verringerung des hohen Fleischverzehrs in Verbindung mit einer mehr pflanzenbasierten Ernährung in einkommensstarken Ländern eine Voraussetzung für einen Wandel hin zu mehr Nachhaltigkeit ist. Lösungsansätze für nachhaltigere Ernährungssysteme müssen dabei auch eine Verringerung von Lebensmittelabfällen entlang der gesamten Wertschöpfungskette umfassen. Dies gilt insbesondere für Fleisch, vor dem Hintergrund des ökologischen Fußabdrucks der Nutztierhaltung.

Um Aussagen hinsichtlich der gegenwärtigen Verzehrs- und Verlustsituation treffen zu können und daraus resultierend gezielte Strategien zur Verringerung der verzehrten Fleischmengen sowie in Bezug auf Fleischverluste zu entwickeln, ist eine umfassende Informationsbasis erforderlich.

Diese Dissertation liefert dementsprechend detaillierte Informationen hinsichtlich des durchschnittlichen Fleischverzehrs, einzelner Konsumentengruppen in Deutschland sowie zu Fleischverlusten bezogen auf einzelne Anfallstellen in Unternehmen des Deutschen Außer-Haus-Marktes. Zudem werden steuerpolitische Intervention und abgestimmte Marketingstrategien zur Reduktion der Fleischnachfrage unter Berücksichtigung des spezifischen Kaufverhaltens einzelner Haushaltssegmente diskutiert. Darüber hinaus werden Maßnahmen abgeleitet, um eine deutliche Verringerung von Fleischverlusten zu erzielen.

Der erste Artikel dieser Dissertation enthält eine aktualisierte und überarbeitete Schätzung des Pro-Kopf-Verzehrs von Schweine-, Rind- und Geflügelfleisch in Deutschland, basierend auf der Versorgungsbilanz und in Anlehnung an eine Warenstromanalyse. Die Berechnung basiert auf Produktionsdaten von Schlachtbetrieben und beinhaltet Anpassungen in Bezug auf die Außenhandelsstatistik, Annahmen zu Verlusten im Zuge der Fleischverarbeitung, auf der Ebene des Groß- und Lebensmitteleinzelhandels sowie bezogen auf den Verzehr in privaten Haushalten und außer Haus. Der für das Jahr 2018 ermittelte durchschnittliche Pro-Kopf-Fleischverzehr von 64,7 kg beinhaltet 34,8 kg Schweinefleisch, 11,5 kg Rindfleisch und 15,8 kg Geflügelfleisch. Dieses Ergebnis macht deutlich, dass Handlungsbedarf besteht, da das ermittelte Verzehrsniveau weder mit nationalen Ernährungsempfehlungen mit Fokus auf die

Gesundheit, noch mit internationalen Klimazielen vereinbar ist. Im Einklang mit existierenden Literaturangaben bestätigen die Schätzergebnisse Diskrepanzen zwischen dem auf Grundlage von Versorgungsbilanzen geschätzten Fleischverzehr und den basierend auf Befragungen ermittelten Verzehrniveaus. Aber auch bezogen auf angebotsseitige methodische Ansätze ist eine internationale Vergleichbarkeit des Pro-Kopf-Fleischverzehrs aufgrund unterschiedlicher Annahmen hinsichtlich der Fleischverwertung und zu Verlusten entlang der Wertschöpfungskette kaum möglich. Um eine kohärentere Berechnung des inländischen Fleischverbrauchs im Rahmen von Versorgungsbilanzen zu ermöglichen, müsste sowohl die Berücksichtigung verschiedener Fleischarten, genießbarer Innereien und von Schlachtnebenprodukten als auch eine entsprechend konsistente Zuordnung von Zolltarifnummern im Rahmen der Außenhandelsstatistik zwischen den EU-Mitgliedstaaten harmonisiert werden.

Artikel (2) umfasst eine Identifizierung und Charakterisierung deutscher Haushaltssegmente auf Grundlage von Einkaufsdaten bezüglich verschiedener Frischfleischprodukte. Eine Clusteranalyse mit voran gestellter Haupkomponentenanalyse liefert vier verschiedene Segmente: „*Schweine- und Rindfleischtraditionalisten*“ (59% der Stichprobe), „*convenience-orientierte Schweinefleischkäufer*“ (11%), „*Geflügelfleisch-liebhaber*“ (25%) sowie „*Liebhaber von rotem Premiumfleisch*“ (5%). Eine multinomiale logistische Regression verdeutlicht, dass das Kaufverhalten dieser Käufergruppen in Bezug auf Fleisch heterogen ist. Daher müssen sie mit unterschiedlicher Priorität angesprochen werden, um einen Wandel des Ernährungsverhaltens zu bewirken. *Schweine- und Rindfleischtraditionalisten*, welche die überwiegende Mehrheit deutscher Haushalte repräsentieren, können als klassische Fleischesser im herkömmlichen Sinne bezeichnet werden und weisen eine eher fleischlastige Ernährung auf. Eine Steuer auf Fleischprodukte könnte den Fleischverzehr dieser Haushalte grundsätzlich mindern, während eine ausgewogenere Ernährung von *convenience-orientierten Schweinefleischkäufern* durch personalisierten Preiswerbung für pflanzliche Alternativen zusätzlich gefördert werden könnte. *Convenience-orientierte Schweinefleischkäufer* stellen zusammen mit *Geflügelfleischliebhabern* eine Gruppe jüngerer Verbraucher dar, deren Ernährung bereits weniger fleischbetont ist. Aufgrund des unterschiedlichen Kaufverhaltens von Verbrauchern wäre eine Veränderung des Ernährungsumfeldes, einschließlich wirksamer Preismaßnahmen, eines maßgeschneiderten Produktangebotes begleitet von gezieltem Labelling und Kommunikationskampagnen ein vielversprechender Ansatz, um eine Änderung des Ernährungsverhaltens zu bewirken. Die Ergebnisse dieser Arbeit deuten darauf hin, dass Marketingstrategien, die insbesondere das Qualitätsverständnis von *Geflügelfleisch*- und *Liebhabern von rotem Premiumfleisch* berücksichtigen, für diese Segmente eher eine qualitative als eine quantitative Veränderung bewirken könnten.

In einem dritten Artikel wird auf Basis computergestützter Telefoninterviews (CATI) und unter Berücksichtigung verschiedener Anfallstellen ein jährliches Aufkommen von Fleischverlusten in Höhe von 85.800 Tonnen für den deutschen Außer-Haus-Markt ermittelt. Ein Vergleich der Gesamtfleischverluste und prozentualer Verlustanteile bezogen auf wöchentliche Fleischeinkäufe in der *Gastronomie*, *Gemeinschaftsverpflegung,* in *Beherbergungsbetrieben* und *sonstigen Betrieben des HaFS Marktes* zeigt, dass vor allem eine Überproduktion sowie Buffet- und Tellerreste einen hohen Anteil an den Gesamtfleischverlusten außer Haus ausmachen. *Gastronomie* und *Gemeinschaftsverpflegung* weisen in einem Vergleich zu den anderen Segmenten den höchsten Anteil an den insgesamt anfallenden Fleischverlusten auf. Da der überwiegende Anteil der Fleischverluste vermeidbaren Verlusten zuzuordnen ist und die Umsetzung der Verlustprävention des unteren Quartils (der jeweils unteren 25%) der vier Segmente zu einer Verlustreduktion von 77% führen würde, besteht durchaus ein Potenzial für eine Verringerung von Fleischverlusten außer Haus. Ein fractional logit model sowie die Ergebnisse einer qualitative Inhaltsanalyse zeigen, dass sowohl unternehmensinterne als auch staatliche Maßnahmen zu einer Reduzierung von Fleischverlusten beitragen können. Unternehmen, die dem Spenden von genießbaren Lebensmitteln an soziale Einrichtungen skeptisch gegenüberstehen, weisen signifikant höhere Fleischverluste auf. Umfangreiche gesetzliche Hygieneanforderungen und der organisatorische Aufwand werden von verschiedenen Betrieben als ein Hemmnis wahrgenommen und hindern die Unternehmen daran, entsprechende langfristige Kooperationen mit Lebensmitteltafeln einzugehen. Kommunikationsmaßnahmen, die ein weniger verschwenderisches Verhalten in HaFS Betrieben bewirken sollen, müssen sowohl Mitarbeiter als auch Gäste erreichen. In diesem Zusammenhang sollten insbesondere die Umweltauswirkungen von Lebensmittel- und Fleischverlusten hervorgehoben werden. 2% der im Jahr 2018 von der deutschen Landwirtschaft insgesamt emittierten CO_2-Äquivalente, könnten eingespart werden, wenn das Abfallmanagement des unteren Quartils eines jeden Segmentes auf alle Betriebe des Außer-Haus-Marktes übertragen werden würde.

Insgesamt zeigen die Ergebnisse dieser Dissertation somit, dass der Fleischkonsum in Deutschland in eine nachhaltigere Richtung gelenkt werden muss. Dies ist insbesondere vor dem Hintergrund zutreffend, dass der durchschnittliche deutsche Fleischverzehr nicht mit Umwelt- und Ernährungsempfehlungen in Übereinklang zu bringen ist, sich nahezu zwei Drittel der deutschen Haushalte noch nicht von traditionellen Kaufgewohnheiten abgewandt haben, und in den meisten Fällen verzehrsfähige Speisereste ein Hotspot für Fleischverluste außer Haus sind.

Die drei Artikel leisten einen wichtigen Beitrag zu einer verbesserten Datenbasis hinsichtlich des Fleischverzehrs und bezüglich Fleischverlusten. Im Zuge eines

umfassenderen nationalen Ernährungsmonitorings würde eine regelmäßige Scanner-basierte Erhebung in privaten Haushalten und die Ermittlung von Verzehrsmengen außer Haus eine detailliertere Analyse der Lenkungswirkung gesetzlicher Eingriffe überhaupt erst ermöglichen. Eine umfassendere Datenerhebung sollte auch im Zuge der deutschen Nationale Strategie zur Reduzierung der Lebensmittelverschwendung angestrebt werden, um die Wirksamkeit entsprechender Maßnahmen bewerten zu können. Gemäß des Delegierten Beschlusses 2019/1597 der Europäischen Kommission sind die nationalen Behörden lediglich angehalten, die Gesamtmenge von Lebensmittelverlusten messen, ohne dabei zwischen Produktkategorien, vermeidbaren und unvermeidbaren Verlusten zu unterscheiden.

In Bezug auf den Fleischverzehr ist zu prüfen, ob aus der Sicht der Verhaltens-, Umwelt- und Wohlfahrtsökonomie eine ausreichende Begründung für weitreichendere staatliche Markteingriffe besteht. Unter Berücksichtigung der Konsumentenheterogenität sollten nachfolgende Studien die Auswirkungen eines Instrumentenmixes sowie die Substitutionseffekte zwischen Fleisch und alternativen Lebensmitteln untersuchen, um mögliche Rebound-Effekte zu bewerten. Im Hinblick auf die Reduktion von Lebensmittelverlusten könnte eine ökologische Beurteilung der Abfallmengen und eine ökonomische Bewertung gezielter Maßnahmen dazu beitragen, erklärte Reduktionsziele zu spezifizieren.

Diese Dissertation reiht sich ein in eine wachsende Anzahl wissenschaftlicher Veröffentlichungen, die auf die Problematik des Fleischkonsums in Zusammenhang mit einer nachhaltigeren Ernährung aufmerksam machen. Allerdings sind die Herausforderung vielschichtig und entsprechende Ernährungsstrategien müssen nationale und internationalen Zielkonflikte abwägen, darunter zum Beispiel Umwelt-, Gesundheits- oder Tierschutzbestrebungen. Darüber hinaus können nachfrageseitige Konzepte für Industrieländer nur ein Teil der Lösung sein, da die Nachfrageentwicklung in Entwicklungsländern mit neuer Dringlichkeit ganzheitliche Ansätze erforderlich macht.

1 Introduction

Feeding a growing world population while counteracting malnutrition and minimising the degradation of ecosystems is a challenge at the global level (WILLETT et al., 2019). Food systems must undergo transformations to ensure food security for present but also future generations and at the same time comply with environmental, economic, and social objectives to meet global, European, and German sustainability goals (FAO, 2018a; EC, 2020; WBAE, 2020).

Especially agricultural livestock farming, and consequently the production of animal sourced foods, are associated with negative environmental effects, such as an increased Global Warming Potential (GWP), larger carbon and blue water footprints, greater land use as well as biodiversity loss in comparison to plant-based foods (GODFRAY et al., 2018; SPRINGMANN et al., 2018). Moreover, the general public is increasingly raising societal and ethical concerns with regard to animal husbandry conditions (RUBY, 2012) and advocates improved animal welfare conditions (WEIBLE et al., 2016). A high consumption of processed and red meat is also under debate against the background of increased health risks (GEIBEL et al., 2021). Therefore, animal products play an integral part within the design of more sustainable food systems (TILMAN and CLARK, 2014; WILLETT et al., 2019). This is especially true in the light of a globally growing meat and milk demand of 35%, and respectively 47%, over the previous two decades (OECD and FAO, 2021).

A sustained and high per capita (p.c.) consumption of animal sourced proteins in various Member States of the European Union (EU) has resulted in calls for regulatory interventions to reduce consumption levels (BONNET et al., 2018). However, as demand behaviour varies for different food categories (FEMENIA, 2019), current consumption and potential developments need to be considered on a product-by-product basis.

Studies have emphasised that curbing meat consumption accompanied by more plant-based diets in high-income-countries is a prerequisite for a shift towards more sustainability (TUKKER et al., 2011; HALLSTRÖM et al., 2014; FUNKE et al., 2022). Directing effects of various demand-side instruments, differing with regard to their restrictiveness and directional impulses, are currently being controversially discussed. Among them are taxes and subsidies to provide financial incentives; labelling, information campaigns, or educational measures to raise awareness among consumers; as well as behavioural actions such as meat-free days or nudges in the desired direction (BONNET et al., 2020). The feasibility of an increased taxation on the consumption of animal products in order to finance a transformation of animal husbandry systems is at the centre of the political debate in Germany (KNW, 2020; DEBLITZ et al., 2021; KARPENSTEIN et al., 2021).

Developing and subsequently implementing nutritional strategies requires comprehensive monitoring (WBAE, 2020). In Germany food balances comprise production, foreign trade, and the domestic supply of meat, edible offal, and by-products. They additionally provide information on total and per capita meat consumption on a regular basis by deducting inedible components, non-food uses as well as losses and waste from domestic supply using a set of meat-type-specific coefficients (BLE, 2021). These coefficients were established in 1987, mainly based on expert assessments (DVF, 1987) and have not been noticeably updated since then (BLE, 2021). Moreover, they provide results that are not consistent with meat consumption levels as indicated by surveys (KOCH et al., 2019).

Factors influencing dietary behaviour are manifold (BROMBACH et al., 2015) and meat eating patterns vary between individuals (CORDTS et al., 2014). Additionally, buying patterns can differ for meat types (CASINI et al., 2015) or meat products (SCOZZAFAVA et al., 2016). Meat-reducing measures therefore need to be tailored to individual consumer segments and their specific behaviour, instead of being based on average and aggregated meat consumption levels (APOSTOLIDIS and MCLEAY, 2016). Against the backdrop of the existence of a citizen-consumer dichotomy (ENNEKING et al., 2019), only limited conclusions can be drawn from literature regarding meat consumer heterogeneity since studies have so far mainly based their segmentation on attitudes (MALEK et al., 2018; GÖTZE and BRUNNER, 2021) or self-reported meat intake levels (CORDTS et al., 2014).

Against the background of planetary boundaries and a globally growing food demand, reducing food that goes uneaten is an integral component of meeting sustainability goals (SEARCHINGER et al., 2018; GERTEN et al., 2020). Considering resource-efficiency (CLUNE et al., 2017), minimising meat loss and waste can especially contribute to reducing the environmental footprint of supply chains (KARWOWSKA et al., 2021). Quantifying meat waste and determining underlying causes is a requirement for the subsequent implementation of reduction measures. However, previous scientific research has focused on the prevention of food wasted in private households (HERZBERG et al., 2020). Studies on meat waste out-of-home, which consider different arising points, distinguish between avoidable and unavoidable waste. Comparable reference values (i.e., purchased meat quantities), are still missing.

The purpose of this dissertation is two-fold. It aspires to contribute to an enhanced nutrition monitoring by examining the current meat consumption level in Germany as well as the scope meat waste within the German Hospitality and Food Service (HaFS) sector. This thesis further provides indications for policy makers and market participants on how to achieve a behavioural shift towards more sustainability by referring to specific meat consumer segments and meat waste hot spots within the HaFS value chain. This

dissertation addresses three thematic priorities: i) the estimation of per capita meat consumption based on a market balance approach to provide an up-to-date database; ii) the identification of meat purchasing patterns and characteristics of related consumer groups in Germany to provide guidance on the primary targets and iii) the quantification of meat waste in HaFS businesses at different points of waste generation as well as the identification of respective driving factors to recommend measures at the private or governmental level.

This dissertation is structured in seven chapters. Subsequent to the introduction presented in chapter 1, chapter 2 provides background information on global meat consumption trends, meat consumption patterns in Germany, and negative externalities associated with meat demand. It further addresses the overarching research questions and the research focus of this. Chapter 3 concerns the methods applied in three articles which are summarised in chapter 4 and classified in terms of their contribution to the overall thesis. Chapter 5 contains the individual contributing articles as published in or submitted to peer-reviewed journals. The main findings of this dissertation are discussed in chapter 6 against the background of existing literature. Final conclusions and indications for policy makers, market participants, and researchers are derived in chapter 7.

2 Thematic overview

This chapter provides an overview of important global trends and the development of meat demand in Germany. It further aims to illustrate external effects of meat consumption and the issue of food loss and waste (FLW) against the background of the sustainability concept in order to enhance the comprehensibility of findings and conclusions drawn in this thesis.

2.1 Meat consumption at global level

Due to their nutritional value animal-based foods, especially meat, are a central component of diets in many cultures. This is particularly the case in developing countries where diets are often restricted and largely grain or tuber based (FISCHER and GARNETT, 2016). An expansion of global meat production based on efficient production and improved breeding techniques has increased the availability of meat products (THORNTON, 2010). Meat has foremost become a staple food in high-income countries where it is on consumers' plates on a daily basis (RÜCKERT-JOHN and KRÖGER, 2019).

Although regional differences are slowly narrowing (OECD and FAO, 2020), available meat quantities are particularly high in specific production regions. ***Table 1*** illustrates meat production and domestic supply for the two periods under review and additionally shows a calculated self-sufficiency rate that equals the ratio of production and domestic supply. Production corresponds to the slaughter volume expressed as carcass weight equivalent (c.w.e.). Official statistics present total consumption figures considering foreign trade and changes in stocks (OECD and FAO, 2021) and therefore refer to the meat quantity available at a corresponding market (domestic supply) including various utilisation paths. However, they also relate to (human) meat consumption by deducting inedible components, non-food uses or losses, and waste from domestic meat supply[1] (BLE, 2021).

In this thesis, the term “meat consumption” is exclusively used in association with a calculated or measured (human) consumption level expressed as c.w.e. or as product weight. Meat purchases by private households are assumed to have been bought for (human) consumption. Meat intake indicates a prepared meat quantity, taking cooking losses into account.

According to ***Table 1***, global meat production has increased by 47% over the past two decades. The largest production gains were generated in Asia (mainly China) (OECD and FAO, 2021), Latin America and African countries, while North America and the EU remained

[1] The corresponding estimation procedure for Germany and further international approaches are examined in article (1) and addressed in the course of chapter 2.2.

important production regions. In Oceania, North and Latin America, and in the EU, production increasingly exceeded domestic demand and lead to self-sufficiency rates above 100%. African and Asian meat production did not meet domestic demand which resulted in a need for imports that can be deducted from the considerable increase in total supply compared to production. During 2018 and 2020, Asia accounted for 45% of the global domestic meat supply (***Table 1***).

Table 1: Regional meat production, domestic supply and self-sufficiency rates for two observation periods and the corresponding change in percentage

Region	Production			Domestic Supply			Self-sufficiency rate	
	ø 1998-2000 in 1,000 t	ø 2018-2020 in 1,000 t	∆ in %	ø 1998-2000 in 1,000 t	ø 2018-2020 in 1,000 t	∆ in %	ø 1998-2000 in %	ø 2018-2020 in %
European Union	38,961	44,672	14.7	35,208	38,940	10.6	110.7	114.7
Oceania	5,426	6,514	20.1	2,610	3,471	33.0	207.9	187.7
North America	40,062	51,563	28.7	37,159	44,540	19.9	107.8	115.8
Latin America	29,516	53,926	82.7	29,055	49,141	69.1	101.6	109.7
Asia	86,955	133,039	53.0	92,084	147,858	60.6	94.4	90.0
Africa	9,638	17,265	79.1	10,269	20,041	95.2	93.9	86.1
World	222,769	326,778	46.7	221,479	325,382	46.9	100.6	100.4
Developed Countries	103,137	132,858	28.8	99,407	122,928	23.7	103.8	108.1
Developing Countries	119,632	193,920	62.1	122,073	202,454	65.8	98.0	95.8

Notes: Total meat production and total supply comprise beef, veal, pork, poultry, and mutton. Differences between production and domestic supply at global level are most likely due to statistical inaccuracies.
Source: Author's own compilation of OECD and FAO (2021).

Global meat supply is expected to reach a new peak at 334 Mio. tons in 2022. Even though the rapid growth during the last two decades has tended to lose momentum, the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) expect an average annual growth rate of 1.2% from 2020 until 2029 onwards (OECD and FAO, 2021).

The global average per capita meat consumption level amounted to 34 kg in 2020 (OECD and FAO, 2021). Regional differences do not only occur with regard to consumed meat quantities but also in relation to the proportion of meat in diets. ***Figure 1*** shows the average share of vegetable products, animal-based foods, and meat in daily protein and calorie consumption for different regions in the year 2019. Whereas in Oceania, the EU, and North- and Latin America, animal-based products and meat accounted for a comparatively high proportion of the daily proteins and calories consumed, diets in African but also Asian countries were still more plant-based.

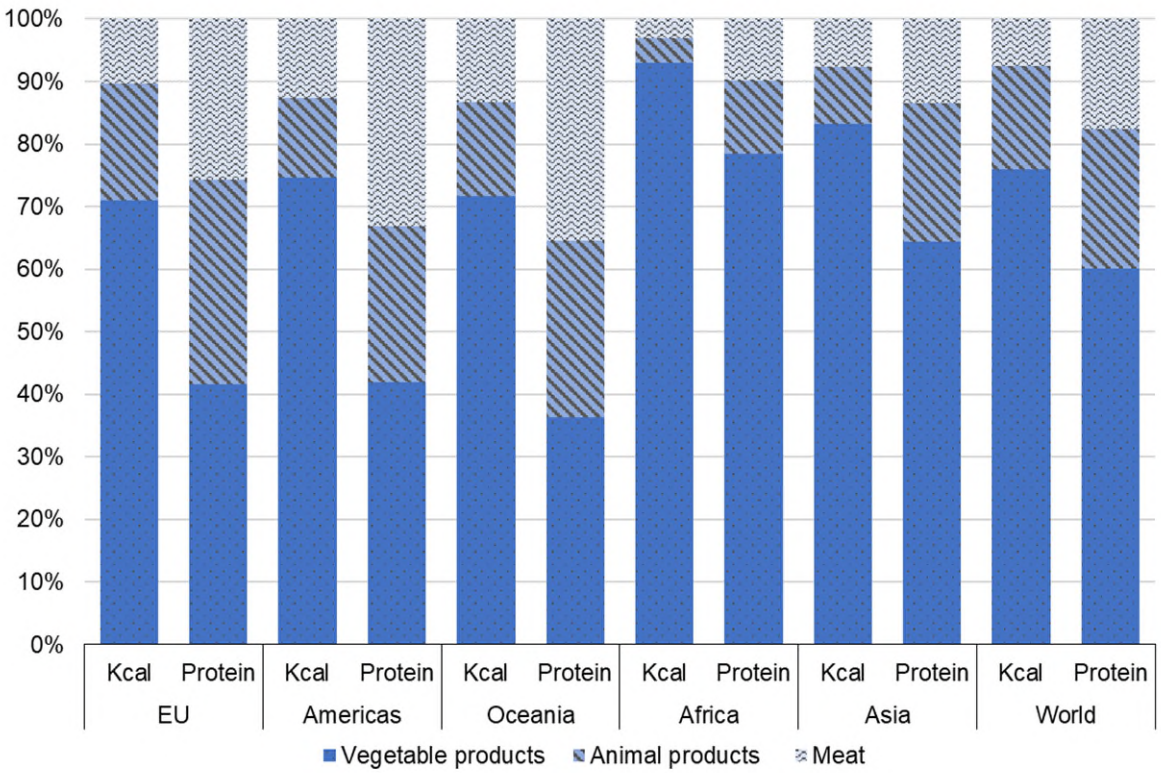

Figure 1: Share of vegetable products, animal-based foods (egg- and milk-based products) and meat in daily per capita calorie and protein consumption in 2019

Notes: Total meat consumption comprises beef, veal, pork, poultry, and further meat types.
Source: Author's own representation of FAO (2021a).

Changes in meat consumption patterns become evident in two ways: countries with comparably high per capita meat consumption levels are experiencing a saturation or even a decreasing meat demand due to environmental, health, or ethical concerns. In contrast, developing economies are increasingly favouring proteins from animal sourced foods, especially meat, in the wake of rising incomes and urbanisation (OECD and FAO, 2020). Previous and projected growth at global level is due to dietary behaviour and population growth in low-income countries which are expected to account for 88% of the increase in domestic supply up to 2029 (OECD and FAO, 2021). On that note, FAO and OECD project an annual average per capita meat consumption growth rate of 0.8% in developing countries, while the corresponding growth rate is estimated at 0.2% for developed countries (OECD and FAO, 2020).

Changing dietary habits are also evident in regard to individual meat types. ***Table 2*** shows the development and regional differences of per capita pork, beef, and poultry consumption. Average European and North American pork consumption has been declining and is expected to stagnate, also because poultry is perceived as the healthier alternative (OECD and FAO, 2020). According to ***Table 2***, an increase is projected for Asian countries, most likely driven by China's economic development. The rather restrained growth of Asian

(and global) pork consumption within the previous two decades can be linked to the outbreak of African swine fever in the corresponding producing countries (e.g., China and Vietnam). Latin American per capita pork consumption has increased due to favourable price trends, making pork, alongside poultry, the favourite meat of the middle class (OECD and FAO, 2020).

According to ***Table 2***, per capita beef consumption has declined in nearly all regions and is expected to continue to fall. An exception are Asian countries which saw an increase in per capita beef consumption, albeit at a low level. Demand for poultry has been the main driver of growth during the previous 20 years encouraged by its nutritional value, comparatively low GWP, religious preferences, and the convenient preparation (OECD and FAO, 2020). Average per capita poultry consumption has increased for all regions within the past two decades and is expected to also rise by 2029 (OECD and FAO, 2021).

Table 2: Per capita consumption of beef, pork, and poultry for different regions and periods of observation

Meat Types	Region	Ø 1998-2000 in kg p.c.	Ø 2018-2020 in kg p.c.	Δ in %	Δ 2020-2029 in %
Pork	European Union	34.8	33.9	**-2.5**	0.1
	North America	23.6	23.0	**-2.6**	**-0.2**
	Oceania	13.2	16.9	28.0	**-1.5**
	Africa	0.7	1.1	45.5	6.2
	Latin America	6.8	11.2	65.0	5.7
	Asia	10.3	10.7	3.8	11.7
	World	11.3	11.4	0.2	3.5
	Developed Countries	21.9	22.6	3.3	**-0.2**
	Developing Countries	8.4	8.8	4.4	8.0
Beef	European Union	11.8	10.7	**-9.6**	**-4.4**
	North America	30.2	25.3	**-16.0**	**-1.5**
	Oceania	20.4	13.8	**-32.4**	**-7.4**
	Africa	3.9	3.9	**-1.0**	**-2.6**
	Latin America	17.5	16.1	**-7.9**	**-0.6**
	Asia	2.8	3.5	27.6	2.7
	World	6.7	6.4	**-4.9**	**-1.8**
	Developed Countries	15.9	14.4	**-9.1**	0.7
	Developing Countries	4.2	4.6	8.7	**-0.4**
Poultry	European Union	16.3	23.9	46.8	5.7
	North America	40.8	48.6	19.3	1.7
	Oceania	21.5	33.2	54.2	3.4
	Africa	3.4	5.4	57.3	1.2
	Latin America	19.4	33.0	70.3	3.1
	Asia	5.6	10.1	80.5	8.7
	World	9.4	14.7	55.6	3.1
	Developed Countries	20.2	30.5	50.6	5.5
	Developing Countries	6.4	11.0	71.8	4.5

Notes: Decreases in per capita meat consumption are indicated in bold type.
Source: Author's own compilation of OECD and FAO (2021); projection based on the FAO OECD "Aglink Cosimo" model (OECD, 2021).

The Gini-Coefficient measures the inequality of a distribution and uses values between 0 and 1, with a coefficient of 1 indicating the most unequal distribution (MAIO, 2007). ***Figure 2*** illustrates a decrease of the Gini-Coefficient during the previous two decades related to average per capita consumption for pork, beef, veal, and poultry in 35 countries. These countries are covered by the economic partial equilibrium model "Aglink Cosimo" used by the OECD and FAO for projections of market balances (***Table 2***) (OECD, 2021). According to ***Figure 2***, global meat consumption levels have been slightly adjusting against the background of an increasing meat demand in the developing world and saturated levels in high-income countries (see ***Table 1***).

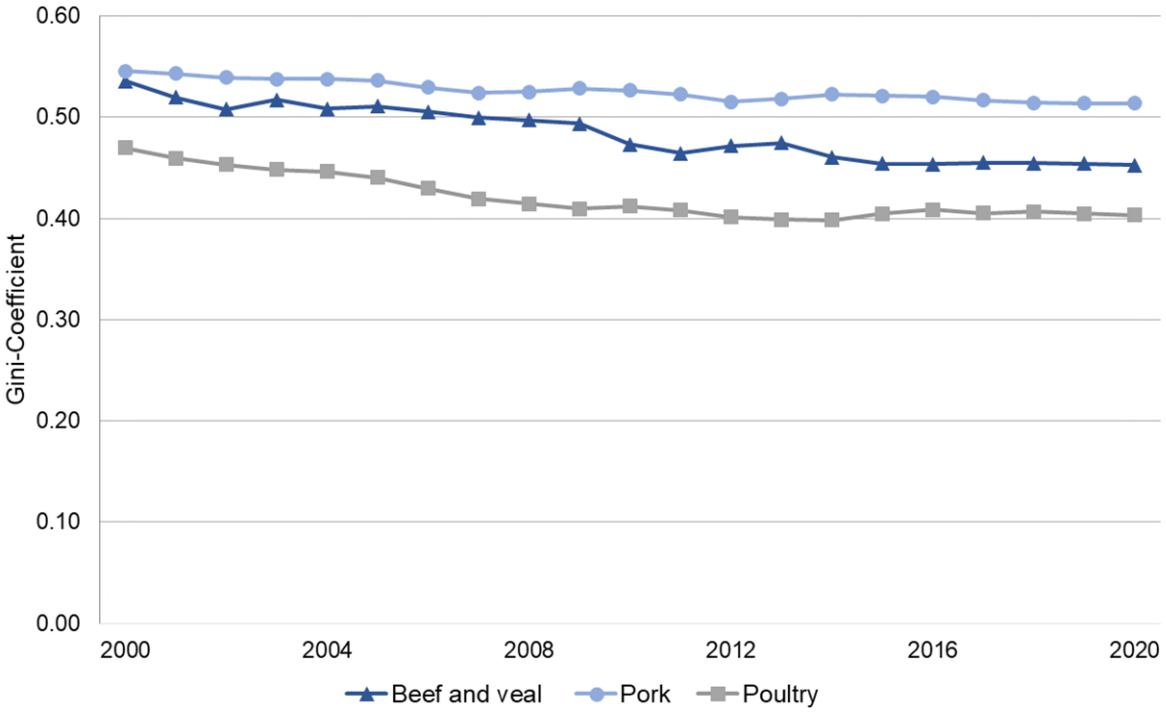

Figure 2: Gini-Coefficient for different meat types from 2000 until 2020
Source: Author's own representation of OECD and FAO (2021).

2.2 Changing meat consumption patterns in Germany

Within the EU, Germany has been amongst the countries with a medium (AMI, 2020) but fairly stable average per capita meat consumption level during the past two decades (BLE, 2021). ***Table 3*** shows key figures of the German meat balance sheet. It includes gross production (slaughter volume in c.w.e. corresponding to domestically raised livestock), net-production (total slaughter volume), foreign trade, the corresponding total domestic supply as well as total and average per capita consumption of beef, veal, pork, poultry, edible offal, and by-products for the two surveyed periods (BLE, 2021). Meat consumption is estimated based on a set of fixed coefficients to convert the domestically available meat supply into total consumption of different meat types (DVF, 1987). The consideration of the population size results in an average per capita meat consumption level (BLE, 2021). The coefficients comprise accumulated and meat-type specific utilisation and loss and waste factors. These cover i) inedible components (12-28%), ii) losses and waste from the slaughter to the consumption level (5-10%), iii) waste at the consumption stage (4%) and iv) industrial and non-food uses (8.5-60%) (DVF, 1987). Thus, e.g., 72% of the domestic supply with pork are actually attributed to human consumption (BLE, 2021). The coefficients were established in 1987 based on experts' assessments (DVF, 1987) and have not been changed or updated noticeably since then. The average total per capita meat

consumption[2] estimated in this manner peaked in 1993 at 64 kg, ranged between 60 and 62 kg until 2018, and came to 57 kg in 2020 (BLE, 2021).

Key figures displayed in ***Table 3*** illustrate a change in preferences. Average per capita annual beef and veal consumption reached 10 kg during the periods under consideration. The negative trade balance indicates that domestic demand was not served by a decreasing domestic production. Pork accounted for the largest share of meat produced, but was increasingly exported as domestic consumption continuously declined. Poultry gained the highest production increase and accounted for 23% of total meat consumption in 2020 as it is more and more domestically preferred. Edible offal and by-products are not considered as a part of the carcass which is why these products are not weighed at the slaughterhouse level. The corresponding production is determined using fixed conversion factors based on net-production (8.5% for veal and beef, 5.3% for pork, 4.4% for mutton, and 3.8% for horse meat) (BZL, 2019). In the wake of a decline in domestic demand, exports of by-products and offal have increased by 300% (***Table 3***) and have become less important for the domestic food supply chain.

[2] Total meat consumption comprises beef and veal, pork, poultry, mutton, horse and goat meat, further meat types, edible offal, and by-products BLE (2021).

Table 3: German supply balance data for different meat types and periods of observation

Supply balance positions	Ø 2000-2002 in 1,000 t c.w.e.	Ø 2018-2020 in 1,000 t c.w.e.	Δ in %
Beef			
Gross production	1,385	1,149	-17.1
Import live animal	16	14	-12.2
Export live animal	74	53	-28.5
Net-production	1,327	1,109	-16.4
Import meat	233	485	108.0
Export meat	566	402	-29.1
Total domestic supply	985	1,192	21.1
Total meat consumption	676	818	21.1
Per capita meat consumption in kg	8.4	9.9	17.3
Pork			
Gross production	3,926	4,804	22.4
Import live animal	196	501	155.3
Export live animal	67	68	1.3
Net-production	4,055	5,237	29.1
Import meat	1,050	1,056	0.6
Export meat	656	2,366	260.5
Total domestic supply	4,453	3,928	-11.8
Total meat consumption	3,210	2,832	-11.8
Per capita meat consumption in kg	39.2	34.1	-13.1
Poultry			
Gross production	978	1,817	85.7
Import live animal	25	162	554.2
Export live animal	152	365	140.6
Net-production	851	1,613	89.6
Import meat	812	971	19.7
Export meat	251	717	185.9
Total domestic supply	1,412	1,868	32.2
Total meat consumption	840	1,111	32.2
Per capita meat consumption in kg	10.4	13.4	28.3
Edible offal and by-products			
Net-production	334	576	72.7
Import meat	81	103	28.3
Export meat	160	639	300.3
Total domestic supply	255	41	-84.0
Total meat consumption	66	11	-84.0
Per capita meat consumption in kg	0.8	0.1	-84.3

Notes: Calculated values are highlighted in grey.
Source: Author's own compilation of BLE (2021).

In addition to food balance sheets (FBS) data, surveys provide demand-sided information on meat consumption in Germany. The second representative National Nutrition Survey (NVS II) calculated a mean self-reported per capita meat intake of 43 kg among German meat consumers based on individual dietary interviews and 24-h recalls conducted between November 2005 and January 2007 (KOCH et al., 2019; STRAßBURG et al., 2019).

Household budget surveys (HBS) collect data on food availability at household level (RUSSO et al., 2016). The Sample Survey of Income and Expenditure (EVS) gathers representative information at five-year intervals on consumption expenditure in private households (DESTATIS, 2021). The market research company Gesellschaft für Konsumforschung (GfK) provides nationally representative household scanner data, including the quantity and expenditure for product-based food purchases (AMI, 2020).

Figure 3 illustrates per capita purchases of different meat types and sliced cold meat for different age groups based on GfK panel data for the year 2020. Additionally, purchases of meat alternatives are displayed which are based on various raw ingredients (i.e., vegetables, egg protein, grains, milk, quorn, soy/tofu, wheat protein). Consumers aged 34 years and below had the highest per capita consumption of meat alternatives, whose total sales have more than doubled from 2017 to 2020. Simultaneously, these households bought the least amount of meat and meat products. Consumers within the age group 50-64 purchased the highest average meat quantity while single-households above 65 years of age bought the lowest quantity of meat alternatives (AMI, 2020).

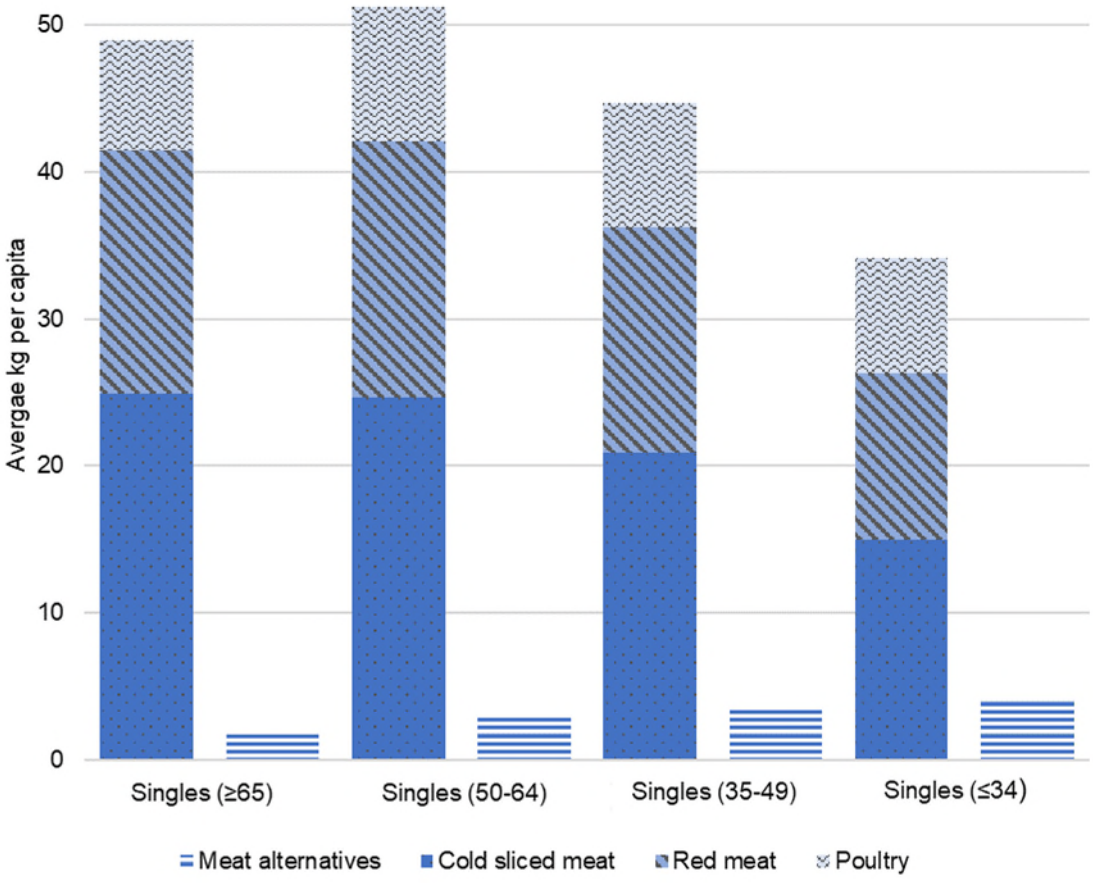

Figure 3: Meat and meat alternative purchases by different age groups for the year 2020
Source: Author's own compilation of AMI (2020).

Figure 3 demonstrates a shift of meat purchasing patterns, whereby the younger generation in particular is moving towards more flexitarian diets. GERHARDT et al. (2019) suggested that in addition to plant-based alternatives, lab-grown or "cultured meat" will increasingly replace conventionally produced meat within the next two decades. At the same time, the share of German consumers abstaining from meat eating has remained low. Vegetarian consumers accounted for 5% of the total population in 2018, while the share of vegan consumers was 1% (FORSA, 2020). Thus, these individual nutritional tendencies still play a subordinate role in relation to German dietary behaviour.

2.3 Negative externalities of meat demand against the background of sustainable food systems

Health issues, animal welfare aspects, and environmental effects are increasingly and critically focused upon by scientific and political communities in the context of high meat consumption:

Scientific studies conducted in western industrialised countries indicate that a reduced intake of red and processed meat is linked to health benefits (GEIBEL et al., 2021). This is mainly due to a high salt content, the presence of nitrite curing salts (BATTAGLIA RICHI et al., 2015), and the high energy value of meat products (WCRF and AICR, 2018). There is evidence that a more flexitarian or vegetarian diet reduces the risk of non-communicable diseases such as colorectal cancer, type II diabetes, and coronary diseases in a range of 6-41% (GEIBEL et al., 2021). The risk of premature mortality might be reduced up to 22% by following a vegan diet (SPRINGMANN et al., 2016). However, these results relate to the general composition of diets, in which the substitution of meat and meat products is one important driver. A causal link between "food risk factors" and the mentioned diseases is taken for granted. In this context, surveys were often based on self-reported consumption quantities. Therefore, there is a need for further research into the interactions of diets and health, especially in middle- and low-income countries (GEIBEL et al., 2021).

In the wake of a shifting human-animal relationship (HÖLKER et al., 2019) animal husbandry conditions are increasingly the subject of social and ethical concerns on the part of the general public (RUBY, 2012). According to a survey among EU citizens, 82% of the respondents saw a need for improvement in livestock conditions and particularly stressed the keeping of poultry (laying hens and broilers) and pigs (EC, 2005). The animal welfare issues mentioned mainly referred to housing conditions in stables (i.e., space availability, light and climate conditions) (CHRISTOPH-SCHULZ and ROVERS, 2020). Long-established practices such as the culling of day-old male chicks and the surgical castration of male piglets without anaesthesia have already been legally abolished according to § 4a and §§ 5, 6, 21 TierSchG. An increasing awareness of the animal welfare issue in Germany

additionally becomes evident by claims of the Competence Network on Animal Husbandry ("Borchert Kommission") and the Commission on the Future of Agriculture (“Zukunftskommission Landwirtschaft”) advocating a comprehensive transformation of German animal husbandry systems (KNW, 2020; ZKL, 2021).

Food systems comprise all stakeholders involved and processes within the food value chain as well as the related “economic, social, and natural environment” (FAO, 2018). As 34% of global greenhouse gas emissions are believed to be linked to agriculture (CRIPPA et al., 2021), the sector can make an important contribution to environmental protection. Animal-based foods and especially meat are associated with a high environmental footprint (WILLETT et al., 2019). Climate gas emissions attributed to livestock originate from fodder production, “enteric fermentation” but also from manure storage and spreading (GERBER et al., 2013). Compared to plant-based foods, meat products therefore have a higher GWP, considering the CO_2 equivalents (CO_2-eq) per kg in the course of life cycle assessment (LCA). While studies linked 0.37 kg CO_2-eq to 1 kg of field-grown vegetables, bone-free chicken was at 3.65 kg CO_2-eq/kg, and 26.61 kg CO_2-eq were attributed to 1 kg of beef (CLUNE et al., 2017). However, the magnitude of the environmental load depends on the type and scope of the corresponding husbandry system and whether it competes with resources used in direct food production (GODFRAY et al., 2018). Moreover, livestock contributes to nutrition security by upcycling human-inedible plants into edible protein (VAN HAL et al., 2019). This is especially relevant with regard to non-arable land or anthropogenic landscapes which can only be used for food production through animal husbandry. That is where livestock production systems are indeed essential to maintaining a variety of ecosystem services (JANZEN, 2011).

Various administrative levels are trying to create more sustainable food systems by addressing the above mentioned issues. At the European level, the Farm to Fork Strategy strives for “fair, healthy, and environmentally friendly” food systems and sets targets to be implemented at national levels. In this context, the reduction of meat consumption is mentioned, since red meat intake exceeds recommendations and “current food consumption patterns are unsustainable from both health and environmental points of view” (EC, 2020). At the German level, the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE) calls for a reduced consumption of animal products in the course of key policy recommendations (WBAE, 2020). In addition to curbing meat consumption, both institutions identify a reduction or minimisation of FLW as a key approach for a shift towards more sustainability (EC, 2020; WBAE, 2020).

Uneaten food quantities are associated with additional resource use, GHG emissions, biodiversity, and economic losses (VILARIÑO et al., 2017). The FAO defines food loss as “the decrease in the quantity or quality of food resulting from decisions and actions by food

suppliers in the chain, excluding retail, food service providers, and consumers" and refers to food quantities that do not return to the supply chain through alternative utilisation (e.g., animal feed) (FAO, 2019). Food waste (FW) occurs at the end of the value chain and is accordingly described as "the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food services, and consumers" (FAO, 2019; UNEP, 2021).

Approximately 14% of the produced edible food is lost (FAO, 2019) and 17% is wasted (UNEP, 2021) at a global scale, whereby the volume of FLW varies at national level and between value chain stages and food types (FAO, 2019). Approximately 11.9 million tons of FLW occurred in Germany in 2015, including 50% of theoretically avoidable loss and waste (SCHMIDT et al., 2019). This refers to foodstuffs that were edible before the time of disposal. Unavoidable FLW consist of inedible components that are usually removed during the preparation process (e.g., bones) (HAFNER et al., 2014). Agriculture accounted for 12%, processing for 18%, trade for 4%, out-of-home consumption for 14% and private households for 52% of the total FLW quantified in Germany (SCHMIDT et al., 2019). As in other high-income countries (FAO, 2011), a large share of food remaining uneaten thus occurs at the end of the value chain (SCHMIDT et al., 2019).

The importance of the FLW issue is reflected by the internationally agreed upon Sustainable Development Goals of the United Nations (SDGs) in the context of SDG Target 12.3. It calls for halving per-capita global food waste at the retail and consumer levels and for reducing food losses along production and supply chains, including post-harvest losses, by 2030 (UN, 2015). According to the EU Waste Framework Directive (EC, 2018), EU Member States are urged to implement a regular monitoring corresponding to the methodological approach established in the Delegated Decision 2019/1597 (EC, 2019). In addition, and as part of the Farm to Fork Strategy, legally binding food waste reduction targets are to be implemented to reduce food waste across the EU (EU, 2021). In the context of the German National Strategy for Food Waste Reduction, specific national measures are to be developed in order to meet SDG 12.3 (BMEL, 2019b). Cooperations between governmental and private actors in the course of five "Dialogue Forums" (i.e., at primary production, processing, wholesale and retail, out-of-home catering, private households) seek to accomplish regular monitoring and FLW reduction through voluntary agreements (SCHMIDT et al., 2019).

However, the aim of associated policy instruments is mainly to reduce the overall amount of FLW (BERETTA and HELLWEG, 2019). But as to varying climate effects associated with individual food categories (CLUNE et al., 2017), distinguishing between product groups is of great relevance (BERETTA and HELLWEG, 2019). Against the background of the above-

mentioned negative external effects of livestock farming, particular efforts should be made to avoid or reduce meat losses and waste.

2.4 Research questions, research focus and scope

With regard to the role of meat in the context of achieving sustainability goals as described above, this dissertation focuses on three thematic priorities. First, per capita meat consumption in Germany is estimated to provide an up-to-date database using a market balance approach. Second, different household segments are identified and characterised based on their purchasing behaviour for fresh-meat products in order to provide guidance on who to primarily target with respect to meat-reduced diets. Third, meat waste in German HaFS businesses is quantified considering different arising points. Influencing factors on meat waste ratios are identified to derive target-oriented reduction options.

Three overarching research questions (RQs) have been identified to fill research gaps and provide suggestions relevant for policy-makers and market participants:

RQ I What is the average meat consumption in Germany based on a market balance approach?

RQ II What are meat purchasing patterns and characteristics of related consumer groups in Germany?

RQ III Are there options to reduce meat waste at different arising points in German Hospitality and Food Service businesses?

As described in chapter 2.2 food balances published by the German Federal Office for Agriculture and Food (BLE) provide information on total and per capita meat consumption on a regular basis (BLE, 2021). The coefficients used to derive consumption from domestic supply are outdated and were established mainly based on experts' assumptions without adequate data support with regard to non-food or industrial uses, meat losses, and meat used for pet-food production (DVF, 1987). The average per capita meat consumption estimated in this manner was 62 kg per capita in 2008 (BLE, 2021). In contrast, the NVS II calculated a mean per capita meat intake of 43 kg among meat consumers (KOCH et al., 2019; STRAßBURG et al., 2019). Despite methodological differences and divergent reference units, the inconsistencies of these results highlight the importance of RQ I, as an up-to-date recording of total and per capita meat consumption in addition to domestic meat supply is

part of a comprehensive information basis. It is therefore also an integral component of nutrition monitoring.

RQ II refers to the lack of information concerning meat purchasing patterns of the German population based on revealed preferences. Considering a citizen-consumer dichotomy, where the response behaviour in surveys deviates from the actual buying behaviour (ENNEKING et al., 2019), an analysis of purchase data enables a reflection of dietary habits. Several studies identified different meat consumer groups in Germany basing their segmentation mainly on attitudes (KAYSER et al., 2013; PIRSICH et al., 2020), whereas CORDTS et al. (2014) based theirs on self-reported meat quantities. These studies provide initial indications regarding the scope of individual meat consumer clusters, but do not allow for a comprehensive assessment of consumption patterns. Previous research investigating the effects of meat taxation considered meat consumption of an average consumer (e.g., SÄLL and GREN, 2015; BONNET et al., 2018) or included individual differentiating characteristics (e.g., income) (PELTNER and THIELE, 2021). However, measures to achieve more plant-based eating need to particularly address consumer groups for which a dietary transformation is a priority from a health and environmental perspective and thus, consider heterogeneity. Answering RQ II based on a behaviour-based approach therefore contributes to existing literature.

RQ III addresses the need to minimise meat waste in the course of more sustainable meat demand. Answering RQ III fills a research gap with a more differentiated quantification of meat waste in German HaFS businesses. Literature references focussing on meat waste with regard to out-of-home consumption which accounts for approximately one third of total meat consumption (author's own calculation based on article (1)), are generally scarce. Existing studies have failed to provide product specific waste ratios (e.g., WRAP, 2013; SCHRANZHOFER et al., 2015). Additionally, previous research did not regard detailed information at various points of arising and waste types (i.e., avoidable and unavoidable meat waste) on a representative scale (e.g., WRAP, 2013; SCHRANZHOFER et al., 2015; XUE et al., 2019). Addressing RQ 3 therefore contributes to existing literature and moreover complies with demands for disaggregated information on FLW (KOESTER and GALAKTIONOVA, 2021). The identification of influencing factors on meat waste ratios based on an enhanced data basis allows options for meat waste reduction and prevention for the HaFS sector to be derived and thus provides conclusions that are relevant for the German National Strategy for Food Waste Reduction.

3 Methodological approaches

The following chapter describes different methodological approaches used in order to address the research questions raised in chapter 2.4. These comprise a qualitative attempt and quantitative approaches including group comparisons by investigating central tendencies (KRUSKAL and WALLIS, 1952) as well as structure-revealing multivariate analysis that allow to examine two or more variables simultaneously (HAIR et al., 2019). The methodology of FBS is explained in detail in chapters 2.1, 2.2, and article (1).

3.1 Assessing qualitative statements

Qualitative research allows gaining profound insights into societal perspectives of individuals or groups and to explain superordinate relationships against the background of behavioural action in real life settings (FLICK et al., 2007). Explorative qualitative approaches are often the method of choice with regard to investigating emerging thematic areas (LAMNEK and KRELL, 2016). In the course of article (3) respondents are asked to comment freely on the topic of meat waste in order to capture attitudes towards waste prevention measures or causes for the incurrence of wasted quantities and thus to complement the results obtained using quantitative attempts. Since qualitative content analysis allows for an empirical analysis following a predefined analytical procedure (MAYRING, 2000), it is suitable for addressing qualitative statements of HaFS businesses in article (3). An inductive approach is applied to form thematic categories deriving the corresponding codes directly from the text material. The codes are gradually combined into three main categories and four subcategories, whereby the established codebook is corroborated by fellow scientists. The results are interpreted by a summarising content analysis according to MAYRING and FENZL (2019).

3.2 The identification of key tendencies

The non-parametric Kruskal-Wallis H test by ranks (KRUSKAL and WALLIS, 1952) is used to test for statistically significant differences between four clusters in relation to the purchased quantity, expenditure, unit value, and shopping locations in article (2). It is also an appropriate way to check for statistically significant differences between *gastronomy*, *communal catering*, *accommodation*, and *further HaFS businesses* with regard to meat waste rations in the course of article (3). The Kruskal-Wallis H test examines whether three or more unrelated or independent samples originate from the same distribution (KRUSKAL and WALLIS, 1952) and is therefore known as the nonparametric pendant to a parametric one-way analysis of variance (ANOVA) (KVAN and VIDAKOVIC, 2007).

In the cases where Kruskal-Wallis results are statistically significant, the Bonferroni-adjusted post-hoc test (BLAND and ALTMAN, 1995) is used for nonparametric pairwise comparison of difference in medians between HaFS segments and clusters, respectively.

3.3 Interdependence techniques

Exploratory factor analysis is typically applied to reduce the structure of large data samples and facilitate subsequent analyses. The procedure achieves a data reduction by aggregating groups of highly correlated variables into independent single factors or components (HAIR et al., 2019). As the GfK dataset used in article (2) comprises 53 different meat products, a factor analysis is applied to identify superordinate meat product groups which reflect the purchasing patterns of households.

Prior to conducting the factor analysis, the appropriateness of the degree of interrelatedness between variables is assessed using the Bartlett test of sphericity (ARMSTRONG and SOELBERG, 1968) and the Kaiser-Meyer-Olkin (KMO) test for sampling adequacy (KAISER, 1970). The former evaluates redundancy between variables (ARMSTRONG and SOELBERG, 1968) while the latter gauges the strength of partial correlation. Ranging between 0 to 1, KMO values above 0.6 deems the sample within an acceptable range (KAISER, 1970).

Principal component analysis (PCA) followed by cluster analysis (CA) is the methodological approach employed to identify consumer segments based on meat product purchases of 11,487 households in the course of article (2). A PCA captures most of the information contained in variables within a smaller number of factors and considers the total variance of variables (HAIR et al., 2019), whereby a communality smaller than one is explained by a loss of information in the course of the aggregation process (CLEFF, 2015). Once the PCA has been performed and under the assumption of uncorrelated factors, the unrotated factor matrix is subjected to an orthogonal factor rotation procedure. According to BACKHAUS et al. (2018), the former procedure allows for an improved interpretation of the results. The number of factors is determined based on the latent root criterion or Kaiser rule, considering eigenvalues greater than 1. In order to further assess the overall fit, the total variance explained by factors is obtained. Cronbach's alpha might be used to verify the reliability in relation to the factors generated and should be at least 0.6 in the course of an exploratory approach (HAIR et al., 2019).

A two-step CA is then carried out using these PCA-based meat product groups in order to classify households into homogeneous segments, which in turn are distinguishable from one another. The hierarchical procedure conducts the aggregation based on the squared Euclidian distance using a sub-sample. The single-linkage or nearest-neighbour method

bases the aggregation on the objects closest to each other and is favoured as it is considered suitable to identifying outliers (HAIR et al., 2019). The termination of the merging process in order to determine the optimal number of clusters within the subsequent Ward's procedure (WARD, 1963) is specified using a dendrogram (CLEFF, 2015). The aggregation of clusters in this case is carried out based on minimising the "within-cluster sum of squares" (HAIR et al., 2019). Once the clusters are drawn from the agglomerative procedure, the partitioning of the entire sample takes place by means of the non-hierarchical clustering technique K-means (MACQUEEN, 1967). In K-means clustering all households are first assigned to one of the predefined clusters, before the cluster composition is enhanced comparing each observation to the cluster centroids (CLEFF, 2015).

3.4 Dependence techniques

Multinomial logistic regression (MNL) models estimate the influence of explanatory variables on the categorical specific regressor with more than two outcomes that have no natural ordering (BACKHAUS et al., 2018). MNL is therefore used to predict the event of cluster-membership and thus characterise segments identified by the previously conducted two-step CA in the course of article (2). This method, which is based on a maximum-likelihood (ML) estimator, is suitable for such a purpose as it allows to isolate the effects of individual explanatory variables or covariates on the categorical dependent variable. A separate regression model is estimated for G-1 outcomes of the dependent variable, while one outcome or cluster serves as a reference category. The estimated coefficients are interpreted accordingly in relation to the base category. Goodness of fit is assessed using several measures, e.g., the likelihood ratio-test and Pseudo-R^2-measures such as Cox and Snell, Nagelkerke, and McFadden (BACKHAUS et al., 2018).

The examination of the influence on a dependent variable taking the value {0,1} can be carried out in the course of binary logistic models (BACKHAUS et al., 2018). Beta regressions are appropriate for modelling data for which the observations lie within an open interval between 0 and 1 (FERRARI and CRIBARI-NETO, 2004). Since the meat waste ratios analysed in article (3) are between 0 and 1, but at the same time take on a value of 0 (i.e., 0% of waste related to purchased meat quantities), a fractional response model is used to investigate the influence of several explanatory variables. The model is based on a quasi-maximum likelihood estimator (QMLE) to determine its parameters (PAPKE and WOOLDRIDGE, 1996).

The calculation of marginal effects facilitates the interpretation of results derived from both MNL and fractional response regression techniques (CAMERON and TRIVEDI, 2009) and is explained in more detail in articles (2 & 3).

4 Summary of articles and their contributions to the overall thesis

This cumulative dissertation comprises three contributing articles which address three overarching research questions that have been outlined in the course of chapter 2.4. The three articles deal with the superordinate topic of German meat demand and address meat consumption and meat waste as important issues to be considered in the context of more sustainable food systems (WILLETT et al., 2019; KARWOWSKA et al., 2021). The following chapter describes the overall conceptual framework of the dissertation as well as the scientific approach and main results of the three contributing articles. ***Table 4*** provides an overview of the individual contributions.

Table 4: Overview of contributing articles

Article	Authors	Title	Journal
(1)	A. J. Thies J. Efken M. Sönnichsen	How much meat do we eat? Estimating per capita meat consumption in Germany based on a market balance approach	Published in *German Journal of Agricultural Economics*
(2)	A. J. Thies D. Weible M. Staudigel	Tailored marketing and policies for more sustainable meat demand – A consumer segmentation based on revealed preferences for Germany	Submitted to and under review at *Agribusiness: An International Journal*
(3)	A. J. Thies F. Schneider J. Efken	The Meat We Do Not Eat. A Survey of Meat Waste in German Hospitality and Food Service Businesses	Published in *Sustainability*

Source: Author's own compilation.

Figure 4 illustrates the corresponding conceptual framework of the dissertation. The contributing articles address different levels in order to answer the individual RQs. First, they examine different segments of the meat market in Germany. Article (2) and (3) focus on at-home or out-of-home consumption, respectively and therefore address market sub-segments, while article (1) analysis the utilisation of the total meat quantity domestically available. Second, the articles focus on different value chain stages. Article (1) follows a supply-side approach and includes a mass flow analysis, while articles (2) and (3) each refer to the demand-side by addressing private households and businesses of the HaFS sector. Third, as they have different objectives, each of the contributing articles refers to an individual reference parameter: i) meat consumption expressed as c.w.e., ii) meat product

purchases expressed as product weight, and iii) meat waste ratios related to purchased meat quantities.

Against this background, the three articles allow for different conclusions to be drawn. Article (1) enables an assessment of average meat consumption as an important reference value in relation to environmental and health benchmarks. Article (2) indicates priority groups for a behavioural change, and article (3) identifies meat waste hot spots for which targeted measures could contribute to considerable resource savings. Furthermore, article (2) provides indications for the implementation of fiscal policies and suggests targeted marketing to promote meat produced under improved animal-welfare conditions or meat substitutes with environmental benefits. In the course of article (3), determining factors on meat waste ratios are assessed to derive waste prevention and reduction options for the HaFS meat value chain.

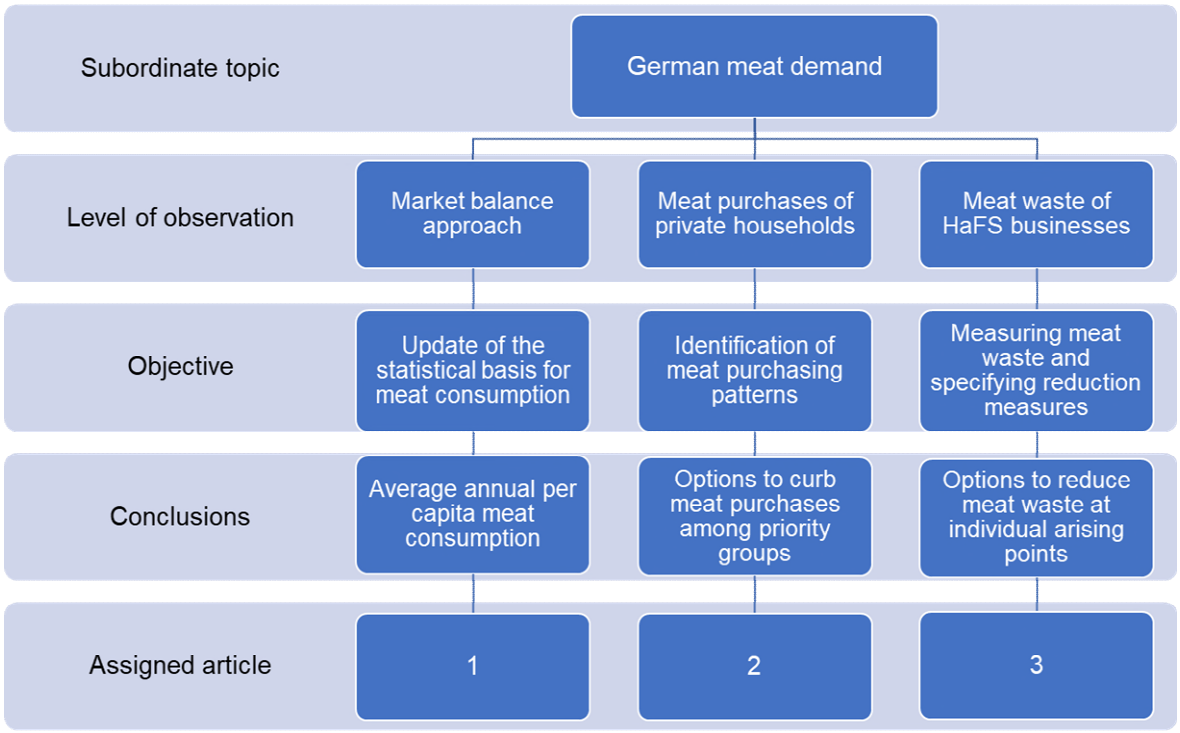

Figure 4: Conceptual framework of the dissertation

Source: Author's own compilation.

Article (1) presents a proposal for a revised pork, beef, and poultry consumption calculation in Germany. The estimation technique uses official statistics on meat production and includes adjustments to external trade statistics with regard to pork, beef, edible-offal, and by-products. The procedure comprises three calculation steps for each meat type. First, the total meat quantity generally available for domestic consumption is determined based

on a random survey of slaughterhouses, considering inedible components (i.e., bones) as well as exported and imported meat quantities of the companies surveyed.

In a second step, total meat consumption corrected for loss and waste is computed by deducting meat losses at the processing- and wholesale-level and waste at the retail-level. The allocation between marketing channels is based on results of the survey at slaughterhouse level. Wasted meat quantities at the consumption stage are obtained considering purchases of private households based on GfK data and purchases of HaFS businesses calculated as residual values. By dividing total consumption through population size in a third step, per capita consumption is estimated. A set of species-specific coefficients corresponds to the ratio of consumption and domestic supply.

The average per capita annual meat consumption of 64.7 kg determined for the year 2018, comprises 34.8 kg pork, 11.5 kg beef, and 15.8 kg poultry. The corresponding coefficients for the derivation of consumption from domestic supply, are 80.8% for beef, 79.8% for pork, and 68.0% for poultry. The results indicate that per capita meat consumption has been underestimated by 3.6 kg and by means of the current coefficients which have been implemented in 1987 (DVF, 1987). Findings of article (1) show an increased per capita consumption of beef and poultry and demonstrate that per capita pork consumption has previously been overestimated by overrating external trade of meat by-products. As the currently applied approach accumulates utilisation and loss and waste factors, without distinguishing between different sales outlets, meat going uneaten is overestimated and per capita figures have tended to be underestimated in the past.

The uncertainty of the estimated meat consumption level is determined to be 20% by means of a sensitivity analysis. In particular, higher waste assumptions at the consumer level including cooking losses result in a reduction of the estimated consumption level to 52 kg per year. Exported meat quantities and sales to pet food producers in relation to production are additionally considered as further sensitive parameters due to likely high standard deviations.

A comparison of international meat consumption measures using FBS data illustrates methodological differences in terms of divergent assumptions on inedible components, non-food uses, pet-food, losses, and waste. Due to the resulting assessment of different value chain stages and product units, consumption levels are hardly internationally comparable. An analysis of German edible offal and by-product exports suggests that the classification by means of the Combined Nomenclature (CN) in external trade statistics needs to be revised. A harmonised assignment of meat, edible offal, and by-products in international trade statistics would enable a uniform construction of FBS and a standardised calculation of domestic meat supply in the first place.

Article (2) deals with a segmentation of German fresh-meat-shoppers based on household panel data provided by the GfK for the year 2014. It uses PCA with Varimax rotation to identify commonalities in purchase patterns with regard to meat types, meat cuts, and preparation methods across single products. A hierarchical CA followed by K-means clustering is performed to identify segments based on each household's average monthly purchase share of product groups derived by PCA.

In this article 21 different meat products are aggregated into nine factors. One factor each summarises lamb, veal, and poultry cuts. An additional factor includes premium cuts of red meat while another factor combines convenience mixed products. Pork and beef products are aggregated in two factors each: sautéed and traditional beef cuts; and traditional and convenience pork cuts. Subsequently, four clusters are identified: a segment of *pork and beef traditionalists* (59% of the total sample), households belonging to *convenience-oriented pork buyers* (11% of the total sample), a cluster labelled as *poultry lovers* (25% of the total sample), and a cluster termed *premium red meat lovers* (5% of the total sample).

Subsequently to a comparison of the identified clusters using a Kruskal-Wallis H test, MNL is performed to further characterise these segments. The cluster type is the dependent variable and socio-demographics, total purchased meat quantity, shopping locations, and attitudinal statements towards meat and food shopping serve as independent variables.

The largest group of *pork and beef traditionalists* should be addressed with priority to achieve an overall more rapid dietary change with a view on health effects due to their high level of meat purchases (1.95 kg per month) and the high proportion of pork cuts with a high fat content. This cluster comprises reference persons of advanced age. Intermediate to high net incomes decrease the chance of cluster membership. Financial incentives in form of a meat tax could contribute to curb meat purchases of these households as they additionally report price sensitivity and pay rather low average meat prices. Personalised price promotions of plant-based alternatives could curb meat consumption of *convenience-oriented pork buyers*, who also need to replace purchased meat products from a health perspective. This segment comprises younger male reference persons, who show the lowest average expenditure and unit value within the sample. As they place price above quality, the extent to which measures of an informative nature could additionally reach *convenience-oriented pork buyers* remains open.

Poultry and *premium red meat lovers* are likely to be guided by informative measures. *Poultry lovers* are health-oriented and exhibit the lowest per capita total meat quantity among clusters. The female headed households state to be quality-conscious, alongside with high unit values for the meat they buy. More targeted labelling, e.g., promoting organic meat or meat produced under improved animal husbandry conditions, might contribute to a

qualitative shift for *poultry* and *premium red meat lovers*. *Premium red meat lovers* likewise value quality food and purchase the largest share of organic meat among clusters. Due to a rather high income level, while stating to be less price sensitive, they may accept further price increases to maintain their long-established dietary habits.

Overall, efforts to shift meat purchases into a more sustainable direction would have to overcome established habits (*pork and beef traditionalists*), low price sensitivity (*premium red meat lovers*), and apathy (*convenience-oriented pork buyers*).

Article (3) quantifies meat waste, defined as food-grade meat products leaving the food value chain in German HaFS businesses at a representative scale. Based on CATI, it examines whether waste ratios differ between *gastronomy, communal catering, accommodation*, and *further HaFS businesses* (Hypothesis 1) and assesses the relevance of storage and preparation waste as well as leftover meat (Hypothesis 2). Waste ratios are compared between segments and on the business-type level using explorative analysis (boxplots), a Kruskal-Wallis H test followed by a post hoc test, and various descriptive statistical parameters. The results are evaluated against the background of a literature review. In order to determine whether awareness of food waste prevention is linked to the incurrence of meat waste (Hypothesis 3) and to derive corresponding reduction measures, a fractional response model with waste ratio as the dependent variable and meat purchases, the respondent's occupation, offered meat types, shopping locations and attitudinal statements towards the food waste awareness as independent variables is conducted. Moreover, a qualitative content analysis provides a more detailed explanation of causes as to wasted meat quantities.

An annual meat waste of 85,800 tons is estimated, with *communal catering* accounting for 36%, *gastronomy* and *further HaFS businesses* for 27%, and the *accommodation* segment for 16% of meat wasted out-of-home. The *gastronomy* segment shows the highest total (7.8%) and avoidable (5.8%) mean waste ratio among segments and in relation to weekly purchased meat quantities. Leftovers, including overproduction, buffet, and plate waste are identified as hot spots in a comparison of meat waste arising points. Leftover meat makes up the greatest share of total meat waste in the *gastronomy* (i.e., 41%) and *accommodation* segment (i.e., 54%) and accounts for 76% of the meat wasted in *communal catering*.

In order to reduce leftovers, businesses are already offering small portions or give leftovers into private hands. The use of doggy bags to take home leftover food is established within the *gastronomy* sector, but less frequently used in *communal catering*. Cooperation with redistribution organisations needs to be fostered to provide edible meat overproduction to food banks, as regression results indicate increased meat waste ratios due to a lack of food donations. However, extensive legal requirements, additional effort, and geographical

conditions (long distances) keep businesses from entering into long term corresponding cooperations with food banks. As assessing the eating behaviour of guests seems a challenge for businesses with a great menu and a large number of customers, a selling of discounted surpluses via mobile applications might set financial incentives and could therefore contribute to further reduce meat waste of these businesses.

Awareness for less wasteful behaviour needs to be raised among staff and guests. In the course of developing communication strategies for individual target groups, the scope of the issue should be emphasised. Results of article (3) illustrate that accepting mean waste ratios of the lower quartile (bottom 25%) of each of the four segments as a feasible benchmark, could save approximately 1,300 kt in CO_2 equivalents or 2% of the total CO_2 equivalents emitted by German agriculture in 2018. A future improvement, as targeted by SDG 12.3 (UN, 2015), appears feasible for the entire German HaFS sector considering the waste management of the lower quartile and individual businesses representing almost every business-type.

5 Articles included as part of the dissertation

5.1 How much meat do we eat? Estimating per capita meat consumption in Germany based on a market balance approach

Annika Johanna Thies, Josef Efken, Monika Sönnichsen
German Journal of Agricultural Economics (2022), 71(2), 76-91.

The publisher Deutscher Fachverlag GmbH has permitted the publication of the article in its final version as part of this dissertation.

Declaration of originality: The concept for this study and the research questions were jointly developed by Dr. Josef Efken, Monika Sönnichsen and the author. The query mask for data collection was developed by Dr. Josef Efken and the author considering assessments of various experts from the slaughter industry. Data collection at the slaughterhouse level was mainly conducted by the author with the helpful assistance of Dr. Josef Efken and Monika Sönnichsen. The development of the estimation concept and data analysis was carried out by the author and discussed with Dr. Josef Efken. The original draft was prepared by the author. Dr. Josef Efken and Monika Sönnichsen reviewed the manuscript.

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How much Meat do we eat? Estimating per Capita Meat Consumption in Germany based on a Market Balance Approach

Annika Johanna Thies and Josef Efken
Thünen Institute of Market Analysis, Braunschweig

Monika Sönnichsen
Max Rubner-Institut (MRI) - Federal Research Institute of Nutrition and Food, Kulmbach

Abstract

Meat consumption has become increasingly relevant within the greater scientific, political, and public debate due to the variety of negative effects that it has on the environment, human health, and animal welfare. In Germany, the statistical basis for "direct consumption" entails uncertainties and is based on parameters dating back to 1987. The following study deals with an updated and revised estimate of the per capita consumption of pork, beef, and poultry in Germany, focusing on the supply-side. Unlike the original approach, the estimate is based on a mass flow analysis. It includes a survey at the slaughterhouse level, adjustments to external trade statistics, and assumptions on loss and waste at five different value chain stages. An average total per capita meat consumption of 65 kg is calculated for the year 2018. Thus, meat consumption has been underestimated by 4 kg per capita based on official statistics by overestimating waste, losses, and non-food uses. Our results provide information regarding per capita and total meat consumption, enable future projections, and give an overview of the use of meat outside the food chain. The approach used is discussed against the background of international comparability and applicability. In this way the study provides important indications for political decision-makers and contributes to more objectivity in the public debate on meat consumption.

Keywords

meat consumption; Germany; food balance data; market balance approach; international comparability

1 Introduction

The general public, the political and scientific communities are critically discussing the effects of the current and projected consumption of livestock proteins: particularly the demand for meat is being controversially re-examined. This demand is associated with negative consequences for human health and adverse effects on the environment, the preservation of natural resources, and animal welfare as a result of intensive animal husbandry in industrialized countries (GODFRAY et al., 2018; SPRINGMANN et al., 2018).

Against this background, scientific studies at different national and institutional levels have indicated the necessity for demand management. In its "Special Report on Climate Change and Land Systems", the Intergovernmental Panel on Climate Change (IPCC) of the United Nations refers to the climate impact of meat-intensive diets and thus shifts the issue into the focus of current public perception at the international level (IPCC, 2019). At the European level, and in the course of the "Farm to Fork Strategy", the European Commission strives for more sustainable food consumption. It also works to counter negative external effects of red meat consumption on the environment and health (EC, 2020b). In Germany, the the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection at the Federal Ministry of Food and Agriculture (WBAE) recently indicated the necessity of reduction in the consumption of meat to design a more sustainable food system (WBAE, 2020).

However, the frequently cited German "food balance sheet data" providing regular information on meat consumption from a market-balance perspective has important limitations. Fixed coefficients are used to convert the domestically available total meat supply into average per capita consumption of different meat types expressed as carcass weight (BLE, 2021). The coefficients adjust for inedible components, losses at the slaughter-level, non-food uses, and waste at the consumer level. They were established in 1987 (DFV, 1987), and have not been changed or updated appreciably since then (BLE, 2021). The average per capita meat consumption level estimated in this manner varied between 60 and 62 kg within the years 2000 to 2018 and was 57 kg in 2020 (BLE, 2021).

In contrast, the second representative National Nutrition Survey (NVS II), measuring food ingested by individuals, calculated a mean per capita meat intake of 43 kg among meat consumers based on dietary interviews and 24-h recalls conducted between November 2005 and January 2007 (KOCH et al., 2019). The NVS II refers to prepared meat quantities including cooking losses in the course of a demand-side approach (STRAßBURG et al., 2019), which partly explains the discrepancy with the supply-side estimates. Mismatches between consumption indicators based on "food balance sheet statistics" or dietary surveys have been reported in various studies (e.g., DOWLER and SEO, 1985; BARRETT, 2010; YU and ABLER, 2014; AMO et al., 2016; THAR et al., 2020). However, results with such high inconsistency raise questions about the accuracy of the application of the 30-year-old set of coefficients in Germany. Incorrect consideration of meat exports, over- or underestimated loss and waste ratios or changing marketing channels might be reasons for an incorrect assessment (over- or underestimation) of consumption based on the supply-side.

Nevertheless, a regular recording of average meat consumption is not only useful with regard to the evaluation of consumption levels and trends to add more objectivity to the emotionally-driven discussion on the topic in Germany. Such monitoring additionally provides information regarding the availability of meat as food, enables future projections, and gives an overview of the use of meat outside the food chain.

The purpose of this paper is two-fold: first, it describes and compares existing estimation procedures (national and international). Second, the paper uses an updated estimation approach for the German per capita consumption of beef, pork, and poultry. The calculation bases on mass flow analysis which accounts for losses and waste along the value chain. Therefore, a survey was conducted at the slaughterhouse level to determine the quantity available for domestic human consumption. Based on descriptive analysis adjustments are made for foreign trade, which are included in the total estimate. Finally, the updated estimation procedure and the results are discussed considering the intended purposes and the international comparability of the estimated meat consumption level.

2 Review of Current Procedures Estimating Meat Consumption

How is per capita food or meat consumption measured? Different types of data are collected regularly in most developed countries to monitor nutrition and the human consumption of various commodities (SERRA-MAJEM, 2001). Household budget surveys (HBSs) are based on nationally representative population samples to collect data on food availability at the household level. Individual dietary surveys (IDSs) based on representative country population samples provide information regarding the quantity of different foods ingested by the individual and for the survey period under review (RUSSO et al., 2016). An approach commonly used by the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2021a, 2021b), the European Commission (EC) (EC, 2021) and national administrations (BLE, 2021) is the estimation of average annual consumption based on food balance sheets including utilisation and loss and waste assumptions (SERRA-MAJEM, 2001; RUSSO et al., 2016).

2.1 International Approaches Estimating Meat Consumption

The FAO calculates meat and edible offal available for national human consumption (referred to as food supply) with country specific data expressed in terms of quantity, calories, protein, and fat per day and capita (FAO, 1972, 2021b). In these food balances, this information is shown conjointly for different meat types, whereas "Supply Utilization Accounts" present data separately for different products or product groups. The FAO calculates per capita supply of different meat types or products considering production, stocks, imports, and exports. In addition, losses and waste incurred in the course of storage and transport up to retail level are deducted (FAO, 2021a, 2021b). At the product level, the "Supply Utilization Accounts" show a per capita supply (inedible bones excluded) for individual product-groups. The industrial utilisation of meat is considered as an additional utilisation path, without explicitly reporting meat used for pet-food production. In principle, feed, seed, and food quantities consumed by tourists and residuals complement the specified utilisation options. Waste at the household level is not considered (FAO, 2021a, 2021c).

The United States Department of Agriculture (USDA) publishes annual national data on human consumption based on supply balances. To show the available supply of a commodity or each meat category, exports, shipments to U.S. territories, and ending stocks are deducted from the sum of production, imports, and beginning stocks. The total and per capita quantities available are shown in carcass weight, retail

weight, and as a boneless quantity (USDA, 2021a, 2021c). In addition to the "Food Availability System", the USDA provides loss-adjusted data on meat availability through the "ERS Food Availability Data System". Data include deductions for the conversion of primary to (boneless) retail weight and from retail to consumer weight. The per capita availability is calculated adjusting for preparation including cooking losses and plate waste (at-home and out-of-home consumption (USDA, 2020, 2021b). Due to limited data availability, this calculation method does not include deductions for meat quantities used in the pet food and animal feed industries (USDA, 2018).

The European Commission (EC) also uses production and trade data when calculating the annual per capita consumption of different meat types. Based on net production and foreign trade, domestic supply (referred to as "total consumption") is calculated as carcass weight (EC, 2021). The EC determines the per capita consumption level, summarised for the 27 Member States of the European Union (EU) considering total population. Carcass weights are transformed into retail weight to adjust for inedible components, fat, trimmings, and further losses and waste up to the consumer level (NELSON et al., 1989; EC, 2021). The conversion factors are 0.70 for beef and veal, 0.78 for pork, 0.88 for poultry, and 0.88 for sheep and goat. Waste at the consumer level is not considered. The EC does not report consumption of edible offal and by-products separately (EC, 2021).

2.2 Current Supply-Side Approach Estimating Meat Consumption in Germany

The Federal Office for Agriculture and Food (BLE) publishes German per capita meat consumption derived from supply balances for meat, edible offal, and by-products on an annual basis. The available domestic supply expressed as carcass weight is calculated by deducting exports and adding imports of meat and meat products from and to net production, which corresponds to slaughter volume (BLE, 2021).

The total available domestic supply is primarily for human consumption, but also for other purposes since inedible components, losses, and waste are still included. These cover (1) non-food material (DFV, 1987), which is used for industrial purposes, further processed and commonly used in biodiesel production and oleo chemistry (NIEMANN, 2017); (2) meat, edible offal, and by-products used as pet-food and in aquacultures; and (3) losses and waste from the slaughter to the consumer level as well as waste at the consumption level (DFV, 1987). For this reason, a set of coefficients is used to convert total domestic supply into per capita consumption by considering population size (BLE, 2021). The German Livestock and Meat Market Association implemented the coefficients in 1987 also based on expert assessments (DFV, 1987).

The estimation concepts presented consider different deduction items. Table 1 gives an overview of the main differences and also includes our updated technique for Germany.

Table 1. Overview of the main differences of estimation methods

Institution	Deduction for inedible components	Deduction for non-food uses	Deduction for pet food production	Deduction for losses and waste during production, processing, and storage	Deduction for consumer waste
FAO	(X)	(X)		X	
USDA	X			X	X
EC	X			X	
BLE	X	X	X	(X)	X
Updated national estimation presented in this study	X	X	X	X	X

Notes: partial consideration of the deducted item in parentheses. In the case of non-selection, the corresponding item is not explicitly shown or specified within the individual estimation procedure.
Source: authors' compilation based on USDA (2018, 2020), BLE (2021), EC (2021), FAO (2021a, b)

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3 Proposal for a Revision of Estimating Meat Consumption in Germany

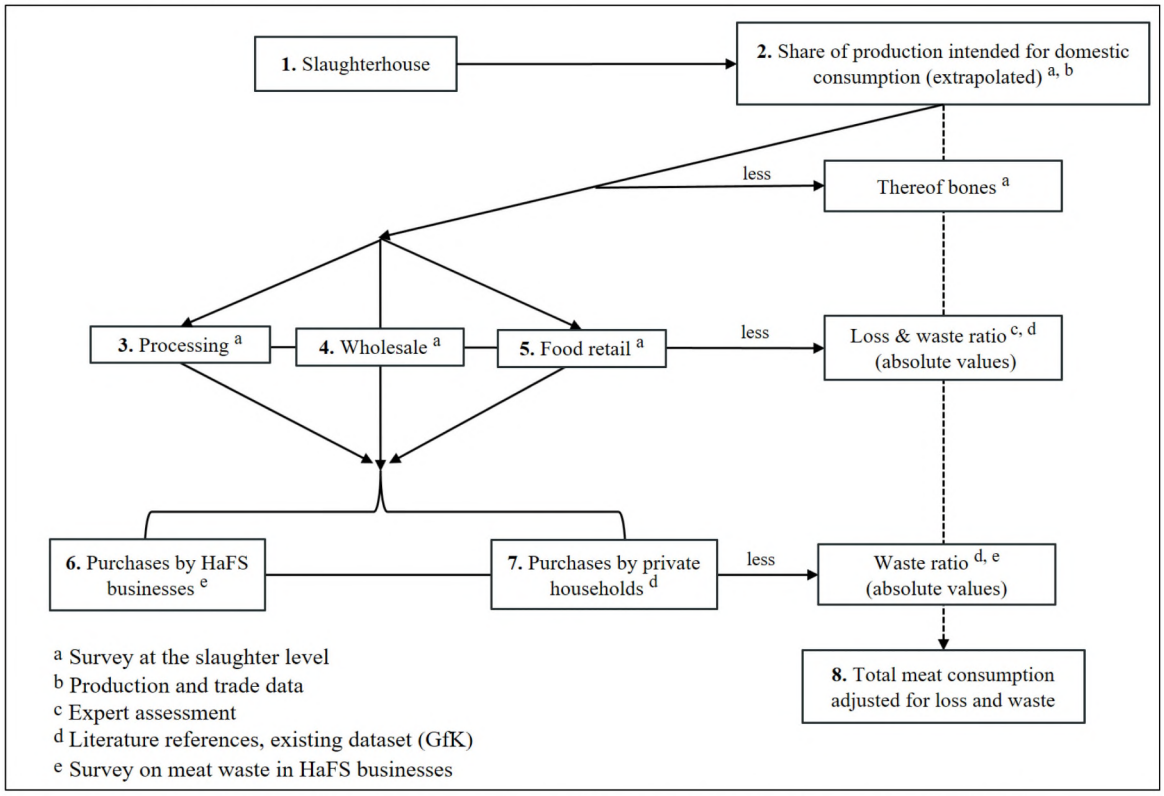
Based on a mass flow analysis we conduct an updated estimate of German per capita beef, pork, and poultry consumption. It uses results of a survey at the slaughterhouse level, official production and adjusted trade data as well as loss and waste assumptions along the value chain. The following chapter describes the methodological procedure and the data collection.

3.1 Market Balance Approach

Figure 1 shows the mass flow analysis which serves as a framework for the estimate. In a first step, the average share of production intended for domestic human consumption as well as inedible bones included are calculated based on a random survey of slaughterhouses. This information is used to extrapolate the total quantity of meat generally available for consumption, using official production and adjusted trade data. We calculate the distribution among different marketing channels (meat processing, wholesale, and food retail) in accordance with the slaughterhouse data to consider different loss and waste ratios. Following the simplified FAO definition, losses are defined as the reduction of edible food or meat quantities at the processing and wholesale level. Waste arises at the retail and consumption level (FAO, 2019). In the course of the estimate, we differentiate between consumption at-home and out-of-home. Hospitality and Food Service (HaFS) businesses are defined as final consumers in the out-of-home sector. Finally, the total loss and waste quantities are derived from the meat generally available for human consumption to calculate total or loss- and waste-adjusted consumption.

The estimate comprises three main calculation steps for each meat type. First, the total quantity of meat generally available for domestic consumption (AC) is determined by considering net-production (Q) (including edible offal and by-products), the share of meat available for domestic consumption (SD), the share of inedible bones (SB) included, as well as adjusted exports (EX) and imports (IM). In a second

Figure 1. Framework for the estimation procedure



Notes: we present value chain stages, for which we assume losses and waste within the estimation procedure (i.e., Tab. 4-5).
Source: authors' own compilation

step, total consumption is computed by deducting absolute losses and waste at the processing-, wholesale-, and retail-level, which are calculated considering the share (S) of each marketing channel (i) and the individual loss or waste ratios (LR, WR). Absolute waste at the consumption level is determined considering consumption in private households (CH), consumption out-of-home (CA), and the individual waste ratios (WR). By dividing total consumption by population size, per capita consumption is estimated.

$$Available\ for\ domestic\ consumption = (Q * SD)(1 - SB) - EX + IM \quad (1)$$

$$Absolute\ losses\ at\ processing, wholesale\ \&\ waste\ at\ retail\ level = \sum_i ((AC * S_i * LR_i) + (AC * S_i * WR_i))$$

$$Absolute\ waste\ in\ private\ households = CH * WR_{CH}$$

$$Absolute\ waste\ out\text{-}of\text{-}home = CA * WR_{CA}$$

$$Total\ consumption = AC - \sum_i((AC * S_i * LR_i) + (AC * S_i * WR_i)) - (CH * WR_{CH}) - (CA * WR_{CA}) \quad (2)$$

$$Per\ capita\ consumption = \frac{Total\ consumption}{Population} \quad (3)$$

3.2 Data Collection

Data Collection at Slaughterhouses Level

Data collection was mainly done at the slaughterhouse level. As the relevance of specific sales channels is most likely to vary between companies, we have aimed for a high market coverage in terms of the national slaughter volume. The random sample comprised six pig slaughterhouses (market coverage: 50%), four cattle slaughterhouses (market coverage: 48%), and seven poultry slaughterhouses (market coverage: 81%). Due to the relatively low number of veal slaughtered compared to young bulls, heifers, and cows (DESTATIS, 2021), the corresponding information from cattle slaughterhouses was also assumed for veal. Abattoirs provided information on the utilisation at the product or product-group level based on their Enterprise-Resource-Planning (ERP) systems (sales data) for an annual period to minimise seasonal effects and for two reference years (2017 and 2018) to recognise annual effects. Certain abattoirs provided information for one year only. The data query was conducted using a predefined Excel-Spreadsheet, which we developed with industry experts to ensure a recording in accordance with the slaughtering process and to avoid double counting (i.e., bones). We distinguished between products removed before and after determination of carcass weight and thus between edible offal, by-products, and meat. Exports, category I-III material[1] (risk material specified by Regulation (EC) No 999/2001 (EP, 2001), material intended for animal feed production or further non-food uses were indicated as possible utilisation paths. The slaughterhouses stated inedible shares (i.e., bones, tendons) and further marketing channels (processing, wholesale, retail) of meat, generally available for domestic consumption. Figure 2 displays the query scheme.

Absolute figures of all surveyed slaughterhouses were summed up to obtain the weighted percentage shares of exports, meat available for domestic consumption, and included bones in their relation to carcass weight (including additional purchases). Percentage shares of the individual marketing channels were determined in relation to the total meat available for domestic consumption, also expressed as carcass weight. In this manner, the information from the sample was extrapolated to the entire market since net production equals the total slaughter volume (expressed as carcass weight equivalent (c.w.e.)).

Data on External Trade

The German balance sheets provide a condensed overview of the meat supply for the individual species, edible offal, and by-products (BLE, 2021). In contrast to meat, the quantity of edible offal and by-products is not weighed but estimated using fixed coefficients in order to determine net production (BZL, 2019). The domestic supply is calculated considering foreign trade (BLE, 2021), where external trade statistics classify products in accordance with the Combined Nomenclature (CN) (EC, 2020a). Other than edible offal there are hardly any products in this nomenclature that do not belong to the carcass and are therefore officially classified as meat. As a result, only few products can generally be categorised as by-products. However, an analysis of the German export volume of edible offal and by-products of the past

[1] According to the negative effects on human and animal health, animal by-products are divided into three risk categories (Categories I-III) and have to be processed differently BMEL (2020).

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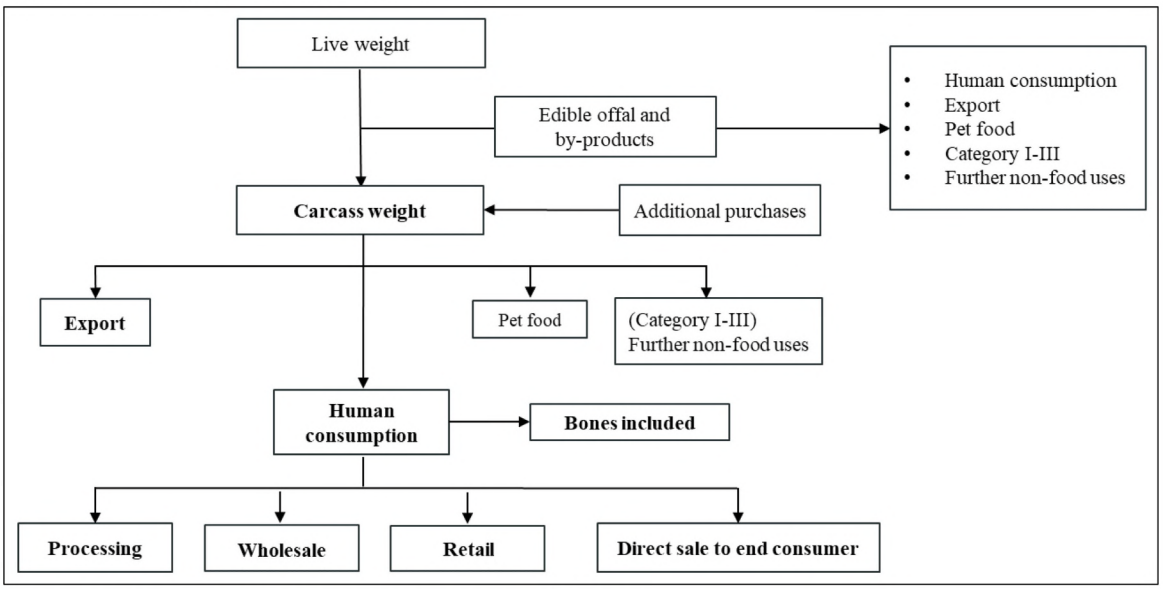
Figure 2. Data query at slaughterhouse level



Notes: information used for the estimation procedure is indicated in bold type.
Source: authors' own compilation

20 years showed that the majority of exports are assigned to CN-codes classified as by-products. In 2019, 89% of the total export volume of edible offal and by-products were pork by-products (EUROSTAT, 2020).

Figure 3 shows the production, export, and domestic supply of edible offal and by-products as presented in the official supply balance from 1999 to 2019. The sharp rise in exports of pork by-products since 2008 would have effectively resulted in a negative domestic supply ("acc. to coef.") if the fixed coefficients were used to calculate net production. To avoid this situation, official net production was manually increased each year from 2008 onwards to maintain a low but positive domestic supply ("off."). This procedure ultimately would result in the creation of edible offal and by-products, which does not seem plausible given the physical composition of the carcass. However, an ongoing incorrect assignment of products and the corresponding CN-codes seems a more realistic explanation. It can therefore be assumed that meat which is attributable to the carcass by definition, is partly declared as a by-product in trade statistics.

To correct the misalignment, we only considered products which are clearly not part of the carcass in the context of external trade of edible offal and by-products. Figure 3 additionally presents the accordingly modified domestic supply.

As a consequence, the remaining CN-codes are now reflected in foreign trade for pork and beef (meat). This adjustment affects the estimation of meat consumption. Due to the increasing export volume for pork in the observation period, and a high export share of the products now allocated to the supply balance for pork (meat), the domestic supply of pork appears to be lower than the quantity shown in the official statistics. This effect is considerably lower for beef. The revised allocation of the CN-codes is included in the estimation procedure in the course of reporting updated import and export quantities for beef, pork, edible offal, and by-products (i.e., Tab. 8).

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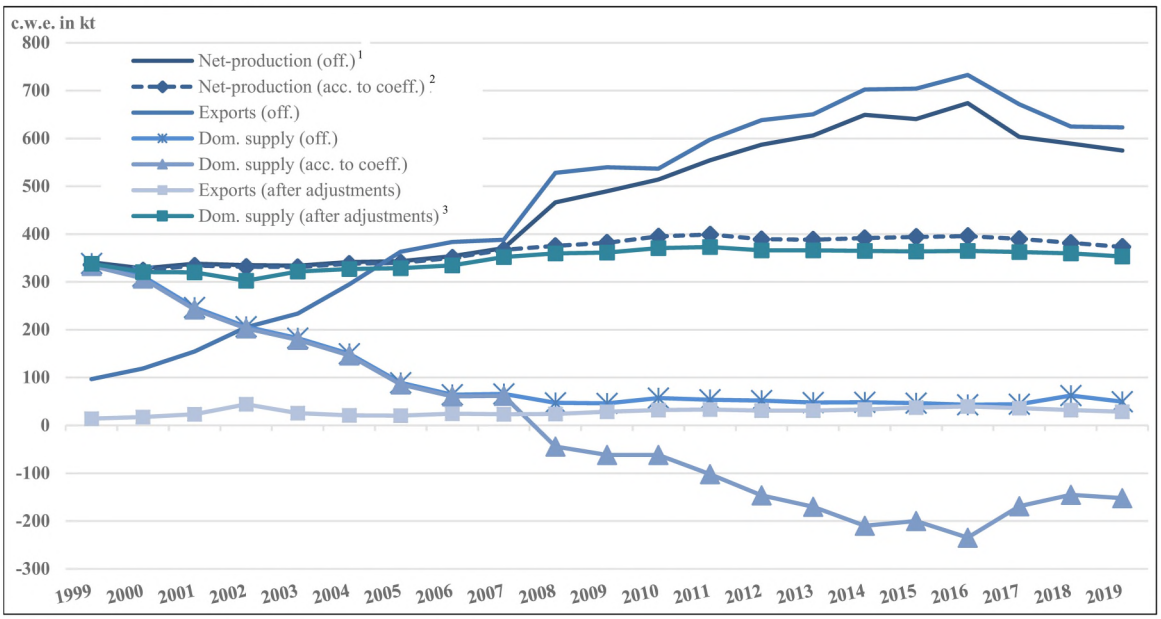
Figure 3. Adjustments for foreign trade of edible offal and by-products, 1999-2019, c.w.e. in kt (kiloton (metric tons[a]))



[a] All values expressed as kiloton refer to "metric" tons.
[1]official statistics; [2]according to the authorised coefficient; [3]according to the authorised coefficient after adjustments to external trade
Source: authors' own representation of food balance sheets BLE (2021) and author's own calculation

Assumptions on Losses and Waste

Loss and waste assumptions for the individual value chain stages were collected from published studies with applicable reference units (meat waste and loss related to the quantity originally sourced or generally available), and from expert interviews. As recent publications on food waste for out-of-home consumption rarely show specific values for meat and do not provide indicators for the calculation of a waste ratio related to the quantity purchased (LIU et al., 2019), we conducted a representative survey among HaFS businesses on meat purchases and waste (THIES et al., 2021a). Table 2 presents an overview of the individual loss and waste ratios. The values given for at-home and out-of-home consumption refer to the avoidable losses and waste (excluding inedible components). This differentiation was not possible at the other stages due to limited data availability. The waste ratio at the retail level includes the product group fish (LEBERSORGER and SCHNEIDER, 2014), which is also among the frozen products for losses in private households (GFK, 2017).

Table 2. Assumptions on losses and waste at different stages of the meat value chain

Loss and waste items	Loss and waste ratio in %	Source
Meat industry	0.10	Expert assessment, Federal Association of the German Meat Industry BVDF (2020)
Wholesale	1.00	Expert assessment, German Meat Industry Association VDF (2020)
Food retail	2.58	LEBERSORGER and SCHNEIDER (2014), author's own calculation based on unpublished raw data
At-home consumption	3.13	GFK (2017), (AMI, 2020a, b), author's own calculation based on raw data
Out-of-home consumption	6.15	THIES et al. (2021a)

Source: authors' own compilation

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4 Application of the Revised Estimation Procedure of German Meat Consumption and Corresponding Implications for Supply Balances

After presenting the conceptual approach for updating the German estimation procedure, chapter 4 demonstrates the implementation of our estimation technique and the corresponding effects on meat supply balances.

4.1 Individual Estimation Steps to Determine Per Capita Pork Consumption

Per capita meat consumption is determined using results from data collection at the slaughter level, official production data, modified trade data as well as loss and waste assumptions. Tables 3 to 7 show the individual estimation steps to determine per capita pork consumption. In accordance with the survey period at the slaughterhouse level, the values shown refer to mean values of the years 2017 and 2018.

In a first step (Table 3), we calculate the quantity of meat generally available for human consumption based on net production (corresponding to the domestic slaughter volume), foreign trade and the information provided by abattoirs:

- Net production (5,438 kt) and the percentage data from slaughterhouses are used to calculate the volume of meat available for domestic human consumption (3,146 kt). Bones included content (8.09%) is deducted.
- The companies additionally reported imported and exported quantities. The total direct imports and exports of fresh meat carried out by German slaughterhouses are calculated by means of net production based on the sample's weighted export or import share. As official trade statistics additionally cover processed and canned meat, we obtain the meat available for domestic consumption by determining the difference between the calculated and the official trade volume (remaining exports and imports). The remaining exports (898 kt) are considered as boneless, as these meat products originate from a domestically produced slaughter volume, of which the share of inedible components has already been deducted as a first step of the calculation (1a). We assume that imports are comparable to domestically sold meat in terms of tissue composition and accordingly also presume a bone content of 8.09%.
- The first calculation step results in the quantity available for human consumption (3,071 kt) (boneless).

In a second step (Table 4) we obtain the absolute losses and waste quantities from the processing to the retail-level by extrapolation.

- The information given by abattoirs serves to determine absolute sales volumes in the various marketing channels (meat processing industry; wholesale; food retail). Applying the ratios results in absolute loss and waste quantities.
- In addition to the direct selling from slaughterhouse to processing, wholesale and retail, we con-

Table 3. Estimate of per capita pork consumption Step 1

1. Calculation of the quantity of pork available for domestic consumption (boneless)					
1a. Net production in kt	Weighted share for dom. cons. acc. to SH[1] data in %	For domestic consumption in kt	Weighted share of bones included acc. to SH data in %	Bones included in kt	Boneless domestic consumption in kt
5,437.76	57.86[2]	3,146.41	8.09	255.65	2,891.76
1b. Exports in kt	Weighted export share acc. to SH data in %	Projected for total market in kt	Remaining exports in kt	Weighted share of bones included, acc. to SH data in %	Boneless remaining exports in kt
3,003.88	38.72[2]	2,105.74	898.14	0.00	898.14
1c. Imports in kt	Weighted import share acc. to SH data in %	Projected for total market in kt	Remaining imports in kt	Weighted share of bones included, acc. to SH data in %	Boneless remaining imports in kt
1,188.06	0.29[2]	15.64	1,172.42	8.09	1,077.53
1d. Available for domestic consumption (boneless) in kt					***3,071.15***

[1]Slaughterhouse (SH); [2]Share of production used for pet-food production or non-food uses corresponds to the difference to 100 percent points, i.e. 57.86% added to 38.72% minus 0.29% equals 96.29%; thus 3.71% are used as pet-food or non-food.
Notes: net production, exports, and imports correspond to mean values of the years 2017 and 2018.
Source: BLE (2021), authors' own calculation

Table 4. Estimate of per capita pork consumption Step 2

2. Calculation of total losses & waste at processing-, wholesale-, & retail-level				
Marketing channel	**Data acc. to SH surveyed in %**	**Calculated in kt**	**Loss & waste ratio in %**	**Calculated loss & waste in kt**
2a. Processing	54.31	1,668.06	0.10	1.67
2b. Wholesale	9.39	288.46	1.00	2.88
2c. Retail	27.24	836.50	2.58	21.56
2d. Processing to retail = (3b ∗ 1.0258) − 2c, i.e. 1,255.26 = (2,039.20 ∗ 1.0258) – 836.50		1,255.26	2.58	32.35
2e. Direct sale to customer	9.06	278.13	0.00	0.00
2f. Total loss & waste at processing-, wholesale- & retail-level in kt				***58.46***

Source: LEBERSORGER and SCHNEIDER (2014), GFK (2017), AMI (2020a, b), BVDF (2020), VDF (2020), authors' own calculation

sider a product flow between processing and food retail. The corresponding sales volume complies with the residual figure comparing (boneless) purchases of private households (purchases of meat, meat products, and sliced cold meat according to data of the "Gesellschaft für Konsumforschung", GfK) without losses at the retail level to meat quantities directly delivered to retailers by the slaughterhouses (837 kt). We accordingly also assume a waste ratio of 2.58% for this meat quantity, sold via retail.

- Further marketing levels that serve direct sales to end customers (e.g., shops on the slaughterhouse premises) are calculated as residual value (278 kt).

Step three (Table 5) involves calculating the share of purchases of HaFS businesses and private households.

- We calculate the share of purchases by HaFS businesses as the remaining quantity (974 kt) after deducting purchases of private households (2,039 kt) from the total boneless consumption (3,013 kt).

To calculate absolute consumer waste, waste ratios described in Table 2 are applied to the purchases by HaFS businesses (974 kt) and private households (2,039 kt) in a fourth step (Table 6).

Table 6. Estimate of per capita pork consumption Step 4

4. Calculation of total waste at the consumption level			
Consumption level	**Quantity in kt**	**Waste in %**	**Calculated waste in kt**
4a. At-home consumption	2,039.20	3.13	63.76
4b. Out-of-home consumption	973.49	6.15	59.89
4c. Total waste at consumption level			***123.65***

Source: GFK (2017), AMI (2020a, b), authors' own calculation

Finally, total meat loss and waste is deducted from the available quantity for human consumption and then divided by population size to show average per capita consumption of pork (34.9 kg). We obtain the coefficient for the derivation of the total quantity consumed by dividing total consumption after losses and waste (2,889 kt) by domestic supply (3,622 kt) (Table 7).

Table 5. Estimate of per capita pork consumption Step 3

3. Calculation of the out-of-home consumption		
3a. Consumption after losses and waste = 1d − 2f, i.e. 3,012.69 = 3,071.15 – 58.46	3,012.69	Calculated in kt
3b. Purchases of private households without bones	2,039.20	According to GfK-Data, without bones, product weight[1] in kt
3c. Purchases of HaFS businesses (3a-3b)	***973.49***	*Calculated as a residual value in kt*

[1]According to expert information, the market coverage of the GfK household panel is between 75% and 90% for meat, meat products, and meat comprising convenience products due to unrecorded quantities or lacking sales data from e. g., weekly markets. Based on the experts' recommendations, 25% were, therefore, added to the stated meat purchases of private households. Bones included were deducted according to GfK (2017).
Source: AMI (2020a, b), authors' own calculation

Table 7. Estimate of per capita pork consumption Step 5

5. Calculation of per capita consumption	
Domestically available for consumption (boneless) (1d) in kt	3,071.15
5a. Total loss and waste (2a-2e, 4a-b) in kt	182.11
5b. Total consumption after losses and waste (1d-5a) in kt	2,889.04
Population size in million	82.78
5c. Per capita consumption in kg	***34.90***
Domestic supply; including adjustments to external trade in kt	3,621.94
5d. Coefficient for the derivation of consumption from domestic supply in %	***79.77***

Notes: domestic supply and population size correspond to mean values of the years 2017 and 2018.
Source: BLE (2021), authors' own calculation

4.2 Corresponding Implications for Meat Supply Balances

Based on the previously determined coefficients (i.e., Table 7), Table 8 shows the estimated supply balance for the year 2018. Estimated values are printed in bold type. The remaining values correspond to the officially published statistics (BLE, 2021) and thus to the results of DFV (1987) regarding the consumption of sheep and goat, horse meat, and further meat types. An average total per capita meat consumption of 64.7 kg is calculated for the year 2018 based on the updated estimation procedure. The average per capita consumption level of beef is 11.5 kg. Pork consumption is 34.8 kg/capita and per capita poultry consumption totals 15.8 kg.

Table 9 shows the estimated consumption levels for pork, beef, and poultry compared to the results of DFV (1987). Additionally, the corresponding coefficients for the derivation of consumption from domestic supply are presented. The comparison results in an increased overall per capita meat consumption of 3.6 kg determined by the updated procedure. With view on the specific meat types, we find an underestimation of beef consumption by 16% and an underrated poultry consumption of 14%. The per capita consumption of pork is overestimated by 3%. The adjustment in external trade in particular exhibits a measurable effect in this regard and accordingly leads to an increase in consumption of edible offal and by-products compared to the official statistics (BLE, 2021).

As described in chapter 4.1, the updated estimation procedure corresponds to a stepwise calculation in which losses and waste are calculated considering total meat quantities at each of the subsequent value chain stages (slaughterhouse, wholesale, meat processing, retail, and at the consumption stages). On this basis, we determine a set of coefficients for the derivation of consumption from domestic supply. The

Table 8. Estimated supply balance for the year 2018

Meat type	Gross production	Imports live animals	Exports live animals	Net production	Import Meat	Export Meat	Domestic supply		Consumption	
	in kt	in kt	in kt	in kt	in kt	in kt	in kt	Per capita in kg	in kt	Per capita in kg
Beef	1,161.5	17.9	55.9	1,123.5	***523.0***	***470.9***	***1,178.0***	***14.2***	***951.6***	***11.5***
Pork	4,926.7	518.2	75.0	5,369.9	***1,191.0***	***2,941.2***	***3,619.7***	***43.7***	***2,887.3***	***34.8***
Poultry	1,821.7	164.7	392.7	1,593.7	994.7	665.9	1,922.5	23.2	***1,307.4***	***15.8***
Edible offal & by-products	553.5	49.1	13.1	***381.6***	***10.2***	***32.3***	***359.5***	***4.3***	***93.5***	***1.1***
Sheep & goat	31.4	3.2	0.1	34.5	56.3	8.1	82.7	1.0	55.0	0.7
Horse	2.7	0.4	1.3	1.8	1.8	0.3	3.3	0.0	2.2	0.0
Further meat types	53.6	0.5	0.3	53.8	55.3	15.8	93.3	1.1	63.0	0.8
Meat total	8,551,0	754.0	538.4	8,558.8	2,832.3	4,134.6	7,259.1	87.6	***5,359.9***	***64.7***
Population size in million										82.89

Source: authors' own representation of food balance sheets BLE (2021) and authors' own calculation (printed in bold type)

Table 9. Comparison with the original estimate and coefficients for the year 2018

Meat type	Estimation by DFV (1987) acc. to BLE (2021)		Updated Estimation	
	Consumption per capita in kg	Coefficient in %	Consumption per capita in kg	Coefficient in %
Beef	9.9	68.6	11.5	80.8
Pork	35.7	72.1	34.8	79.8
Poultry	13.8	59.5	15.8	68.0
Edible offal and by-products	0.2		1.1	
Further meat types	1.5		1.5	
Meat total	***61.1***		***64.7***	

Source: authors' own representation of food balance sheets based on BLE (2021) and authors' own calculation

original estimation procedure accumulates overall utilisation and loss and waste factors, which are then deducted from domestic meat supply, without considering actual meat quantities at the individual value chain stages. Despite these methodological differences, results of both estimation approaches lie in a comparable range.

4.3 Evaluation of Sensitive Parameters estimating per Capita Meat Consumption

However, the revised estimate contains uncertainties: the share of meat available for domestic consumption and the export share vary between the slaughterhouses surveyed. Both parameters are related to the meat quantity available for domestic consumption, which is calculated within the first step of the estimation procedure. Since we achieve a market coverage of 55%, considering the total slaughter volume of pig, cattle, and poultry, the sample size may influence the estimated per capita meat consumption level. Imports played a minor role for all slaughterhouses and, therefore, have a negligible influence on the result.

The quantity of meat, edible offal, and by-products sold to pet food producers by slaughterhouses is lower than initially assumed when the lucrative nature of this sales channel is considered (THIES et al., 2019). Since the quantity of (raw) meat, edible offal, and by-products used for pet food production has not been recorded so far, a verification of the information provided by slaughterhouses is nearly impossible. In the context of the estimation procedure, however, underestimating the share of production sold to pet food producers is reflected in an overestimation of the meat available for domestic consumption, since the sum of sales in different marketing channels corresponds to the total production in carcass weight.

A sensitivity analysis illustrates the potential influence of the above-mentioned parameters (i.e., Tab. 10). According to the standard deviation of the reported export shares for the specific meat types, we reduce the weighted overall export share for pork, e.g., by 17 percent points and increase the share intended for domestic consumption, respectively.

Additionally, we increase the share of meat sold to the pet food industry by approximately seven percent points for beef, pork, and poultry each. As a result, the projected total quantity intended for pet food production (including meat, edible offal, and by-products), is close to the total production volume of pet food shown in official statistics, which is not specified according to individual meat types (DESTATIS, 2019). Moreover, this quantity is not expressed as carcass weight and may include additional components (e.g., grains, vegetables).

We further adopt waste assumptions at the consumer level (at-home and out-of-home) used within the USDA loss-adjusted meat availability dataset. These waste ratios are reported on a species-specific basis (20% for beef and veal, 29% for pork, 18% poultry), include cooking losses and refer to edible meat quantities available at the consumption level (USDA, 2021b). They can, therefore, be applied in our estimation procedure. Since the consumption stage accounts for a large share of the total waste and loss in food value chains (HERZBERG et al., 2020) and as the USDA waste ratios are substantially higher than waste assumptions applied in this study, they are suitable for assessing the uncertainty range of our results.

The results of the sensitivity analyses (Table 10) show that there are considerable uncertainty ranges regarding the parameters used. In particular, higher waste assumptions and cooking losses lead to 20% lower per capita meat consumption resulting in an average per capita consumption level of 52 kg, which

Table 10. Results of the sensitivity analysis for the year 2018

Meat type	Meat consumption per capita in kg	Meat consumption per capita in kg decreased for exports	Meat consumption per capita in kg increased for pet food	Meat consumption per capita in kg increased for waste ratios and cooking losses
Beef	11.5	11.4	10.7	9.6
Pork	34.8	34.0	30.9	25.8
Poultry	15.8	15.3	14.7	13.6
Edible offal and by-products	1.1	1.1	1.1	1.1
Further meat types	1.5	1.5	1.5	1.5
Total	***64.7***	***63.3***	***58.9***	***51.6***

Source: authors' own calculation

still exceeds average meat intake according to NVS II based on self-reported meat quantities (KOCH et al., 2019). Results of this study are, thus, also in line with recently published literature, which identified inconsistencies between per capita consumption levels based on a market-balance approach and those indicated by individual dietary surveys (AMO et al., 2016; THAR et al., 2020).

5 Discussion

Based on a revised estimation procedure, this study determined an average per capita meat consumption of 65 kg for the year 2018, comprising of 35 kg pork, 12 kg beef, and 16 kg poultry. Accordingly, we found an underestimation of total per capita meat consumption by 3.6 kg compared to official statistics (BLE, 2021) and confirmed the deviation of consumption indications based on supply balances and dietary surveys (AMO et al., 2016; THAR et al., 2020).

The updated estimate presented considered various marketing channels differentiated by meat types and the corresponding specific loss and waste assumptions. The original approach, however, applied accumulated utilisation and loss and waste factors without distinguishing between different sales outlets. Consequently, losses and waste quantities were overestimated and per capita figures have tended to be underestimated in the past.

Food balance sheets are an important database to monitor long-term trends, as meat production is recorded on a regular and comprehensive basis (German Act on Agricultural Statistics ((§ 59 AgrStatG (German Act on Agricultural Statistics))). The updated meat type specific coefficients identified in this study allow for the derivation of nutritional trends with regard to meat consumption.

An analysis of foreign trade in edible offal and by-products revealed difficulties with the allocation and definition of CN-codes in official trade statistics. In this context, there is a need for further research, as incorrect allocations of CN-codes are most likely not only to be found in German foreign trade in meat. Indeed, both domestic supply and the consumption level calculated are influenced by incorrect assignment.

Our analysis additionally provided insights into the relevance of the different species-specific sales outlets, the meat production share sold to pet food producers as well as the distribution of at-home and out-of-home meat consumption, on which there is nearly no data to date. The calculation of species-specific meat quantities at the individual value chain stages provided indications regarding the main sources of loss and waste. Minimising lost and wasted meat is particularly important against the background of the resource-intensive production of this food product group and the associated negative external effects on environmental sustainability (THIES et al., 2021b).

Besides the sensitive parameters already mentioned (export share, meat sold for pet-food production and waste assumptions), further limitations of the presented results have to be considered.

One important limitation of the study is the sample size. The sensitivity of the requested information kept several slaughterhouses from participating. Although a high market concentration is usually reflected by a small number of reporting companies, specific marketing strategies of individual companies might have been overrepresented. Marketing channels of rather small and regional slaughterhouses might deviate from the sample. In view of their correspondingly low market share, this is likely to have a minor effect on the estimated consumption level. The sensitivity

analysis indicated that the share of domestic and foreign sales has little influence on the result.

Participating slaughterhouses reported that marketing shares are volatile and can change even in the course of a single year. This is the reason why the results of the survey provide a transitory picture. At the same time, changes in domestic meat supply are gradual with view on meat types and quantity (BLE, 2021), we assume that profound shifts between marketing channels or at the consumption level (at-home and out-of-home) also occur rather successively. We, therefore, also assume a temporary validity of the estimated coefficients.

Nevertheless, a regular data collection at slaughterhouse level would be desirable in terms of precise monitoring, also because meat products are increasingly produced tailored to specific customer needs (BVDF, 2020) and off-cuts as well as inedible components might increasingly be utilised at early value chain stages. The implementation of regular surveys will depend on the cooperative willingness of stakeholders. However, the aggregation of the required data (i.e., bones included in product-based sales) was perceived as challenging, as the required information is not relevant for marketing purposes of slaughterhouses.

The findings of this study contribute to more objectivity in the public debate on meat consumption in Germany. On the one hand, the gap between domestically available supply and consumption was described in detail. On the other hand, remaining uncertainties and limitations have been outlined. Political decision-makers should consider both aspects in the course of interpretation and communication.

At the same time, the average annual per capita meat consumption found, considering the uncertainty range (including cooking losses), was above the recommendations of the German Nutrition Society (DGE) regarding a balanced diet (maximum of 31 kg/capita) (DGE, 2020) and a level consistent with "planetary health" according to the EAT-Lancet Commission (approximately 16 kg/capita) (WILLETT et al., 2019). Also, against the background of these distinct consumption recommendations, consideration should be given to the purpose for which the results of this study are used. We calculated an average consumption level, that comprises children, adults and elderly, intensive meat consumers, and vegetarians. Dietary behaviour is influenced by a variety of internal and external factors (BROMBACH and BARTSCH, 2014) and varies within a society (CORDTS et al., 2014). Therefore, no conclusions about meat demand behaviour of individual consumer groups can be drawn from the results. Consequently, they cannot serve as a basis for evaluating targeted demand-sided measures to curb meat consumption and aiming to reduce health risks of individual consumer groups. In the course of national monitoring, regularly conducted individual or household nutrition surveys, which comprise at-home and out-of-home meat consumption, should be used in a complementary way together with food balance data to comprehensively address nutritional issues (RODRIGUES et al., 2007; AMO et al., 2016).

With regard to international comparability, a differentiation of the "consumption term" would be target-oriented, clarifying whether official statistics or studies refer to the actually ingested meat quantity or the quantity to be allocated to human consumption. The presentation of different approaches based on food balance data demonstrated that a comparison of meat consumption levels between countries focussing on the supply-side is hardly possible due to different utilisation as well as loss and waste assumptions. In this context, there has not yet been any international agreement on standardisation, which however might be challenging in view of the various market structures. Nevertheless, consultations on the consistent calculation of domestic meat supply within food balances would be a starting point. In particular, the allocation of CN-codes to the different animal species, edible offal and by-products should be more precisely defined and harmonised across countries and in official trade statistics. A supportable approach in this context has been provided by the announcement of the United Nations Economic Commission for Europe (UNECE) Specialised Section on Meat to align the UNECE meat cut codes according to the UNECE meat standards with the Harmonized Commodity Description and Coding System (HS) (UNECE, 2020).

6 Concluding Remarks

This paper introduced a revised estimation procedure of human meat consumption using a market balance approach and following a mass flow analysis to update the official German statistical basis for "direct consumption" and contributes to a more comprehensive national nutrition monitoring. In order to convert the domestically available meat supply into average per capita consumption, a set of coefficients was de-

rived which also allows us to continuously report future meat consumption levels and to identify nutritional trends.

A meat consumption level of 65 kg per capita on average is not compatible with national health (DGE, 2020) and international environmental goals (WILLETT et al., 2019). Therefore, there is a need for further political debate and scientific research that first of all identifies consumer groups to enable the development of targeted reduction measures. Although there is a common understanding that a reduction in meat consumption can significantly contribute to the achievement of sustainability goals (WBAE, 2020), a specific desirable consumption level in relation to a given time frame is not yet on the political agenda. As the "diet-environment-health trilemma" is a challenge at the global level (CLARK et al., 2018), consistent calculations of food balances would at least allow for a comparison of domestic meat supply levels. There also is a need for further action in this matter.

Literature

AMI (2020a): Analysen der AMI auf Basis des GfK-Haushaltspanels (AMI analyses based on the GfK household panel). Agrarmarkt Informations-Gesellschaft mbH, Bonn.

AMI (2020b): Neuberechnung Fleischverzehr: Anteile Schwein, Rind und Geflügel in Fleischwaren/Wurst. (Recalculation of meat consumption: proportions of pork, beef and poultry in meat products/sliced cold meat). Written communication received at 14.04.2020.

AMO, E., F. ESCRIBANO, M.-J. GARCÍA-MESEGUER and I. PARDO (2016): Are the eating habits of university students different to the rest of the Spanish population? Food availability, consumption and cost. In: Spanish Journal of Agricultural Research 14 (2): e0103.

BARRETT, C.B. (2010): Measuring food insecurity. In: Science (New York, N.Y.) 327 (5967): 825-828.

BLE (Bundesanstalt für Landwirtschaft und Ernährung) (2021): Fleisch und Geflügel. Versorgungsbilanzen (Meat and poultry. Supply Balances). Versorgung mit Fleisch in Deutschland seit 1991. In: https://www.ble.de/DE/BZL/Daten-Berichte/Fleisch/fleisch_node.html, call: 18.8.2020.

BMEL (2020): Kategorisierung von tierischen Nebenprodukten (Categorisation of animal by-products). In: https://www.bmel.de/DE/themen/tiere/tiergesundheit/tierische-nebenprodukte/tierische-nebenprodukte-kategorie.html, call: 17.3.2020.

BROMBACH, C. and S. BARTSCH (2014): What remains, what will change? A 3-Generation-Study on Consumption and Food Handling. In: Ernährungs Umschau (11): 171-177.

BVDF (Bundesverband deutscher Wurst- & Schinkenproduzenten) (2020): Neuberechnung des menschlichen Fleischverzehrs (Recalculation of per capita meat consumption). Federal Association of the German Meat Industry e.V. Personal verbal and written communication received at 21.01.2020.

BZL (Bundesinformationszentrum Landwirtschaft) (2019): Umrechnungsfaktoren für Innereien (Conversion factors for edible offal). The Federal Centre for Agriculture. Department for Market Information, Critical Infrastructure Agriculture. Written communication received at 31.01.2019.

CLARK, M., J. HILL and D. TILMAN (2018): The Diet, Health, and Environment Trilemma. In: Annual Review of Environment and Resources 43 (1): 109-134.

CORDTS, A., S. NITZKO and A. SPILLER (2014): Consumer Response to Negative Information on Meat Consumption in Germany. In: International Food and Agricultural Management Review 17 (Special Issue A): 83-106.

DESTATIS (2019): Produzierendes Gewerbe. Produktion des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden. (Manufacturing industry. Production of manufacturing and mining and quarrying). Fachserie 4 Reihe 3.1. Wiesbaden. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/Publikationen/Downloads-Konjunktur/produktion-jahr-2040310187004.pdf?__blob=publicationFile, call: 4.1.2021.

DESTATIS (2021): Geschlachtete Tiere, Schlachtmenge: Deutschland, Jahre, Tierarten, Schlachtungsart [41331-0001] (Slaughtered animals, slaughter quantity: Germany, years, animal species, slaughter method). In: https://www-genesis.destatis.de/genesis/online?language=de&sequenz=tabelleErgebnis&selectionname=41331-0001#abreadcrumb, call: 16.4.2021.

DFV (Deutscher Fleischer-Verband) (1987): Ergebnisbericht (Report on results). Arbeitskreissitzung des Bundesmarktverbandes für Vieh und Fleisch im BML am 14. Januar 1987, 14.00 bis 17.00 Uhr / Ermittlung realistischer Fleischverzehrswerte. Frankfurt am Main.

DGE (Deutsche Gesellschaft für Ernährung e.V.) (2020): Die Nährstoffe. Bausteine für Ihre Gesundheit (The nutrients. Modules for your health). Bonn.

DOWLER, E.A. and Y.O. SEO (1985): Assessment of energy intake. Estimates if food supply v measurement of food consumption. In: Food Policy 10 (3): 278-288.

EC (European Commission) (2020a): Commission Implementation Regulation (EU) 2020/1577 of 21 September 2020 amending Annex I to Council Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature and on the Common Customs Tariff. In: Official Journal of the European Union L361/63.

EC (2020b): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. Brussels.

EC (2021): Short-term. A short-term outlook for EU agricultural markets. Data. EU balance sheets, production and yield by EU country (EU-27). https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/markets/outlook/short-term_en, call: 1.4.2021.

EP (European Parliament) (2001): Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies. In: Official Journal of the European Communities L 147/1.

EUROSTAT (2020): EU trade since 1988 by CN8 [DS-016890]. http://epp.eurostat.ec.europa.eu/newxtweb/, call: 15.1.2021.

FAO (1972): Technical conversion factors for Agricultural Commodities. http://www.fao.org/fileadmin/templates/ess/documents/methodology/tcf.pdf, call: 8.4.2021.

FAO (2019): The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. Rom.

FAO (2021a): FAOSTAT Statistical Database. Livestock primary. Supply utilization accounts. http://www.fao.org/faostat/en/#data/SL, call: 1.3.2021.

FAO (2021b): FAOSTAT Statistical Database. New Food Balances. http://www.fao.org/faostat/en/#data/FBS, call: 1.3.2021.

FAO (2021c): Food Supply Data - Meat. Food and Agriculture Organization of the United Nations. Statistics Division (ESS). Personal verbal and written communication received at 25.01.2021.

GFK (Gesellschaft für Konsumforschung) (2017): Systematische Erfassung von Lebensmittelabfällen der privaten Haushalte in Deutschland (Systematic recording of food waste from private households in Germany). Schlussbericht zur Studie. Nuremberg.

GODFRAY, H.C.J., P. AVEYARD, T. GARNETT, J.W. HALL, T.J. KEY, J. LORIMER, R.T. PIERREHUMBERT, P. SCARBOROUGH, M. SPRINGMANN and S.A. JEBB (2018): Meat consumption, health, and the environment. In: Science (New York, N.Y.) 361 (6399).

HERZBERG, R., T.G. SCHMIDT and F. SCHNEIDER (2020): Characteristics and Determinants of Domestic Food Waste: A Representative Diary Study across Germany. In: Sustainability 12 (11): 4702.

IPCC (Intergovernmental Panel on Climate Change) (2019): Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. In: Shukla, P.R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.) (in press).

KOCH, F., T. HEUER, C. KREMS and E. CLAUPEIN (2019): Meat consumers and non-meat consumers in Germany: a characterisation based on results of the German National Nutrition Survey II. In: Journal of Nutritional Science 8 (e21): 1-13.

LEBERSORGER, S. and F. SCHNEIDER (2014): Food loss rates at the food retail, influencing factors and reasons as a basis for waste prevention measures. In: Waste Management (New York, N.Y.) 34 (11): 1911-1919.

LIU, G., L. XUE, Z. CAO, N. PRASS, S. GOLLNOW, J. DAVIS, S. SCHERHAUFER, K. OSTERGREN, F.D. MENNA, L. GARCIA HERRERO, M. VITTUARI and J. BROEZE (2019): Integration of LCC and LCA results to higher system levels: The German meat and EU tomato cases. REFRESH, Wageningen.

NELSON, E.K., L.A. DUEWER and T.L. CRAWFORD (1989): Reevaluation of the beef carcass to retail weight conversation factor. Agricultural Economic Report No. 623. Economics Division, Economic Research Service. United States Department of Agriculture, Washington, D.C.

NIEMANN, H. (2017): Statistik der Verarbeitungsbetriebe Tierischer Nebenprodukte 2016 (Animal by-products processing plant statistics 2016). In: Tierische Nebenprodukte Nachrichten 69 (2): 22-26.

RODRIGUES, S.S.P., C. LOPES, A. NASKA, A. TRICHOPOULOU and M.D.V. de ALMEIDA (2007): Comparison of national food supply, household food availability and individual food consumption data in Portugal. In: Journal of Public Health 15 (6): 447-455.

RUSSO, V., L. NANNI COSTA, C. SERMONETA and ASPA COMMISSION (eds.) (2016): Estimation of real per capita consumption of meat in Italy. Proceedings ICAS VII Seventh International Conference on Agricultural Statistics. Rom.

SERRA-MAJEM, L. (2001): Food availability and consumption at national, household and individual levels: implications for food-based dietary guidelines development. In: Public Health Nutrition 4 (28): 673-676.

SPRINGMANN, M., M. CLARK, D. MASON-D'CROZ, K. WIEBE, B.L. BODIRSKY, L. LASSALETTA, W. de VRIES, S.J. VERMEULEN, M. HERRERO, K.M. CARLSON, M. JONELL, M. TROELL, F. DECLERCK, L.J. GORDON, R. ZURAYK, P. SCARBOROUGH, M. RAYNER, B. LOKEN, J. FANZO, H.C.J. GODFRAY, D. TILMAN, J. ROCKSTRÖM and W. WILLETT (2018): Options for keeping the food system within environmental limits. In: Nature 562 (7728): 519-525.

STRAßBURG, A., M. EISINGER-WATZL, C. KREMS, A. ROTH and I. HOFFMANN (2019): Comparison of food consumption and nutrient intake assessed with three dietary assessment methods: results of the German National Nutrition Survey II. In: European Journal of Nutrition 58 (1): 193-210.

THAR, C.-M., R. JACKSON, B. SWINBURN and C. N. MHURCHU (2020): A review of the uses and reliability of food balance sheets in health research. In: Nutrition Reviews 78 (12): 989-1000.

THIES, A.J., J. EFKEN and D. WEIBLE (2019): Der Handel mit dem Hähnchenfleisch. Eine Analyse Deutscher und Europäischer Exporte unter Einbeziehung von Handelsdaten. 59. Jahrestagung der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V. (GEWISOLA), Braunschweig.

THIES, A.J., J. EFKEN and M. SÖNNICHSEN (2021a): Abschlussbericht zur Neuberechnung der Koeffizienten zur Ermittlung des menschlichen Fleischverzehrs aus der Versorgungsbilanz Fleisch für Schwein-, Rind- und Geflügelfleisch (Final report on the recalculation of the coefficients for determining human meat consumption from the meat supply balance sheet for pork, beef and poultry). Schriftlicher Auftrag, BMEL (unpublished). Johann-Heinrich von Thünen Institute, Institute of Market Analysis and Max Rubner-Institute, Department of Safety and Quality of Meat, Braunschweig, Kulmbach.

THIES, A.J., F. SCHNEIDER and J. EFKEN (2021b): The Meat We Do Not Eat. A Survey of Meat Waste in German Hospitality and Food Service Businesses. In: Sustainability 13 (9): 5059.

UNECE (United Nations Economic Commission for Europe) (2020): Report of the twenty-eighth session of the Specialized Section on Standardization of Meat. UNECE, Geneva. https://unece.org/fileadmin/DAM/trade/agr/meetings/ge.11/2020/GE11_2020_2E.pdf, call: 14.4.2021.

USDA (United States Department of Agriculture) (2018): Retail weight calculation, human meat intake. Economic Research Service, USDA. Personal verbal and written communication received at 11.10.2018.

USDA (2020): Food Availability (Per Capita) Data System. Loss-Adjusted Food Availability Documentation. https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/loss-adjusted-food-availability-documentation/, call: 5.3.2021.

USDA (2021a): Food Availability (Per Capita) Data System. Food Availability. Dataset. Red meat, poultry, and fish. https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/food-availability-per-capita-data-system/#Food%20Availability, call: 27.5.2021.

USDA (2021b): Food Availability (Per Capita) Data System. Loss-Adjusted Food Availability. Dataset. Meat poultry, fish, eggs, and nuts. https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/, call: 8.4.2021.

USDA (2021c): Food Availability (Per Capita) Data System Food. Food Availability Documentation. https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/food-availability-documentation/, call: 8.4.2021.

VDF (Verband der Fleischwirtschaft) (2020): Recalculation of the human meat consumption. German Meat Industry Association e.V. Written communication received at 21.04.2020.

WBAE (Wissenschaftlicher Beirat für Agrarpolitik beim Bundesministerium für Ernährung und Landwirtschaft) (2020): Politik für eine nachhaltigere Ernährung (Policy for a more sustainable diet). Eine integrierte Ernährungspolitik entwickeln und faire Ernährungsumgebungen gestalten. Kurzfassung. Berlin.

WILLETT, W., J. ROCKSTRÖM, B. LOKEN, M. SPRINGMANN, T. LANG, S. VERMEULEN, T. GARNETT, D. TILMAN, F. DECLERCK, A. WOOD, M. JONELL, M. CLARK, L.J. GORDON, J. FANZO, C. HAWKES, R. ZURAYK, J.A. RIVERA, W. de VRIES, L. MAJELE SIBANDA, A. AFSHIN, A. CHAUDHARY, M. HERRERO, R. AGUSTINA, F. BRANCA, A. LARTEY, S. FAN, B. CRONA, E. FOX, V. BIGNET, M. TROELL, T. LINDAHL, S. SINGH, S.E. CORNELL, K. SRINATH REDDY, S. NARAIN, S. NISHTAR and C.J.L. MURRAY (2019): Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. In: The Lancet 393 (10170): 447-492.

YU, X. and D. ABLER (2014): Where have all the pigs gone? Inconsistencies in pork statistics in China. In: China Economic Review 30 (C): 469-484.

Contact author:
ANNIKA JOHANNA THIES
Johann Heinrich von Thuenen Institute
Institute of Market Analysis
Bundesallee 63, 38116 Braunschweig
e-mail: annika.thies@thuenen.de

5.2 Tailored marketing and policies for more sustainable meat demand - A consumer segmentation based on revealed preferences for Germany

Annika Johanna Thies, Matthias Staudigel and Daniela Weible

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Tailored marketing and policies for more sustainable meat demand - A consumer segmentation based on revealed preferences for Germany

The ongoing debate about negative environmental and health effects of meat consumption has resulted in calls for public sector intervention. Effective policy and marketing instruments need to address preferences, habits, and restrictions of individual consumer groups and their specific behaviour. The present study uses revealed-preference data to identify and describe consumer segments based on fresh meat product purchases. Based on German household scanner data for 2014, we obtain meat product groups of close substitutes via factor analysis and use these to identify consumer segments by means of cluster analysis. We characterise segments regarding socio-demographics, food shopping attitudes, and meat purchase behaviour using multinomial logit models. The resulting clusters suggest one large segment of "pork and beef traditionalists" and three smaller clusters of "poultry lovers", "convenience-oriented pork buyers", and "premium red meat lovers". Clusters derived by this behaviour-based approach indicate that sustainable low-meat consumption patterns are not as widespread as commonly portrayed by segmentation studies using attitudes and self-reported meat intake. Segment characteristics provide guidance on who to target with priority regarding meat consumption levels. Accordingly, pork and beef traditionalists and convenience-oriented pork buyers may react to financial incentives, whereas poultry and premium red meat lovers may be influenced by targeted labelling and quality signals.

Keywords: Meat consumption, consumption patterns, segmentation, Germany, marketing and policy design

1 Introduction

The globally high and rising meat demand has been linked to unsustainable developments with regard to increased levels of global warming potential (GWP), blue water footprint, land use, nutrient loading (SPRINGMANN et al., 2018), and biodiversity loss compared to plant-based diets (GODFRAY et al., 2018). The increased demand is also associated with adverse health effects, especially with several non-communicable diseases (GEIBEL et al., 2021). Against this backdrop, various studies have called for a reduction of meat demand in industrialised countries (GODFRAY et al., 2018; WILLETT et al., 2019; BONNET et al., 2020) as well as higher animal welfare standards to meet the ethical demands of the general public (WEIBLE et al., 2016).

Policy and marketing strategies to shift consumption patterns away from meat-focused towards more plant-based diets have been vividly discussed. Policy instruments considered by EU Member States comprise taxation of meat, information measures such as labelling and social marketing campaigns to raise awareness as well as behavioural interventions such as meat-free days or nudging (BONNET et al., 2020). Private-sector activities include the introduction of plant-based meat alternatives (e.g., vegetarian or vegan burgers and nuggets) (THAVAMANI et al., 2020) or hybrid products replacing parts of the meat component by plant-based ingredients (e.g., “beef and carrot mince”, “chicken sausages with feta”) (GRASSO and JAWORSKA, 2020). Also, organic meat is often advertised as a more sustainable alternative recognised for enhanced water conservation, soil fertility, biodiversity, and slightly improved animal welfare (SANDERS and HEß, 2019).

A remaining question with regard to these strategies is, whether they even reach consumers with unhealthy or unsustainable meat consumption patterns. For example, consumers with particularly high meat consumption levels might be price-insensitive, and disinterested customers might generally not feel addressed by established or newly implemented animal welfare concepts, environmental or health labels. Studies investigating nutritional and environmental effects of fat (JENSEN et al., 2016) or carbon meat taxes (EDJABOU and SMED, 2013; SÄLL and GREN, 2015; CAILLAVET et al., 2016; BONNET et al., 2018) have mostly considered meat consumption of an average consumer. However, ROOSEN et al. (2022) recently reported substantially lower price elasticities for those consumer groups with the highest per-capita consumption of fresh meat. Neglecting heterogeneous consumer behaviour might lead to a shortfall of the desired effect. A negligible market share of meat substitutes and a share of 3% of organic meat in total meat purchases of private German households in 2020 (AMI, 2020), suggest that marketing strategies most likely address consumers who are health-conscious or environmentally aware and therefore serve niche consumer groups only.

Accordingly, a comprehensive dietary transformation needs policy and marketing measures to be tailored to consumer segments (APOSTOLIDIS and MCLEAY, 2016). Such measures should, in view of the external effects mentioned above, particularly address consumers for whom a dietary change would be most desirable from an environmental footprint or health perspective. Hence, insights into the buying behaviour and scope of these specific consumer groups are needed.

A number of studies have derived consumer segments with a focus on consumer attitudes (APOSTOLIDIS and MCLEAY, 2016; MALEK et al., 2018; GÖTZE and BRUNNER, 2021) or lifestyle (ORTIZ et al., 2021), and less frequently in combination with self-reported meat quantities or consumption frequency (CORDTS et al., 2014; ESCRIBA-PEREZ et al., 2017). While these studies provide partial indications with regard to consumer segments for which meat consumption change should be a priority (KAYSER et al., 2013; CORDTS et al., 2014), they do not allow for a comprehensive identification of heterogeneous consumption patterns. KAYSER et al. (2013) described the share of meat types for the individual segments, which is important in terms of health and the environment,

but missed providing indications of different meat cuts to allow for a detailed assessment of actual purchasing patterns or to draw conclusions for marketing strategies. This perspective was also not covered by APOSTOLIDIS and MCLEAY (2016), who did, however, describe price relevance, which would facilitate the evaluation of likely effects of taxes or labelling approaches. Against the backdrop of the existence of a citizen-consumer dichotomy in which the response behaviour in surveys deviates from the actual purchasing behaviour (ENNEKING et al., 2019), only limited conclusions can therefore be drawn from literature regarding the corresponding meat buyer groups and their specific purchasing behaviour.

The objective of the present study is to segment meat consumers based on revealed preferences from actual purchase data in order to identify segments that have to be addressed with priority and to suggest targeted policy and marketing measures. As buying patterns and shopping motives can vary considerably for different meat types (FONT-I-FURNOLS and GUERRERO, 2014; CASINI et al., 2015), but also for different cuts of meat (SCOZZAFAVA et al., 2016), we apply a product level consideration of various prepared cuts to allow for an accurate analysis of the related purchasing behaviour. Our study addresses the following research questions:

I. Which consumer segments emerge from using meat purchase behaviour as clustering variables?
II. How do these segments differ from those obtained by studies clustering over self-reported consumption or attitudes?
III. For which consumer segments should changes in consumption be a priority and how can these be addressed by targeted policy and marketing instruments?

To the best of our knowledge, there is no empirical evidence on consumer segmentation with reference to purchase behaviour at a disaggregated level. We investigate the case of fresh meat in Germany, a key European market with a persistently high per capita meat consumption of 57 kg in 2020 (BLE, 2021). We segment German fresh meat buyers using representative household scanner data collected by the market research company “Gesellschaft für Konsumforschung” (GfK) for the year 2014 and initially perform a principal component analysis to group different meat products in terms of meat type, preparation method, and quality in a meaningful way. The purchasing shares of the resulting nine different product groups serve as inputs for a two-step cluster analysis to identify household segments that are more homogeneous regarding purchasing patterns of different meat cuts. These clusters are then characterised in the scope of socio-demographics, total shopping quantity, shopping locations, and several attitudinal statements using a multinomial logistic regression. Based on their profiles we provide conjectures on policy and marketing implications.

2 Data and methods

2.1 Sample

The study employed nationally representative household scanner data from the *GfK ConsumerScan* panel. Using hand-held scanners, households reported the quantity of and expenditure for their fresh meat purchases on a daily basis. The resulting data set covers information on 53 different fresh meat products, with combinations of different cuts (e.g., chops) and species comprising (1) pork, (2) beef and veal, (3) poultry (chicken, turkey, goose, other poultry meat) (4) pork and beef mixed meat products and (5) lamb and red meat of other species

(specialities). In addition, the date of purchase, retail outlet, and production method (e.g., organic) are indicated for each observation. The dataset contains socio-demographic information including age, sex, and occupation of the household's reference person, household size, net household income, and place of residence. Furthermore, households had to respond to several statements regarding their food and meat purchasing behaviour on a five-point Likert scale.

We analysed purchases of 14,631 households for the year 2014 and converted the purchase data to average monthly per capita values resulting in one observation per household, considering the equivalent weighting of the Organisation for Economic Co-operation and Development (OECD) (DESTATIS, 2021). As no information was available on the exact number of household members for the category "four or more", a household size of four members was assumed (this is here the case for 1,672 households, with 14.6% of all households covered in the sample). Due to missing attitude statement values, the final dataset consisted of 11,487 households. Information on the demographic distribution of the sample is presented in ***Table 1*** together with descriptive statistics.

Table 1: Definition and descriptive statistics for demographic variables in the total sample (N = 11,487)

Variable	Definition	N	Share in %
Age	Age of household reference person		
Young (≤ 39)		2,289	19.9
Intermediate (40-59)		4,830	42.0
Old ((≥ 60)		4,368	38.0
Household size	Number of household members		
1 person		2,992	26.0
2 people		4,931	42.9
3 people		1,892	16.5
4 people or more		1,672	14.6
Net income	Household net income		
Low (≤ 1,999 €)		4,968	43.2
Intermediate (2,000 to 3,999 €)		5,619	48.9
High (≥ 4,000 €)		900	7.8
Gender	Gender of the household reference person		
Male		2,347	20.4
Female		9,140	79.6
Occupation	Occupational group of the household		
White collar	reference person	4,014	34.9
Blue collar		1,626	14.2
Civil servant		533	4.6
Freelancer		143	1.2
Farmer, Self-employed		12	0.1
Person of private means		4,777	41.6
Self-employed		382	3.3

Source: Authors' own compilation of GfK data for 2014.

Table 2 provides descriptive statistics for monthly per capita meat purchase quantities for individual meat types and fresh meat in total. Pork is most in demand with a purchase quantity of 0.88 kg per capita and month. The average purchase quantity for beef and veal appears to be relatively low, i.e., 0.26 kg. The mean poultry quantity purchased is 0.43 kg. Lamb and speciality meat show the lowest average purchase quantity and the highest unit value while having the highest variation in purchase quantities. The unit value for beef and veal, i.e., the expenditure per kilogramme, on the other hand is the second highest compared with the other meat types, whereas pork has the second lowest unit value. Beef and pork mixed meat products are purchased at a lower overall level and show the lowest unit value (5.29 €/kg).

The mean purchasing quantity found in our data is comparable to the distribution of individual meat types reported by the meat supply balances in 2020 (BLE, 2021). Therefore, we regard our data for 2014 as a suitable basis to draw implications for current purchasing behaviour.

Table 2: Summary statistics for quantity (Q), expenditure (X) and unit value (UV) of monthly per capita meat purchases across meat types

Meat type		Mean	Median	SD	Min	Max	CV
Total meat	Q in kg	1.8	1.47	1.32	0.06	20.95	0.73
	X in €	11.05	9.00	8.22	0.52	135.3	0.74
	UV in €/kg	6.44	5.94	2.16	1.85	31.14	0.34
Pork	Q in kg	0.88	0.64	0.89	0.00	20.95	1.00
	X in €	4.87	3.69	4.61	0.00	72.65	0.95
	UV in €/kg	6.02	5.67	1.83	0.99	30.00	0.30
Beef and veal	Q in kg	0.26	0.14	0.38	0.00	8.51	1.44
	X in €	2.37	1.11	3.73	0.00	72.14	1.57
	UV in €/kg	9.06	8.15	3.97	0.90	44.92	0.44
Poultry	Q in kg	0.43	0.30	0.50	0.00	8.57	1.17
	X in €	2.40	1.70	2.73	0.00	51.87	1.14
	UV in €/kg	6.24	5.98	2.50	1.00	35.96	0.40
Pork and beef mixed meat	Q in kg	0.19	0.10	0.27	0.00	4.19	1.37
	X in €	0.93	0.51	1.27	0.00	24.69	1.36
	UV in €/kg	5.29	4.58	1.75	1.49	18.50	0.33
Lamb, red meat of other species (specialities)	Q in kg	0.03	0.00	0.11	0.00	4.83	4.44
	X in €	0.31	0.00	1.27	0.00	50.70	4.15
	UV in €/kg	14.66	12.61	7.76	2.99	44.81	0.53

Source: Authors' own compilation of GfK data for 2014.

2.2 Methods

This study attempts to identify buyer segments based on their purchases of a variety of meat products. As the GfK data report an extensive number of meat products including various species, cuts, and preparation methods, we used exploratory factor analysis in a first step to identify commonalities in purchase patterns across single items. In particular, we argue that the individual products ending up in a household's monthly shopping basket serve similar overarching goals. Different poultry cuts frequently bought by the same households within a month, for example, indicate the desire for leaner, healthier meat. Other households might buy different products for quick preparation such as steaks or chops. Hence, we expected to obtain more meaningful product groups in terms of meat type, preparation method, quality, and further consumer preferences and to aggregate the individual cuts accordingly. We used principal components with Varimax rotation to define the underlying structure in the data matrix and considered factor loadings larger than 0.40 (HAIR et al., 2019).

A cluster analysis was conducted in a second step to identify clusters as homogeneously as possible using the aggregated monthly purchase shares of the product groups derived by factor analysis as inputs for the segmentation. Specifically, a two-step cluster analysis including a hierarchical clustering with a subset of 500 households followed by K-means clustering was performed to identify different buyer segments. In a first step, a single-linkage analysis based on the nearest neighbour method was performed to eliminate outliers (HAIR et al., 2019). A total of 14 respondents was eliminated as their purchasing behaviour differed clearly from the rest of the sample. The optimum number of clusters was determined using Ward's method, which is based on the squared Euclidian distance. Based on the resulting dendrogram, four clusters appeared to be the optimal number. Applying the non-hierarchical K-means algorithm allows allocation of all households to the specified number of clusters (HAIR et al., 2019).

To first describe the individual segments, statistically significant differences with regard to the purchased quantity, expenditure, unit value, and shopping locations were evaluated using a Kruskal–Wallis H test followed by a post hoc analysis (pairwise comparison) (DINNO, 2015). To further characterise the clusters, a multinomial logistic regression was performed with cluster type as dependent variable and socio-demographics, total purchased quantity, shopping locations and attitudinal statements towards meat and food shopping as independent variables. This approach allows the effects of individual variables on cluster membership to be isolated and controlled for potential confounding. We use the first cluster as the base category in the MNL. To facilitate interpretation of the estimated coefficients, we report the results as Average Marginal Effects of each variable on the probability of segment membership for all four clusters (CAMERON and TRIVEDI, 2009). Goodness of fit was assessed by means of a deviance likelihood ratio-test and various Pseudo-R^2-measures (Cox and Snell, Nagelkerke, and McFadden) (HAIR et al., 2019).

3 Results

3.1 Results of the factor analysis

A highly significant Bartlett's test of sphericity and a Kaiser-Meyer-Olkin (KMO) criterion of 0.73 indicated that the original data matrix of available meat cuts was suitable for factor analysis (BACKHAUS et al., 2018). Based on the correlation matrix we removed seven cuts for further analysis and one category that could not be clearly assigned to any meat type. 24 meat cuts ambiguously loaded on several factors, which we also eliminated for the final analysis. We argue that the omitted products do not contribute to illuminating heterogeneity of purchasing behaviour. The remaining data had a KMO of 0.59, which is acceptable (HAIR et al., 2019). We retained all factors with eigenvalues greater than 1, resulting in a final number of nine factors. The PCA delivered product groups that are homogeneous along the dimensions of species, cut, and preparation type.

Table 3 shows the factor loadings for the 21 different meat cuts used to generate the factors. Values in bold type indicate loadings that have been allocated to a common factor. Cuts of pork are considered in Factor 1, comprising traditional pork cuts such as gammon steak, chops, and minced pork as well as in Factor 7 comprising gyros and goulash, both convenience pork products. Factor 2 summarises various cuts of poultry, especially chicken and turkey breast and filet, and Factor 3 covers cuts of veal. Different groups of cuts are identified for beef: one group of sautéed beef cuts such as steak and sirloin (Factor 4) and traditional beef cuts such as rump, topside or silverside (Factor 5). Lamb cuts other than filet are comprised in Factor 6. Beef filet is considered in Factor 8 together with lamb filet, representing premium cuts of red meat. Factor 9 covers

convenience mixed products consisting of pork and beef such as cevapcici and minced meat. We used the standardised (deviations from the total samples' mean) shares of the nine product groups in total monthly purchase meat quantities in the clustering procedure.

Table 3: Factor loadings for per capita monthly purchases of different meat cuts

	Factor loadings								
	Factor 1 Traditional pork cuts	**Factor 2 Poultry cuts**	**Factor 3 Veal cuts**	**Factor 4 Sautéed beef cuts**	**Factor 5 Traditional beef cuts**	**Factor 6 Other lamb cuts than filet**	**Factor 7 Convenient pork cuts**	**Factor 8 Premium cuts of beef and lamb**	**Factor 9 Convenient mixed products**
Gammon steak, pork	**0.697**	-0.002	0.021	0.065	0.097	0.074	0.057	-0.047	0.007
Chops, pork	**0.677**	0.026	-0.033	-0.036	0.058	-0.053	0.071	0.010	0.033
Minced pork	**0.567**	-0.123	-0.024	-0.058	-0.095	-0.029	0.052	0.099	-0.033
Breast, breast filet, chicken	-0.022	**0.777**	-0.034	-0.024	-0.025	-0.018	-0.008	0.032	0.006
Breast, breast filet, turkey	-0.027	**0.732**	0.002	0.037	0.027	-0.039	0.031	0.022	-0.007
Further cuts, poultry	0.342	**0.410**	0.142	0.063	0.050	0.232	0.018	-0.085	-0.020
Goulash, veal	-0.019	-0.034	**0.830**	-0.024	-0.010	-0.084	0.015	-0.008	0.006
Further cuts, veal	0.016	0.026	**0.792**	0.058	0.039	0.145	-0.029	0.076	-0.011
Sirloin, beef	0.023	-0.067	0.018	**0.788**	0.026	-0.020	-0.009	-0.007	-0.008
Steak, beef	-0.019	0.086	0.013	**0.770**	0.037	0.005	0.005	0.056	0.003
Rump, beef	-0.089	-0.035	0.013	-0.005	**0.820**	0.079	0.008	0.029	-0.006
Topside or silverside, beef	0.212	0.050	0.016	0.081	**0.752**	-0.048	0.022	0.010	-0.002
Further cuts, lamb	0.094	-0.007	0.035	0.034	0.003	**0.669**	-0.069	-0.003	-0.018
Chops, lamb	-0.091	-0.033	0.048	-0.016	0.164	**0.619**	0.053	0.073	-0.015
Back, lamb	0.002	-0.014	-0.005	0.078	-0.074	**0.593**	-0.004	0.064	0.040
Gyros, pork	-0.041	0.037	-0.008	0.021	-0.010	-0.008	**0.812**	-0.014	0.044
Goulash, pork	0.190	-0.027	-0.004	-0.038	0.002	-0.012	**0.734**	-0.001	-0.042
Filet, lamb	-0.010	0.005	0.050	-0.050	-0.012	0.038	0.015	**0.841**	0.014
Filet, beef	0.035	0.062	0.010	0.278	0.122	0.022	-0.074	**0.610**	-0.041
Minced pork/beef	0.024	-0.071	-0.001	-0.032	-0.024	-0.024	0.003	0.018	**0.731**
Cevapcici, pork/beef	-0.021	0.068	-0.005	0.024	-0.017	0.022	0.015	-0.021	**0.730**

Note: Bartlett's test of sphericity = 0.000; Kaiser-Meyer-Olkin (KMO) = 0.589;
Total variance explained through factors = 55.04%.
Source: Authors' own calculation based on GfK data for 2014.

3.2 Description of segments

Four different clusters of fresh-meat-buying households are designated, as illustrated in ***Figure 1***, which shows the standardised mean share of the total monthly meat purchases per capita for the nine different product groups: each bar indicates the deviation from the sample mean.

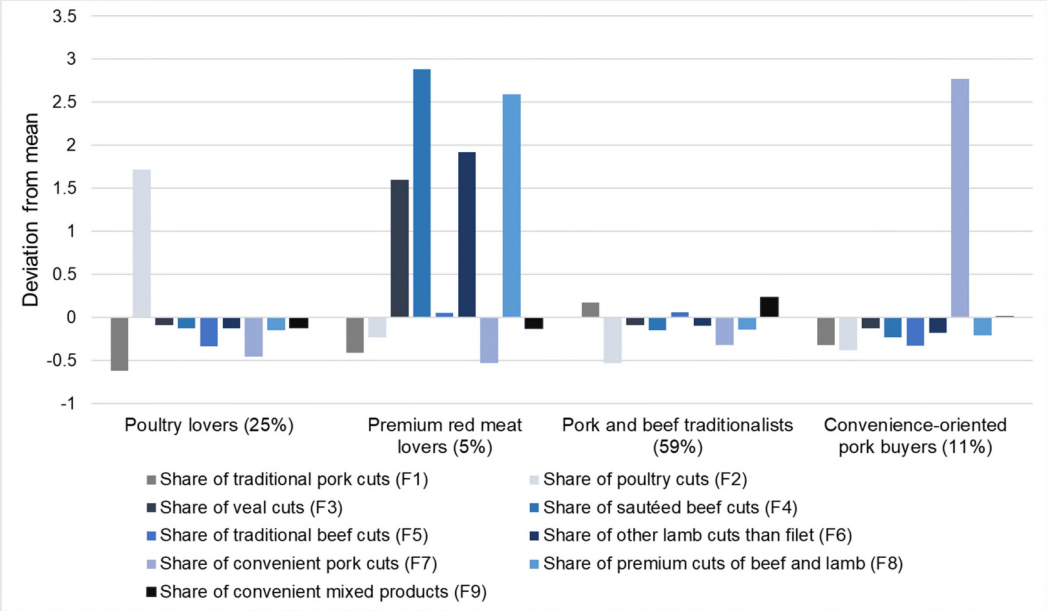

Figure 1: The four identified segments and their mean deviation from the total sample's mean
Source: Authors' own calculation based on GfK data for 2014.

The first cluster stands out due to an above-average share of poultry purchases, whereas the share of all other meat types, and especially traditional pork cuts, are below the average of the entire sample. Therefore, we term this consumer segment *poultry lovers*, which includes 2,817 households or 25% of the total sample.

The second cluster exhibits high shares for four product groups of red meat cuts, in particular veal, sautéed beef cuts, premium cuts of beef and lamb, and other lamb cuts. The share of traditional beef cuts is slightly above average and cuts of poultry, pork, and mixed products are below average. The second cluster is labelled *premium red meat lovers* accounting for 5% or 616 households in the sample.

The third cluster is the largest cluster with 6,745 households or a share of 59% of all households. As a main feature of this segment there are no strongly marked deviations from the overall means in the nine product groups. Thus, almost two-thirds of the households share quite similar consumption patterns with regard to the type of meat or specific cuts. Allocated households purchase traditional pork cuts, traditional beef cuts and convenient mixed products at a slightly higher rate than the total sample's mean. Poultry cuts, convenience pork cuts and sautéed and premium cuts of beef and lamb are purchased less frequently. We therefore term this segment *pork and beef traditionalists*.

The remaining 11% of all households are allocated to the fourth segment, which is entitled *convenience-oriented pork buyers*. A total of 1,295 households buy an above-average share of convenience pork cuts and convenience mixed products, whereas the values of all other product groups are below average.

To further describe the four clusters, statistical key figures indicate the mean monthly purchasing quantity, expenditure, and unit value as well as proportionate organic meat purchases and shopping locations, which ***Table 4*** shows for each cluster. Additionally, statistically significant differences between the segments regarding these variables are indicated.

Table 4: Monthly fresh meat purchases and shopping locations for each cluster

Cluster	1 Poultry lovers	2 Premium red meat lovers	3 Pork and beef traditionalists	4 Convenience-oriented pork buyers
Variables	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**
Purchases per capita in kg***	1.54^{a}±1.22	1.71^{b}±1.22	1.95^{c}±1.38	1.62^{b}±1.06
Expenditure in € ***	9.27^{a}±6.70	16.23^{b}±12.06	11.66^{c}±8.38	9.35^{a}±6.39
Unit value in €/kg***	6.42^{a}±1.97	9.98^{b}±3.33	6.21^{c}±1.86	5.91^{d}±1.49
Share of organic meat purchases***	0.02^{a}±0.08	0.03^{b}±0.09	0.02^{c}±0.08	0.01^{d}±0.05
Share of meat purchased at supermarket ***	0.23^{a}±0.30	0.34^{b}±0.33	0.28^{c}±0.32	0.23^{a}±0.30
Share of meat purchased at butcher***	0.04^{a}±0.14	0.15^{b}±0.27	0.10^{c}±0.22	0.07^{d}±0.19
Share of meat purchased at hypermarket***	0.16^{a}±0.27	0.15^{a}±0.26	0.23^{b}±0.31	0.17^{a}±0.28
Share of meat purchased at discount***	0.53^{a}±0.36	0.26^{b}±0.30	0.34^{c}±0.33	0.51^{a}±0.36

Note: SD = Standard deviation; Kruskal-Wallis H test was applied to test H0: There are no mean differences on the regarded variable between the four consumer segments. *** indicate p-value signif. ≤ 0.0001. Letters accompanying mean values are the compact letter displays resulting from pairwise comparisons using Dunn's test. Values with the same compact letters are not significantly different.
Source: Authors' own calculation based on GfK data for 2014.

Poultry lovers purchase 1.54 kg fresh meat per capita and month on average, which is significantly lower than other segments. They also show the lowest expenditure and relatively high unit values. *Poultry lovers* generate almost half of their meat purchases with a combination of three poultry cuts (Factor 2) (***Table A1***), purchased primarily at discount stores.

Premium red meat lovers purchase 1.71 kg of fresh meat in total per month on average, which is slightly below the average for all households (1.80 kg). Households in this cluster have the highest monthly expenditure for fresh meat and pay the highest prices on average, which differentiates them significantly from the other clusters. They also have the largest share of organic relative to total meat purchases and the highest share of purchases in butcher shops (15%). In addition to high-priced meat products and traditional beef products, buyers in this segment demand poultry cuts in comparatively high quantities (***Table A1***).

The large segment of *pork and beef traditionalists* exhibits the highest average monthly fresh meat purchase quantity with 1.95 kg per capita, significantly different from all other segments. These households have the lowest share of organic relative to total meat purchases and shop primarily at discounters (34%), followed by supermarkets (28%), and hypermarkets (23%).

Convenience-oriented pork buyers have the second lowest purchase quantity of fresh meat per capita (1.62 kg) and indicates the lowest average expenditure and unit value within the sample. Allocated households shop mainly at discount stores, whereas the share of purchases at the butcher shop is comparatively low.

3.3 Explanation of cluster membership

Each of the identified segments is further characterised using a multinomial logistic (MNL) regression. Results of the MNL regression are provided in ***Table 5***. Explanatory variables include socio-demographics, place of residence, total purchase quantity of fresh meat, purchase frequency at discount stores, and butcher shops as well as five statements on attitudes towards food and meat shopping for which we assume equidistance (further descriptive statistics of the explanatory variables can be found in the appendix, ***Table A1***). The significant coefficients are the Average Marginal Effects, i.e., when multiplied by 100%, they indicate the percentage-point-change in the probability to belong to one cluster resulting from a one-unit change in the independent variable. The deviance likelihood ratio-test (χ^2 (df=72) = 1788) is highly significant with a p-value of ≤ 0.0001, McFadden Pseudo-R^2 is 0.074.

Table 5: Results of multinomial logit model presented as average marginal effects, dependent variable: cluster membership

Cluster	1 Poultry lovers	2 Premium red meat lovers	3 Pork and beef traditionalists	4 Convenience - oriented pork buyers
Age (base: young (≤ 39))				
Intermediate (40-59)	-0.048***	0.012**	0.042***	-0.006
	(0.011)	(0.006)	(0.013)	(0.008)
Old (≥ 60)	-0.104***	0.009	0.140***	-0.045***
	(0.014)	(0.007)	(0.016)	(0.010)
Gender (base: male)				
Female	0.054***	-0.001	-0.029**	-0.024***
	(0.010)	(0.005)	(0.012)	(0.009)
Net income (base: low (≤ 1,999 €))				
Intermediate (2,000 – 3,999 €)	0.014	0.034***	-0.029***	-0.019***
	(0.009)	(0.005)	(0.011)	(0.007)
High (≥ 4,000 €)	0.024	0.108***	-0.094***	-0.038***
	(0.017)	(0.013)	(0.019)	(0.011)
Household size (base: 1 person)				
2 people	-0.038***	-0.036***	0.062***	0.012
	(0.011)	(0.008)	(0.013)	(0.008)
3 people	-0.047***	-0.041***	0.055***	0.034***
	(0.014)	(0.009)	(0.016)	(0.010)
4 or more people	-0.033**	-0.052***	0.038**	0.046***
	(0.015)	(0.009)	(0.018)	(0.012)
Occupation (base: white collar)				
Blue collar	-0.040***	-0.020***	0.046***	0.015
	(0.012)	(0.006)	(0.014)	(0.009)
Civil servant	0.010	-0.016**	-0.017	0.023
	(0.019)	(0.008)	(0.022)	(0.015)
Freelancer	0.048	0.007	-0.075*	0.020
	(0.037)	(0.017)	(0.041)	(0.029)
Farmer/Self-Employed	-0.017	-0.054***	0.116	-0.046
	(0.120)	(0.004)	(0.125)	(0.063)
Person of private means	-0.036***	0.007	0.031**	-0.002
	(0.012)	(0.007)	(0.013)	(0.009)
Self-employed	0.031	0.016	-0.037	-0.010
	(0.023)	(0.012)	(0.025)	(0.016)
Residence (base: village (< 5,000 inhabitants))				
Small town (5,000 to 49,999 inhabitants)	0.010	0.010*	-0.022*	0.001
	(0.011)	(0.006)	(0.013)	(0.009)
Urban (≥ 50,000 inhabitants)	0.046***	0.019***	-0.056***	-0.009
	(0.012)	(0.006)	(0.014)	(0.009)
Fresh meat purchases	-0.062***	0.001	0.082***	-0.021***
(on average per month and capita)	(0.005)	(0.002)	(0.005)	(0.004)

To be continued on next page

Table 5 continued

Cluster	1 Poultry lovers	2 Premium red meat lovers	3 Pork and beef traditionalists	4 Convenience -oriented pork buyers
Purchases at discount stores	0.104***	-0.020***	-0.121***	0.037***
(on average per month and capita)	(0.006)	(0.004)	(0.007)	(0.005)
Purchases at butcher shop	-0.112***	0.015***	0.071***	0.025***
(on average per month and capita)	(0.018)	(0.004)	(0.016)	(0.009)
Attitudinal statements				
When buying food, I always look for quality, even if it is more expensive…	0.015***	0.010***	-0.009*	-0.016***
	(0.004)	(0.002)	(0.005)	(0.003)
When it comes to food, I pay more attention to the price than to the brand…	-0.008**	-0.006***	0.013***	0.001
	(0.004)	(0.002)	(0.005)	(0.003)
I like to spoil myself with good food…	-0.002	0.014***	-0.003	-0.009***
	(0.004)	(0.002)	(0.004)	(0.003)
In my spare time I am involved with animals…	-0.004	-0.004***	0.005	0.002
	(0.003)	(0.001)	(0.003)	(0.002)
When buying food, the issue of cholesterol plays a role…	-0.001	-0.002	0.001	0.002
	(0.003)	(0.002)	(0.004)	(0.003)

Notes: Coefficients indicate average marginal effects based on multinomial logit regression with *poultry lovers* as base-category. Standard errors are reported in parentheses. Test statistic: LR (Likelihood ratio) test: $\chi 2$ (df=72) = 1788; Nagelkerke=0.164; Cox and Snell=0.144; McFadden's R^2 = 0.074. *** p ≤ 0.001, ** p ≤ 0.005, * p ≤ 0.01
Source: Authors' own calculation based on GfK data for 2014.

The results in ***Table 5*** show that households are five and ten percentage points less likely to belong to the cluster of *poultry lovers* if the household reference person's age is equal to or greater than 40 and 60, respectively. In contrast, a female household reference person significantly increases the likelihood of cluster membership. Single households are significantly more likely to belong to this cluster than households with two or more members. A "blue-collar worker" or a "person of private means" significantly lowers the probability of being a *poultry lover*, compared to white collar workers. Net household income does not affect the cluster membership of *poultry lovers*. In contrast, an urban residency increases the probability of cluster membership by five percentage points. An increase in total meat purchases per capita and month by one kilogram significantly lowers the probability of cluster membership by 6 percentage points. In addition, households in this cluster tend to prefer shopping at discount stores. Regarding the attitudinal statements, the results of the regression analysis show that the probability of cluster membership increases for households stating that they look for quality when buying food, even if it is more expensive. Along the same line, the probability decreases for households stating to pay more attention to the price than to the brand.

A reference person in the intermediate age group significantly increases the chance of belonging to the smallest cluster of *premium red meat lovers*. The same holds true for intermediate and high incomes, whereas households with two or more members have a significantly lower probability of belonging to this segment. An occupation as a blue collar worker or a farmer/being self-employed decreases the likelihood of cluster membership. Living in an urban area increases the probability of being a *premium red meat lover*. Similarly, households in this cluster have a higher purchasing frequency at butcher shops and tend to value quality when shopping for fresh meat: they look for quality, like to spoil themselves with good food, and do not pay attention to the price.

The chance of belonging to the largest segment of *pork and beef traditionalists* increases with an intermediate or advanced age of the household's reference person. An age above 60 increases cluster membership significantly by a remarkable 14 percentage points. Intermediate to high net incomes, however, decrease the chance of being classified a traditional pork and beef cut shopper. A household size of two or more members raises the chance of membership, while urban residency lowers the probability as compared to living in a village. Households of this segment rate the price of food as an important purchasing criterion. Also, higher total meat purchases per month increase the chance of cluster membership significantly, as does a high share of meat sourced from butchers.

The likelihood of belonging to the segment of *convenience-oriented pork buyers* is high for younger households with male reference persons, lower incomes, and three or more members. Also, pork and convenience favouring households place price above quality and do not indicate the desire to spoil themselves with good food. An increase in the monthly purchase quantity of fresh meat by one kilogram decreases the chance to be allocated to this segment by 2 percentage points. Higher shopping frequencies at both butcher shops and discount stores increase the probability of cluster membership, while occupation and residency do not have any significant influence.

4 Discussion

This study used revealed preference data to identify consumer segments, relevant for targeted policy and marketing measures. We applied a product level consideration of various prepared cuts to allow for an accurate analysis of the household segment related purchasing behaviour. We found meaningful household segments that differ with regard to their meat purchasing behaviour. The cluster profiles provide important insights into the state of consumer diversity and based on that allow to derive important implications for market actors and policy makers.

4.1 Main findings

Based on their meat product purchases we identified four heterogeneous buyer segments: a large group of *pork and beef traditionalists* (59%), a cluster of *poultry loving households* (25%), households belonging to *convenience-oriented pork buyers* (11%) and a segment of *premium red meat lovers* (5%).

Based on the actual meat purchases, we conclude that the share of *pork and beef traditionalists,* which can be described as classic meat eaters in the most conventional sense, is still high within the German population. This stands in contrast to existing studies that conducted meat consumer segmentations based on attitudes towards single aspects of eating or self-reported total meat quantities, which usually painted a more sustainable picture. GÖTZE and BRUNNER (2021) labelled 45% of Swiss consumers as environmentally conscious, mostly regular meat eaters. At the same time, CORDTS et al. (2014) described the minority of German consumers as meat fans and big eaters (12%) and identified 22% as "meat lovers with an affinity for sustainability". KAYSER et al. (2013) identified 33% of German meat consumers as "heavy meat consumers" without considering actual consumed quantities or additional purchasing patterns.

Pork and beef traditionalists had the highest average per capita meat purchases with the most diversified assortment of meat types demanded among all segments, but bought a high proportion of pork cuts, which are comparatively high in fat. Accordingly, a change in diet would be especially desirable to counteract health risks

and promote more sustainable dietary patterns. With a view on the rather advanced age of *pork and beef traditionalist's* reference persons, it may also be a question of generational change in addition to targeted measures to witness a transformation of the average dietary behaviour. The 51-65 age group made up 23% of the total German population in 2020 due to the high birth rate within this generation ("baby-boomers") (EFKEN and MEEMKEN, 2021). We can expect that the high meat demand of "baby-boomers" will have less of an effect on the future average meat consumption of the German population within the next two decades for two reasons. First, a considerable part of this cohort will experience a higher mortality, second, their high consumption levels are likely to decline with increasing age (EFKEN and MEEMKEN, 2021). However, against the backdrop of the remaining time window to achieve climate targets (UN, 2015), such a "natural" dietary transformation would probably not proceed at the required pace.

In addition to one large segment of households, we found three smaller consumer groups that distinguish considerably from each other with regard to their meat shopping habits. The smallest segment of *premium red meat lovers* mainly purchased high-priced beef and lamb cuts and also indicated monthly per capita meat purchases which were above the average of the entire sample. Contrary to *pork and beef traditionalists*, *premium red meat lovers* were more quality- than price-oriented. These households bought the largest share of organic meat compared to total fresh meat purchases among clusters and paid comparatively high prices for all fresh meat product groups. Hence, only a small part of households actually has "willingness to pay" (WTP) above average unit values, which is in contrast to survey-based studies that typically report higher and more wide-spread WTP for sustainability attributes such as animal welfare (EC, 2016).

The cluster of *convenience-oriented pork buyers* together with *poultry lovers* exhibited a tendency towards reduced meat consumption. The female-headed and rather young segment of *poultry lovers* generated almost half of their meat purchases with a combination of three poultry cuts (Factor 2). As they purchased the lowest share of traditional pork cuts and had the lowest monthly per capita meat purchases, they consume a rather healthy assortment of meat types. The mainly male-headed households belonging to the cluster of *convenience-oriented pork buyers* especially favoured meat cuts that can be prepared quickly and purchased the second-lowest meat quantity among clusters.

On the one hand, a reduced demand for meat among younger generations is in line with findings of the National Consumption Survey II, which calculated meat consumption based on individual dietary interviews that were conducted between November 2005 and January 2007. Results indicated that 15 to 18-year-old consumers exhibit a 7% reduction of meat consumption compared to the overall average (KREMS et al., 2013). According to SPILLER et al. (2021), twice as many 15 to 29-year-old consumers considered themselves to be vegetarian or vegan in 2021 compared to the total German population. An evaluation of GfK data on meat substitutes accordingly revealed that within single households, the group consumers under 34 years of age showed the highest average per capita purchase of meat substitutes while indicating the lowest meat purchases in the year 2020 (GFK, 2021).

On the other hand, and contrary to conventional wisdom and the impression given by surveys partly identifying a "green" quality and health focused young generation (SAVELLI et al., 2019; BRÜMMER and ZANDER, 2020), our results draw a more differentiated picture. *Convenience-oriented pork buyers* favoured meat cuts, which are not necessarily associated with a balanced diet, had comparably low unit-values and have placed more emphasis on the price and not on the quality of the food they purchased. *Poultry lovers* with an affinity for health mainly and foremost shopped in discount markets; which was also not intuitively to be expected and should be examined in the course of further research.

Since per capita fresh meat purchases were on average, and for all segments, above 16 kg per capita and year, they exceeded the EAT-Lancet Commission recommended consumption level consistent with "planetary health diets" (WILLETT et al., 2019). Thus, a dietary transformation would be desirable with view on the environment and for all households. The mean annual meat consumption level suggested by the German Nutrition Society (DGE) (23 kg) was not reached (DGE, 2020); however, out-of-home consumption and processed meat products were not included in the dataset.

4.2 Policy implications

We identified *pork and beef traditionalists*, who purchase 24 kg of fresh meat annually with a preference for chops, gammon steak and minced pork, as a priority group when aiming to achieve a more rapid dietary change with view towards health and environmental effects. In terms of corresponding policy approaches, financial incentives primarily guide decision-making, including meat taxes, which are at the centre of the current political debate in Germany. The feasibility of an excise as well as an ad valorem tax resulting from abolishing the reduced value-added tax (VAT) rate on animal products, i.e., increasing it from 7% to 19% to finance improved animal husbandry conditions, is currently being examined (KNW, 2020; DEBLITZ et al., 2021; KARPENSTEIN et al., 2021).

Pork and beef traditionalists reported high price sensitivity when purchasing food, paid rather low average prices for meat, and had lower incomes than other clusters. Thus, price-related measures such as taxes have considerable potential to effectively reduce fresh meat consumption of this segment. ROOSEN et al. (2022) recently illustrated distinct reactions to price and expenditure variation across meat-types as well as household groups. Due to their diversified assortment of demanded meat types it would be interesting to look more closely at substitution effects with regards to meat types and cuts purchased, production practices, and the place of purchase in the event of a price change for *pork and beef traditionalists*. The effect of a meat tax must be especially considered in light of this particular cluster in order to assess the anticipated total effect of such a tax. At the same time, we assume that a significant price increase would be needed to cause a real change in consumer behaviour, particularly for those persons with a deeply anchored habit of regular meat consumption (BROMBACH et al., 2015).

The rather young households belonging to *convenience-oriented pork buyers* (11%) expressed less quality-motivation but price-consciousness with comparably low unit-values for meat they bought. This group also seems to be susceptible to financial incentives. Raising the price could possibly generate a more substantial drop in meat demand for this group, since habits are not yet so deeply rooted. By introducing a tax based on CO_2 emissions, substitute products and plant-based alternatives could become more favourable compared to meat. As positive financial incentives are associated with less negative emotional response (JUST and HANKS, 2015), balanced diets could additionally be encouraged by price promotions of plant-based alternatives. Especially personalised price promotion (PPP) have recently been discussed as a promising measure to achieve timely sales of perishable foods contributing to the reduction of food waste as well as to incentivise purchases of food products with a healthier nutrient profile (NGUYEN et al., 2019). In a similar vein, PPP might target price sensitive *convenience-oriented pork buyers* to make purchases and long-term adoption of plant-based meat alternatives more attractive.

4.3 Marketing implications

SANCHEZ-SABATE and SABATÉ (2019) found that consumers who are willing to curb or change their meat consumption are more likely to be rather young and female. According to KUMAR and KAPOOR (2017) quality-conscious young consumers are particularly accessible via labels. This is why the segment of *poultry lovers* is a particularly interesting target group for market participants. We assume, that these households could be reached easily since they favour rather healthy poultry cuts, stated to look for quality when purchasing food with comparably high unit values for the meat products they bought, and belonged more often to the younger age group. This is why instruments with informative character, such as an animal welfare label, could possibly promote the consumption of meat with improved animal welfare requirements in this target group as generally envisaged by the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE) (WBAE, 2020).

Environmental consequences of meat consumption seem to be a particular driving factor influencing changes in dietary behaviour of young consumers (ZÜHLSDORF et al., 2021). Further research is required on the purchase motivation of young *poultry lovers* in this context to evaluate the potential directing effect of labels focussing on health, animal welfare, and climate. Examining the underlying quality perception of these buyers would be particularly interesting against the background of the announcement by certain German discounters to exclusively offer fresh meat produced under improved husbandry conditions (outdoor climate and organic husbandry) from 2030 onwards (SCHULZE STEINMANN and ARDEN, 2021). According to NADERI and VAN STEENBURG (2018) “rational and self-oriented motives” have encouraged millennials to behave in an environmentally friendly way. This aspect should be considered in the course of developing targeted marketing measures based on shopping motivations of poultry lovers to ease their choice for e.g., “animal-welfare meat” or healthier meat subsidies.

From an environmental footprint perspective, *premium red meat lovers* would initially have to be targeted, since the production of beef and lamb notably causes higher negative environmental effects than pork and poultry (CLUNE et al., 2017). These households are an additionally relevant segment to successfully derive marketing strategies, as they apparently value quality food and like to spoil themselves with good foodstuffs. They had the largest share of organic meat compared to total fresh meat purchases. Due to their financial provision and their correspondingly low price sensitivity in their food shopping, they may accept further price increases in order to maintain their long-established dietary habits instead of lowering their meat consumption or substituting beef and lamb with poultry, which has a smaller environmental footprint (CLUNE et al., 2017). They might therefore be willing to pay additional prices for meat that is produced more sustainably, regionally or under better animal welfare conditions. Therefore, targeted marketing can bring about a change towards more sustainability for *premium and red meat lovers*. A detailed examination of these households' quality understanding (in terms of meat texture or animal husbandry system) could provide further important insights for market participants in this regard.

A low income significantly increased the chance of belonging to *convenience-oriented pork buyers.* Research has shown that target groups in precarious living conditions are in principle more difficult to reach via information approaches and that low incomes pose limits on purchase options (SPILLER et al., 2017). Due to an additional lack of interest in quality aspects, the extent to which measures of an informative nature could potentially reach *convenience-oriented pork buyers* remains open. Nevertheless, this segment appears to be an interesting audience from a marketing point of view as households favour products that can be prepared quickly,

without meat being their main focus. They could therefore be encouraged to increasingly consume ready-to-eat, low-priced meat substitutes, for which manufacturers and retailers need to develop a targeted product range and by suitable promotion measures, possibly accompanied by appealing financial incentives.

Increasing the availability of “hybrid meat substitutes” with a reduced meat component, which are close to conventional meat products regarding most product characteristics, could be a way to gradually achieve a reduction in meat consumption, even for “taste-driven” meat enthusiasts with little interest in health information (APOSTOLIDIS and MCLEAY, 2016). This could also affect *traditional pork and beef buyers* by partly changing their nutrition environment. Curbing consumption of all meat products does not seem feasible for this segment; diets through financial interventions accompanied by attractive substitutes might be achievable.

4.4 Limitations

In the course of assessing our results, the limitations should be considered. Although the present analysis provides important insights into heterogeneous consumer segments with regard to fresh meat, covering about 50% of household meat purchases (AMI, 2020), future research may also include processed meat. Along the same line, a significant share of meat is consumed out-of-home (THIES et al., 2021). As *convenience-oriented pork buyers* buy products that are easy and quick to prepare, they might tend towards an increased meat consumption in canteens or pubs, which was not considered in our data set. Additional data sources, which however are not yet available, would be needed to map purchasing behaviour of *convenience-oriented pork buyers* even more comprehensively. Additionally, our analysis did not characterise non-meat buyers, as the central focus of our study was to identify and address meat consumers.

The analysis of meat purchasing behaviour was household-based and thus conducted at an aggregated level. Attitudes and socio-demographics were related to the households’ reference person, responsible for the purchasing of all household members. Nevertheless, the preferences of all household members are reflected in the purchasing behaviour of the respective responsible person, which led to a well-founded distinction of consumer segments. Certain caution is appropriate for the interpretation of gender as the data feature a large share of housewives among participants. However, we argue that the measured effects for gender are rather at a lower bound and would even be more pronounced considering all family members.

Still, there is need for future nutritional monitoring enhanced with a regular collection of individual dietary data (THAR et al., 2020). Also, needed are implications regarding price instruments built on self-reported sensitivity. Future research may cluster explicitly based on estimated parameters of price elasticities or WTP, e.g., via latent class models.

5 Concluding remarks

Based on household panel data for 2014 and using factor and cluster analysis followed by a multinomial logit model, we determined heterogeneous demand behaviour among German meat buyers regarding meat products, purchased quantities, expenditures and shopping locations.

We found that the majority of German households has not yet moved away from traditional meat consumption habits and would have to be encouraged to change their dietary behaviour, especially through financial incentives. Three smaller household segments clearly differed in their meat demand behaviour and might be reached through targeted marketing with different emphases. We characterised them as health-conscious but discounter-favouring (*poultry lovers*), quality-affine and price-insensitive (*premium red meat lovers*), and convenience-loving but not quality-seeking (*convenience-oriented pork buyers*).

Effective solutions need to consider these individual profiles by increasing the availability of meat substitutes that are convincing and attractive for each of the consumer segments regarding habits, quality and taste as well as convenience. Lessons learned from tobacco policy campaigns showed that a mix of instruments, in particular, is promising (ORTH and TÖPPICH, 2010). A correspondingly tailored product range may therefore be accompanied by targeted labelling and communication campaigns as well as effective pricing measures to bring about a change in the “food environment” and, in turn, in dietary behaviour.

References

AMI (2020): *AMI analyses based on the GfK household panel*. AMI, Bonn.

APOSTOLIDIS, C. and F. MCLEAY (2016): *Should we stop meating like this? Reducing meat consumption through substitution*. In: Food Policy 65: 74–89.

BACKHAUS, K., B. ERICHSON, W. PLINKE and R. WEIBER (2018): *Multivariate Analysemethoden (Multivariate analysis techniques)*. Eine anwendungsorientierte Einführung. 15th ed. Springer Gabler, Berlin, Germany.

BLE (2021): *Fleisch und Geflügel. Versorgungsbilanzen (meat and poultry. Supply balances)*. Versorgung mit Fleisch in Deutschland seit 1991. Excel file. In: https://www.ble.de/DE/BZL/Daten-Berichte/Fleisch/fleisch_node.html. Call: 5.3.2021.

BONNET, C., Z. BOUAMRA-MECHEMACHE and T. CORRE (2018): *An Environmental Tax Towards More Sustainable Food: Empirical Evidence of the Consumption of Animal Products in France*. In: Ecological Economics 147: 48–61.

BONNET, C., Z. BOUAMRA-MECHEMACHE, V. RÉQUILLART and N. TREICH (2020): *Viewpoint: Regulating meat consumption to improve health, the environment and animal welfare*. In: Food Policy 97: 101847.

BROMBACH, C., S. BARTSCH and G. WINKLER (2015): *Ernährungsverhalten im Verlauf von drei Generationen (Dietary behaviour over the course of three generations)*. In: Schweizer Zeitschrift für Ernährungsmedizin 5: 20–24.

BRÜMMER, N. and K. ZANDER (2020): *Einstellungen junger Erwachsener zu Bio-Lebensmitteln. Eine Online-Mixed-Methods-Studie (Young adults' attitudes toward organic foods. An online mixed methods study)*. In: Austrian Journal of Agricultural Economics and Rural Studies 29.14: 115–121.

CAILLAVET, F., A. FADHUILE and V. NICHÈLE (2016): *Taxing animal-based foods for sustainability: environmental, nutritional and social perspectives in France*. In: European Review of Agricultural Economics 43 (4): 537–560.

CAMERON, A. C. and P. K. TRIVEDI (2009): *Microeconometrics Using Stata.* Stata Press, College Station, TX, USA.

CASINI, L., C. CONTINI, C. ROMANO and G. SCOZZAFAVA (2015): *Trends in food consumptions: what is happening to generation X?* In: British Food Journal 117 (2): 705–718.

CLUNE, S., E. CROSSIN and K. VERGHESE (2017): *Systematic review of greenhouse gas emissions for different fresh food categories*. In: Journal of Cleaner Production 140: 766–783.

CORDTS, A., N. DUMAN, H. GRETHE, S. NITZKO and A. SPILLER (2014): *Potenziale für eine Verminderung des Fleischkonsums am Beispiel Deutschland und Auswirkungen einer Konsumreduktion in OECD-Ländern auf globale Marktbilanzen und Nahrungsmittelpreise (Potentials for a reduction of meat consumption using the example of Germany and effects of a reduction of consumption in OECD countries on global market balances and food prices)*. In: Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e. V. (49): 209–222.

DEBLITZ, C., J. EFKEN, M. BANSE, F. ISERMEYER, C. ROHLMANN, H. TERGAST, P. THOBE and M. VERHAAGH (2021): *Politikfolgenabschätzung zu den Empfehlungen des Kompetenznetzwerks Nutztierhaltung (Policy impact assessment on the recommendations of the Farm Animal Husbandry Competence Network)*. Thünen Working Paper No. 173. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://literatur.thuenen.de/digbib_extern/dn063574.pdf. Call: 11.10.2021.

DGE (2020): Die Nährstoffe. Bausteine für Ihre Gesundheit (The nutrients. Modules for your health). Deutsche Gesellschaft für Ernährung e. V., Bonn, Germany.

DESTATIS (2021): *OECD-Skala*. In: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Soziales/Sozialberichterstattung/Glossar/oecd-skala.html. Call: 1.6.2021.

DINNO, A. (2015): *Nonparametric Pairwise Multiple Comparisons in Independent Groups using Dunn's Test*. In: The Stata Journal: Promoting communications on statistics and Stata 15 (1): 292–300.

EC (2016): *Attitudes of Europeans towards Animal Welfare*. Special Eurobarometer 442. European Commission, Brussels, Belgium. In: https://www.bioecoactual.com/wp-content/uploads/2016/03/Eurobarometer-2016-Animal-Welfare.pdf. Call: 19.10.2021.

EDJABOU, L. D. and S. SMED (2013): *The effect of using consumption taxes on foods to promote climate friendly diets – The case of Denmark*. In: Food Policy 39: 84–96.

EFKEN, J. and J. MEEMKEN (2021): *Der Markt für Fleisch und Fleischprodukte (The market for meat and meat products)*. Supplement. In: German Journal of Agricultural Economics 70: 47–67.

ENNEKING, U., R. KLEINE-KALMER, A. DAUERMANN and R. VOIGT (2019): *Kaufbereitschaft bei verpackten Schweinefleischprodukten im Lebensmitteleinzelhandel*. Realexperiment und Kassenzonen-Befragung (Willingness to buy packaged pork products in food retailing: Real-life experiment and checkout zone survey). Bereich Agrar- und Lebensmittelmarketing, Osnabrück, Germany.

ESCRIBA-PEREZ, C., A. BAVIERA-PUIG, J. BUITRAGO-VERA and L. MONTERO-VICENTE (2017): *Consumer profile analysis for different types of meat in Spain*. In: Meat Science 129: 120–126.

FONT-I-FURNOLS, M. and L. GUERRERO (2014): *Consumer preference, behaviour and perception about meat and meat products: an overview*. In: Meat Science 98 (3): 361–371.

GEIBEL, I., F. FREUND and M. BANSE (2021): *The Impact of Dietary Changes on Agriculture, Trade, Environment and Health: A Literature Review*. In: German Journal of Agricultural Economics 70 (3): 139–164.

GFK (2021): *GfK data set based on the GfK household panel. Private household purchases of meat and meat substitutes from 2017-2020.*

GODFRAY, H. C. J., P. AVEYARD, T. GARNETT, J. W. HALL, T. J. KEY, J. LORIMER, R. T. PIERREHUMBERT, P. SCARBOROUGH, M. SPRINGMANN and S. A. JEBB (2018): *Meat consumption, health, and the environment*. In: Science (New York, N.Y.) 361 (6399): 1–8.

GÖTZE, F. and T. A. BRUNNER (2021): *A Consumer Segmentation Study for Meat and Meat Alternatives in Switzerland*. In: Foods 10 (6).

GRASSO, S. and S. JAWORSKA (2020): *Part Meat and Part Plant: Are Hybrid Meat Products Fad or Future?* In: Foods 9 (12).

HAIR, J. F., W. C. BLACK, B. J. BABIN and R. E. ANDERSON (2019): *Multivariate data analysis.* 8th ed. Cengage, Andover Hampshire, UK.

JENSEN, J. D., S. SMED, L. AARUP and E. NIELSEN (2016): *Effects of the Danish saturated fat tax on the demand for meat and dairy products*. In: Public Health Nutrition 19 (17): 3085–3094.

JUST, D. R. and A. S. HANKS (2015): *The Hidden Cost of Regulation: Emotional Responses to Command and Control*. In: American Journal of Agricultural Economics 97 (5): 1385–1399.

KARPENSTEIN, U., F. FELLENBERG, A. SCHINK, C. JOHANN, K. DINGEMANN, M. KOTTMAN, M. EN DROIT, J. AUGUSTIN and B. GAUSING (2021): *Machbarkeitsstudie zur rechtlichen und förderpolitischen Begleitung einer langfristigen Transformation der deutschen Nutztierhaltung (Feasibility study on legal and funding policy support for a long-term transformation of the German livestock farming)*. Für das BMEL nach Beschlüssen des Deutschen Bundestages, der Agrarministerkonferenz der Bundesländer und des Kompetenznetzwerks Nutztierhaltung im Auftrag der Bundesanstalt für Landwirtschaft und Ernährung (BLE). Berlin/Bonn/Kraainem/Herne, Germany. In: https://www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Nutztiere/machbarkeitsstudie-borchert.pdf?__blob=publicationFile&v=11. Call: 10.10.2021.

KAYSER, M., S. NITZKO and A. SPILLER (2013): *Analysis of differences in meat consumption patterns*. In: International Food and Agribusiness Management Review 16 (2): 43–56.

KNW (2020): *Empfehlungen des Kompetenznetzwerks Nutztierhaltung (Recommendations of the Animal Husbandry Competence Network)*. Kompetenznetzwerks Nutztierhaltung, Berlin, Germany. In: https://www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Nutztiere/200211-empfehlung-kompetenznetzwerk-nutztierhaltung.pdf?__blob=publicationFile&v=2. Call: 14.6.2021.

KREMS, C., C. WALTER, T. HEUER and I. HOFFMANN (2013): *Nationale Verzehrsstudie II Lebensmittelverzehr und Nährstoffzufuhr auf Basis von 24h-Recalls (National Nutrition Survey II Food consumption and nutrient intake based on 24h-recalls)*. Karlsruhe, Germany. In: https://www.mri.bund.de/fileadmin/MRI/Institute/EV/Lebensmittelverzehr_N%C3%A4hrstoffzufuhr_24h-recalls-neu.pdf. Call: 12.12.2021.

KUMAR, N. and S. KAPOOR (2017): *Do labels influence purchase decisions of food products? Study of young consumers of an emerging market*. In: British Food Journal 119 (2): 218–229.

MALEK, L., W. J. UMBERGER and J. ROLFE (2018): *Segmentation of Australian meat consumers on the basis of attitudes regarding farm animal welfare and the environmental impact of meat production*. In: Animal Production Science 58 (3): 424.

NADERI, I. and E. VAN STEENBURG (2018): *Me first, then the environment: young Millennials as green consumers*. In: Young Consumers 19 (3): 280–295.

NGUYEN, M. T. T., A. EMBERGER-KLEIN and K. MENRAD (2019): *A Systematic Review on the Effects of Personalized Price Promotions for Food Products*. In: Journal of Food Products Marketing 25 (3): 257–275.

ORTH, B. and J. TÖPPICH (2010): *Veränderungen von Wissen, Einstellungen und Rauchverhalten bei Jugendlichen in Deutschland. Ergebnisse wiederholter Repräsentativbefragungen der Bundeszentrale für gesundheitliche Aufklärung*. In: Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz 53 (2): 133–143.

ORTIZ, A., C. DÍAZ-CARO, D. TEJERINA, M. ESCRIBANO, E. CRESPO and P. GASPAR (2021): *Consumption of fresh Iberian pork: Two-stage cluster for the identification of segments of consumers according to their habits and lifestyles*. In: Meat Science 173: 108373.

ROOSEN, J., M. STAUDIGEL and S. RAHBAUER (2022): *Demand elasticities for fresh meat and welfare effects of meat taxes in Germany*. In: Food Policy 106: 102194.

SÄLL, S. and I.-M. GREN (2015): *Effects of an environmental tax on meat and dairy consumption in Sweden*. In: Food Policy 55: 41–53.

SANCHEZ-SABATE, R. and J. SABATÉ (2019): *Consumer Attitudes Towards Environmental Concerns of Meat Consumption: A Systematic Review*. In: International Journal of Environmental Research and Public Health 16 (7).

SANDERS, J. and J. HEß (2019): *Leistungen des ökologischen Landbaus für Umwelt und Gesellschaft (Benefits of organic farming for the environment and society)*. Thünen Report 65. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_71.pdf. Call: 15.11.2021.

SAVELLI, E., F. MURMURA, L. LIBERATORE, N. CASOLANI and L. BRAVI (2019): *Consumer attitude and behaviour towards food quality among the young ones: empirical evidences from a survey*. In: Total Quality Management & Business Excellence 30 (1-2): 169–183.

SCHULZE STEINMANN, M. and M. ARDEN (2.7.2021): *Tierwohl-Fleisch. Interview mit Aldi-Management: „Das Ding drehen wir nicht mehr zurück“ (Animal welfare meat. Interview with Aldi management: “We’re not turning this thing back”)*. In: top agrar online.

SCOZZAFAVA, G., A. M. CORSI, L. CASINI, C. CONTINI and S. M. LOOSE (2016): *Using the animal to the last bit: Consumer preferences for different beef cuts*. In: Appetite 96: 70–79.

SPILLER, A., A. ZÜHLSDORF, K. JÜRKENBECK and M. SCHULZE (2021): *Jugendumfrage. Weniger Fleisch, mehr Future (Survey among young people. Less meat, more future)*. In: Heinrich-Böll-Stiftung, Bund für Umwelt, Naturschutz Deutschland, Le Monde Diplomatique (Ed.): Fleischatlas. Daten und Fakten über Tiere als Nahrungsmittel. Berlin, Germany.

SPILLER, A., A. ZÜHLSDORF and S. NITZKO (2017): *Die Mischung macht´s: Strategien und Instrumente der Ernährungspolitik (It‘s all in the mix: Strategies and instruments of food policy)*. In: Ernährung im Fokus 9-10 2017: 268–273.

SPRINGMANN, M., M. CLARK, D. MASON-D‘CROZ, K. WIEBE, B. L. BODIRSKY, L. LASSALETTA, W. de VRIES, S. J. VERMEULEN, M. HERRERO, K. M. CARLSON, M. JONELL, M. TROELL, F. DECLERCK, L. J. GORDON, R. ZURAYK, P. SCARBOROUGH, M. RAYNER, B. LOKEN, J. FANZO, H. C. J. GODFRAY, D. TILMAN, J. ROCKSTRÖM and W. WILLETT (2018): *Options for keeping the food system within environmental limits*. In: Nature 562: 519–525.

THAVAMANI, A., T. J. SFERRA and S. SANKARARAMAN (2020): *Meet the Meat Alternatives: The Value of Alternative Protein Sources*. In: Current Nutrition Reports 9 (4): 346–355.

THIES, A. J., F. SCHNEIDER and J. EFKEN (2021): *The Meat We Do Not Eat. A Survey of Meat Waste in German Hospitality and Food Service Businesses*. In: Sustainability 13 (9): 5059.

UN (2015): *Paris Agreement*. United Nations, New York, USA. In: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf. Call: 10.12.2021.

WBAE (2020): *Politik für eine nachhaltigere Ernährung (Policy for a more sustainable diet)*. Eine integrierte Ernährungspolitik entwickeln und faire Ernährungsumgebungen gestalten. Gutachten. Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim BMEL, Berlin.

WEIBLE, D., I. CHRISTOPH-SCHULZ, P. SALAMON and K. ZANDER (2016): *Citizens’ perception of modern pig production in Germany: a mixed-method research approach*. In: British Food Journal 118 (8): 2014–2032.

WILLETT, W., J. ROCKSTRÖM, B. LOKEN, M. SPRINGMANN, T. LANG, S. VERMEULEN, T. GARNETT, D. TILMAN, F. DECLERCK, A. WOOD, M. JONELL, M. CLARK, L. J. GORDON, J. FANZO, C. HAWKES, R. ZURAYK, J. A. RIVERA, W. de VRIES, L. MAJELE SIBANDA, A. AFSHIN, A. CHAUDHARY, M. HERRERO, R. AGUSTINA, F. BRANCA, A. LARTEY, S. FAN, B. CRONA, E. FOX, V. BIGNET, M. TROELL, T. LINDAHL, S. SINGH, S. E. CORNELL, S. K. REDDY, S. NARAIN, S. NISHTAR and C. J. L. MURRAY (2019): *Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems*. In: The Lancet 393 (10170): 447–492.

ZÜHLSDORF, A., K. JÜRKENBECK, M. SCHULZE and A. SPILLER (2021): *Politicized Eater: Jugendreport zur Zukunft nachhaltiger Ernährung*. Göttingen, Germany. In: https://www.uni-goettingen.de/de/document/download/ecc93c87045b061c7e7f61ff5f5f206f.pdf/Jugendreport%20zur%20Zukunft%20nachhaltiger%20Erna%CC%88hrung.pdf. Call: 21.20.2021.

Appendix

Table A1: Monthly fresh meat purchases per capita, cluster in kg and product group expressed as share of in relation to total monthly meat purchase per capita

Buyer Segment	Mean	Median	SD	Min	Max	cv
1 Poultry lovers, purchase per capita in kg	1.54	1.22	1.22	0.06	14.72	0.79
Share of traditional pork cuts (F1)	0.03	0.00	0.06	0.00	0.39	1.66
Share of poultry cuts (F2)	0.48	0.43	0.19	0.24	1.00	0.39
Share of veal cuts (F3)	0.00	0.00	0.00	0.00	0.12	5.17
Share of short roasted beef cuts (F4)	0.01	0.00	0.02	0.00	0.20	2.44
Share of traditional beef cuts (F5)	0.00	0.00	0.02	0.00	0.43	3.60
Share of other lamb cuts than filet (F6)	0.00	0.00	0.01	0.00	0.14	5.63
Share of convenient pork cuts (F7)	0.02	0.00	0.03	0.00	0.15	1.74
Share of premium cuts of beef and lamb (F8)	0.00	0.00	0.01	0.00	0.10	4.32
Share of convenient mixed products (F9)	0.00	0.00	0.01	0.00	0.25	4.30
2 Premium and red meat lovers, purchase per capita in kg	1.71	1.37	1.22	0.12	8.74	0.71
Share of traditional pork cuts (F1)	0.06	0.02	0.09	0.00	0.74	1.52
Share of poultry cuts (F2)	0.16	0.14	0.15	0.00	0.70	0.91
Share of veal cuts (F3)	0.03	0.00	0.05	0.00	0.31	2.07
Share of short roasted beef cuts (F4)	0.11	0.06	0.16	0.00	1.00	1.41
Share of traditional beef cuts (F5)	0.02	0.00	0.05	0.00	0.33	3.53
Share of other lamb cuts than filet (F6)	0.05	0.00	0.10	0.00	0.71	2.00
Share of convenient pork cuts (F7)	0.01	0.00	0.03	0.00	0.20	2.30
Share of premium cuts of beef and lamb (F8)	0.05	0.02	0.08	0.00	0.47	1.45
Share of convenient mixed products (F9)	0.00	0.00	0.01	0.00	0.18	4.45
3 Pork and beef traditionalists, purchase per capita in kg	1.95	1.62	1.38	0.06	20.95	0.71
Share of traditional pork cuts (F1)	0.13	0.08	0.15	0.00	1.00	1.18
Share of poultry cuts (F2)	0.11	0.11	0.09	0.00	0.45	0.83
Share of veal cuts (F3)	0.00	0.00	0.00	0.00	0.12	4.52
Share of short roasted beef cuts (F4)	0.01	0.00	0.02	0.00	0.16	2.44
Share of traditional beef cuts (F5)	0.02	0.00	0.06	0.00	0.87	2.50
Share of other lamb cuts than filet (F6)	0.00	0.00	0.01	0.00	0.14	4.58
Share of convenient pork cuts (F7)	0.03	0.00	0.03	0.00	0.15	3.33
Share of premium cuts of beef and lamb (F8)	0.00	0.00	0.01	0.00	0.10	3.80
Share of convenient mixed products (F9)	0.01	0.00	0.07	0.00	1.00	5.01
4 Convenience-oriented pork buyers, purchase per capita in kg	1.62	1.35	1.06	0.25	7.94	0.65
Share of traditional pork cuts (F1)	0.07	0.04	0.09	0.00	0.66	1.32
Share of poultry cuts (F2)	0.14	0.11	0.12	0.00	0.62	0.89
Share of veal cuts (F3)	0.00	0.00	0.00	0.00	0.10	6.04
Share of short roasted beef cuts (F4)	0.01	0.00	0.02	0.00	1.67	3.26
Share of traditional beef cuts (F5)	0.01	0.00	0.02	0.00	0.32	3.53
Share of other lamb cuts than filet (F6)	0.00	0.00	0.01	0.00	0.11	7.99
Share of convenient pork cuts (F7)	0.21	0.17	0.12	0.10	1.00	0.59
Share of premium cuts of beef and lamb (F8)	0.00	0.00	0.00	0.00	0.12	6.66
Share of convenient mixed products (F9)	0.01	0.00	0.03	0.00	0.57	4.08

Source: Authors' own calculation based on GfK data for 2014.

5.3 The meat we do not eat. A survey of meat waste in German hospitality and food service businesses

Annika Johanna Thies, Felicitas Schneider, Josef Efken

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Erratum: The table caption in ***Table 6*** of the article “The meat we do not eat. A survey of meat waste in German hospitality and food service businesses” incorrectly states that coefficients indicate average marginal effects of a multinomial logistic regression. However, coefficients illustrate average marginal effects of a fractional response regression.

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

Annika Johanna Thies *, Felicitas Schneider and Josef Efken

Institute of Market Analysis, Johann Heinrich von Thuenen Institute, 38116 Braunschweig, Germany; felicitas.schneider@thuenen.de (F.S.); josef.efken@thuenen.de (J.E.)
* Correspondence: annika.thies@thuenen.de

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

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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%.

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	-	-

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.

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.

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.

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

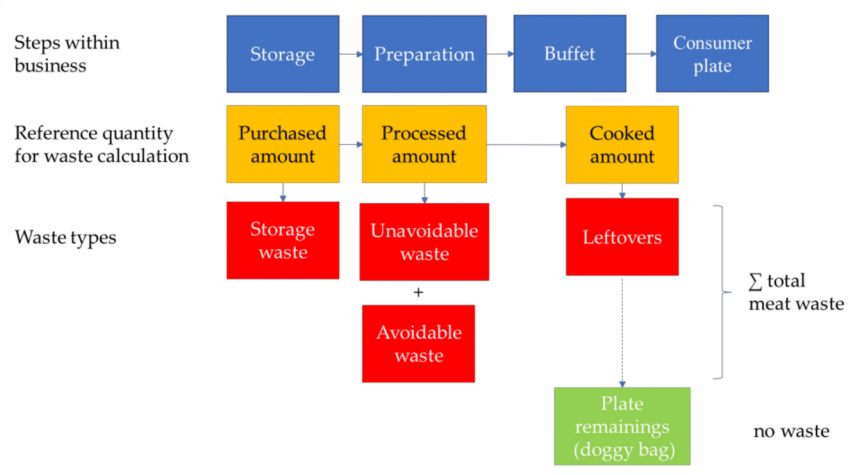

Figure 1. Model for meat waste flows within each assessed HaFS business.

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.

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).

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

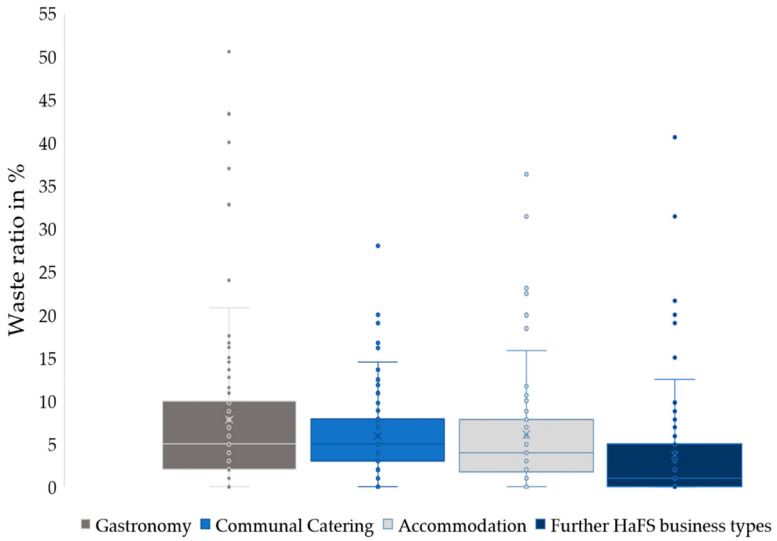

Figure 2. Distribution of total meat waste ratios for the four assessed segments.

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

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.

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).

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 Appendix A).

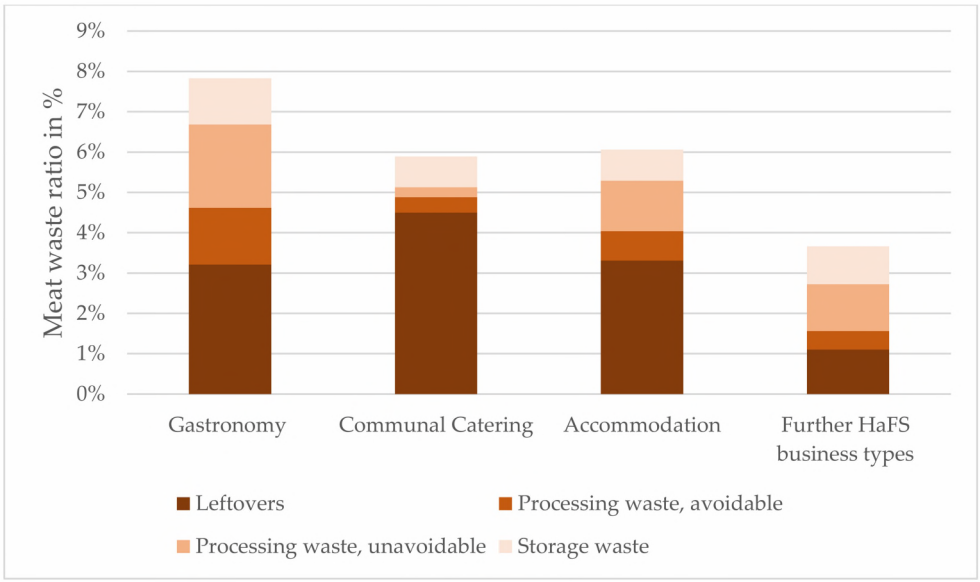

Figure 3. Arising points of meat waste within HaFS segments in percentage.

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.

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%

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.

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.

4.4. Results of Qualitative Statements of Respondents

Based on the qualitative content analysis, three different categories as well as four subcategories 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.

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-R^2 = 0.027. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

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

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.

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 Ger-

many 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.

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Appendix A

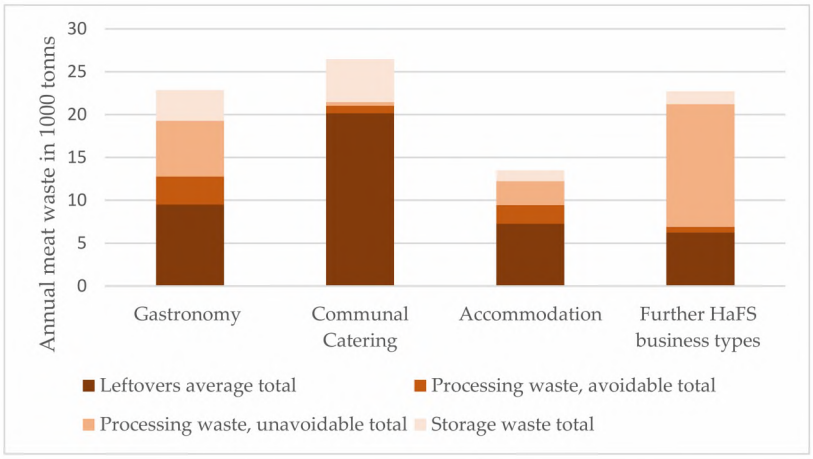

Figure A1. Arising points of meat waste within HaFS segments in 1000 tons.

References

1. Gerten, D.; Heck, V.; Jägermeyr, J.; Bodirsky, B.L.; Fetzer, I.; Jalava, M.; Kummu, M.; Lucht, W.; Rockström, J.; Schaphoff, S.; et al. Feeding ten billion people is possible within four terrestrial planetary boundaries. *Nat. Sustain.* **2020**, *3*, 200–210. [CrossRef]
2. Searchinger, T.; Waite, R.; Hanson, C.; Ranganathan, J. *Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. Synthesis Report*; World Resource Institute: Washington, DC, USA, 2018.
3. United Nations. Resolution Adopted by the General Assembly on 25 September 2015: 70/1. In *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
4. Champions 12.3. Call to Global Action on Food Loss and Waste; Champions 12.3: 2020. Available online: https://champions123.org/publication/call-global-action-food-loss-and-waste (accessed on 30 April 2021).
5. Xue, L.; Liu, G.; Parfitt, J.; Liu, X.; van Herpen, E.; Stenmarck, Å.; O'Connor, C.; Östergren, K.; Cheng, S. Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data. *Environ. Sci. Technol.* **2017**, *51*, 6618–6633. [CrossRef] [PubMed]
6. Caldeira, C.; De Laurentiis, V.; Sala, S. *Assessment of Food Waste Prevention Actions: Development of an Evaluation Framework to Assess the Performance of Food Waste Prevention Actions, EUR 29901 EN.*; Publications Office of the European Union: Luxembourg, 2019; ISBN 978-92-76-12388-0. [CrossRef]
7. Goossens, Y.; Wegner, A.; Schmidt, T. Sustainability Assessment of Food Waste Prevention Measures: Review of Existing Evaluation Practices. *Front. Sustain. Food Syst.* **2019**, *3*, 1–18. [CrossRef]
8. European Commission. *Commission Delegated Decision (EU) 2019/1597 of 3 May 2019 Supplementing Directive 2008/98/EC of the European Parliament and of the Council as Regards a Common Methodology and Minimum Quality Requirements for the Uniform Measurement of Levels of Food Waste*; Official Journal of the European Union: Luxembourg, 2019; p. L248/77.
9. Eurostat. Guidance on Reporting of Data on Food Waste and Food Waste Prevention According to Commission Implementing Decision (EU) 2019/2000. Version of June 2020; European Commission. Available online: https://ec.europa.eu/eurostat/documents/342366/351811/Guidance+on+food+waste+reporting/5581b0a2-b09e-adc0-4e0a-b20062dfe564 (accessed on 13 March 2021).
10. CNCDA—National Commission for Combating Food Waste. National Strategy and Action Plan to Combat Food Waste: Version in Accordance with the Resolution of the Council of Ministers No. 46/2018. In *The Portuguese Official Journal (Diário da República)*; 1st Series; No. 82; CNCDA: Lisbon, Portugal, 2018.
11. Livsmedelsverket; Jordbruksverket; Naturvardsverket. More to Do More—Action Plan for Food Loss and Food Waste Reduction by 2030; Summary, Sweden. 2018. Available online: https://www.livsmedelsverket.se/bestall-ladda-ner-material/sok-publikationer/artiklar/2018/2018-more-to-do-more-action-plan-for-food-loss-and-food-waste-reduction-by-2030?AspxAutoDetectCookieSupport=1 (accessed on 30 April 2021).
12. Official Gazette of the Republic of Croatia 61/2019. *Decision on Adoption of the Plan for Prevention and Reduction of Food Waste Generation of the Republic of Croatia 2019–2022*; The Government of the Republic of Croatia: Zagreb, Croatia, 2019.
13. Schmidt, T.G.; Schneider, F.; Leverenz, D.; Hafner, G. *Lebensmittelabfälle in Deutschland-Baseline 2015*; Johann Heinrich von Thünen-Institut: Brauschweig, Germany, 2019.

14. The Scottish Government. *Food Waste Reduction Action Plan*; The Scottish Government: Edinburgh, Scotland, 2019.
15. Beretta, C.; Hellweg, S. Potential environmental benefits from food waste prevention in the food service sector. *Resour. Conserv. Recycl.* **2019**, *147*, 169–178. [CrossRef]
16. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; De-Clerck, F.; Wood, A.; et al. Food in the Anthropocene: The EAT—Lancet Commission on healthy diets from sustainable food systems. *Lancet* **2019**, *393*, 447–492. [CrossRef]
17. Beretta, C.; Stucki, M.; Hellweg, S. Environmental Impacts and Hotspots of Food Losses: Value Chain Analysis of Swiss Food Consumption. *Environ. Sci. Technol.* **2017**, *51*, 11165–11173. [CrossRef]
18. FAO. Food Wastage Footprint Full-Cost Accounting: Final report. In *Food Wastage Footprint*; FAO: Rome, Italy, 2014.
19. FAO. *Food Wastage Footprint: Impacts on Natural Resources Summary Report*; FAO: Rome, Italy, 2013.
20. Scherhaufer, S.; Moates, G.; Hartikainen, H.; Waldron, K.; Obersteiner, G. Environmental impacts of food waste in Europe. *Waste Manag.* **2018**, *77*, 98–113. [CrossRef]
21. Tonini, D.; Albizzati, P.F.; Astrup, T.F. Environmental impacts of food waste: Learnings and challenges from a case study on UK. *Waste Manag.* **2018**, *76*, 744–766. [CrossRef]
22. Bonnet, C.; Bouamra-Mechemache, Z.; Réquillart, V.; Treich, N. Viewpoint: Regulating meat consumption to improve health, the environment and animal welfare. *Food Policy* **2020**, *97*, 1–11. [CrossRef]
23. Godfray, H.C.J.; Aveyard, P.; Garnett, T.; Hall, J.W.; Key, T.J.; Lorimer, J.; Pierrehumbert, R.T.; Scarborough, P.; Springmann, M.; Jebb, S.A. Meat consumption, health, and the environment. *Science* **2018**, *361*, 6399. [CrossRef]
24. Ruby, M.B. Vegetarianism. A blossoming field of study. *Appetite* **2012**, *58*, 141–150. [CrossRef]
25. The Economist. *The Retreat from Meat: Why People in Rich Countries Are Eating More Vegan Food*; The Economist: London, UK, 2018.
26. IPCC—Intergovernmental Panel on Climate Change. *Summary for Policymakers—Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*; IPCC: Geneva, Switzerland, 2019.
27. WBAE—Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und Gesundheitlichen Verbraucherschutz beim Bundesministerium für Ernährung und Landwirtschaft. *Politik für Eine Nachhaltigere Ernährung (Policy for a More Sustainable Diet): Eine Integrierte Ernährungspolitik Entwickeln und Faire Ernährungsumgebungen Gestalten. Kurzfassung*; WBAE: Berlin, Germany, 2020.
28. Shepon, A.; Eshel, G.; Noor, E.; Milo, R. The opportunity cost of animal-based diets exceeds all food losses. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, 3804–3809. [CrossRef]
29. IPBES—Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *Summary for policymakers—The Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*; IPBES: Bonn, Germany, 2019.
30. Herzberg, R.; Schmidt, T.G.; Schneider, F. Characteristics and Determinants of Domestic Food Waste: A Representative Diary Study across Germany. *Sustainability* **2020**, *12*, 4702. [CrossRef]
31. AMI. *Analysen der AMI auf Basis des GfK-Haushaltspanels (AMI Analyses Based on the GfK Household Panel)*; AMI: Bonn, Germany, 2020.
32. BLE. Fleisch und Geflügel: Versorgungsbilanzen (Meat Supply Balance). *Versorgung mit Fleisch in Deutschland Seit 1991*. Available online: https://www.ble.de/DE/BZL/Daten-Berichte/Fleisch/fleisch_node.html (accessed on 16 March 2021).
33. Silvennoinen, K.; Nisonen, S.; Pietiläinen, O. Food waste case study and monitoring developing in Finnish food services. *Waste Manag.* **2019**, *97*, 97–104. [CrossRef]
34. Engström, R.; Carlsson-Kanyama, A. Food losses in food service institutions Examples from Sweden. *Food Policy* **2004**, *29*, 203–213. [CrossRef]
35. Matzembacher, D.E.; Brancoli, P.; Laís, M.; Eriksson, M. Consumer's food waste in different restaurants configuration: A comparison between different levels of incentive and interaction. *Waste Manag.* **2020**, *114*, 263–273. [CrossRef]
36. Reinders, M.J.; van Lieshout, L.; Pot, G.K.; Neufingerl, N.; van den Broek, E.; Battjes-Fries, M.; Heijnen, J. Portioning meat and vegetables in four different out of home settings: A win-win for guests, chefs and the planet. *Appetite* **2020**, *147*, 104539. [CrossRef]
37. Wang, L.; Liu, G.; Liu, X.; Liu, Y.; Gao, J.; Zhou, B.; Gao, S.; Cheng, S. The weight of unfinished plate: A survey-based characterization of restaurant food waste in Chinese cities. *Waste Manag.* **2017**, *66*, 3–12. [CrossRef]
38. Noleppa, S.; Cartsburg, M. *Das Große Wegschmeißen (The great throwaway): Vom Acker bis zum Verbraucher: Ausmaß und Umwelteffekte der Lebensmittelverschwendung in Deutschland*; WWF: Berlin, Germany, 2015.
39. Xue, L.; Prass, N.; Gollnow, S.; Davis, J.; Scherhaufer, S.; Östergren, K.; Cheng, S.; Liu, G. Efficiency and Carbon Footprint of the German Meat Supply Chain. *Environ. Sci. Technol.* **2019**, *53*, 5133–5142. [CrossRef]
40. WRAP. *Overview of Waste in the UK Hospitality and Food Service Sector*; WRAP: Banbury, UK, 2013.
41. Schranzhofer, A.; Rockenbauer, R.; Tragner, F.; Hala, V.; Hrad, M.; Ottner, R.; Obersteiner, G.; Schneider, F.; Lebersorger, S.; Manhardt, A.M.; et al. *Vermeidung von Lebendmittelabfall in Gastronomie, Beherbergung und Großküchen (Avoidance of Food Waste in Gastronomy, Accommodation and Canteen Kitchens). Endbericht (Final Report)*; United Against Waste: Vienna, Austria, 2015.
42. Papargyropoulou, E.; Steinberger, J.K.; Wright, N.; Lozano, R.; Padfield, R.; Ujang, Z. Patterns and Causes of Food Waste in the Hospitality and Food Service Sector: Food Waste Prevention Insights from Malaysia. *Sustainability* **2019**, *11*, 6016. [CrossRef]
43. Dinno, A. Nonparametric Pairwise Multiple Comparisons in Independent Groups using Dunn's Test. *Stata J.* **2015**, *1*, 292–300. [CrossRef]

44. Papke, L.E.; Wooldridge, J.M. Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *J. Appl. Econom.* **1996**, *11*, 619–632. [CrossRef]
45. Cameron, A.C.; Trivedi, P.K. *Microeconometrics Using Stata*; Stata Press: College Station, TX, USA, 2009; p. 692.
46. Mayring, P.; Fenzl, T. Qualitative Inhaltsanalyse (Qualitative Content Analysis). In *Handbuch Methoden der Empirischen Sozialforschung*; Baur, N., Blasius, J., Eds.; Springer Fachmedien Wiesbaden: Wiesbaden, Germany, 2019; pp. 633–648.
47. Thies, A.; Efken, J.; Sönnichsen, M. *Abschlussbericht zur Neuberechnung der Koeffizienten zur Ermittlung des Menschlichen Fleischverzehrs aus der Versorgungsbilanz Fleisch für Schwein-, Rind- und Geflügelfleisch (Final Report on the Recalculation of the Coefficients for Determining Human Meat Consumption from the Meat Supply Balance Sheet for Pork, Beef and Poultry)*; Schriftlicher Auftrag: BMEL. Unpublished; Johann Heinrich von Thünen-Institut: Braunschweig, Max Rubner-Institut, Federal Research Institute of Nutrition and Food Department of Safety and Quality of Meat: Kulmbach, Germany, 2021.
48. Schmidt, T.; Claupein, E.; Dirksmeyer, W.; Hafner, G.; Waskow, F. *Wege zur Reduzierung von Lebensmittelabfällen—Pathways to Reduce Food Waste (REFOWAS): Maßnahmen, Bewertungsrahmen und Analysewerkzeuge Sowie Zukunftsfähige Ansätze für Einen Nachhaltigen Umgang mit Lebensmitteln unter Einbindung Sozioökologischer Innovationen (Measures, Evaluation Frameworks and Analysis Tools as well as Sustainable Approaches for a Sustainable Handling of Food with the Integration of Socio-Ecological Innovations)*; Johann Heinrich von Thünen-Institut: Braunschweig, Germany, 2019.
49. Haenel, H.-D.; Rösemann, C.; Dämmgen, U.; Döring, U.; Wulf, S.; Eurich-Menden, B.; Freibauer, A.; Döhler, H.; Schreiner, C.; Osterburg, B.; et al. *Calculations of Gaseous and Particulate Emissions from German Agriculture 1990–2018: Report on Methods and Data (RMD) Submission 2020*; Johann Heinrich von Thünen-Institut: Braunschweig, Germany, 2020.
50. Umweltbundesamt. Energieverbrauch Privater Haushalte (Energy Consumption of Private Households). Available online: https://www.umweltbundesamt.de/daten/private-haushalte-konsum/wohnen/energieverbrauch-privater-haushalte#endenergieverbrauch-der-privaten-haushalte (accessed on 16 March 2021).
51. Statistisches Bundesamt. Umweltnutzung und Wirtschaft (Environment and Economy): Tabellen zu den Umweltökonomischen Gesamtrechnungen Teil 5: Verkehr und Umwelt, Landwirtschaft und Umwelt. Available online: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Publikationen/Umweltnutzung-Wirtschaft/umweltnutzung-und-wirtschaft-tabelle-5850007187006-teil-5.pdf?__blob=publicationFile (accessed on 28 March 2021).
52. Pradhan, P.; Costa, L.; Rybski, D.; Lucht, W.; Kropp, J.P. A Systematic Study of Sustainable Development Goal (SDG) Interactions. *Earth's Future* **2017**, *5*, 1169–1179. [CrossRef]
53. Elimelech, E.; Ert, E.; Ayalon, O. Bridging the gap between self-assessments and measured household food waste: A hybrid valuation approach. *Waste Manag.* **2019**, *95*, 259–270. [CrossRef]
54. Giordano, C.; Alboni, F.; Falasconi, L. Quantities, Determinants, and Awareness of Households' Food Waste in Italy: A Comparison between Diary and Questionnaires Quantities'. *Sustainability* **2019**, *11*, 3381. [CrossRef]
55. van Herpen, E.; van Geffen, L.; Nijenhuis-de Vries, M.; Holthuysen, N.; van der Lans, I.; Quested, T. A validated survey to measure household food waste. *MethodsX* **2019**, *6*, 2767–2775. [CrossRef]
56. GSARS. *Field Test Report on the Estimation of Crop Yields and Post-Harvest Losses in Ghana*; GSARS: Rom, Italy, 2017.
57. Kuntscher, M.; Schmidt, T.; Goossens, Y. *Lebensmittelabfälle in der Außer-Haus-Verpflegung-Ursachen, Hindernisse und Perspektiven -(Food Waste in Out-of-Home Catering—Causes, Obstacles and Perspectives-)*; Johann Heinrich von Thünen-Institut: Braunschweig, Germany, 2020.
58. Głuchowski, A.; Czarniecka-Skubina, E.; Buła, M. The Use of the Sous-Vide Method in the Preparation of Poultry at Home and in Catering—Protection of Nutrition Value Whether High Energy Consumption. *Sustainability* **2020**, *12*, 7606. [CrossRef]
59. Kataria, J.; Garner, L.J.; Monu, E.A.; Wang, Y.; Morey, A. Investigating the effects of Functional Ice (FICE) on Salmonella-food safety, microbial spoilage and quality of raw poultry thigh meat during refrigerated storage. *PLoS ONE* **2020**, *15*, e0234781. [CrossRef]
60. United Against Waste. *Food Waste 4.0: Zwischenbilanz 2020—Reduktionsziele, Warenverlust und Umweltkennzahlen (Interim Balance 2020—Reduction Targets, Loss of Goods and Environmental Indicators)*; United Against Waste: Planstadt, Germany, 2020.
61. Tabellarische Übersicht der Umfrageergebnisse zu Restlos Genießen. *Befragungszeitraum: 13.07–15.07.2017*; Kanter Emnid: Munich, Germany, 2017.
62. BMEL. Ausgezeichnetes Engagement Gegen Lebensmittelverschwendung: Die Gewinner und Nominierten des Zu gut für die Tonne!—Bundespreises 2018 (Totally Worthy of an Award—Outstanding Commitment against Food Waste: The Winners and Nominees of the Too Good for the Bin! National Award 2018). Available online: https://www.ble-medienservice.de/frontend/esddownload/index/id/1194/on/7737_DL/act/dl (accessed on 17 March 2021).
63. BMEL. *National Strategy for Food Waste Reduction*; Bundesministerium für Ernährung und Landwirtschaft: Berlin, Germany, 2019.
64. WRAP. *Meat in a Net Zero World: Optimising Productivity and Minimising Waste from Farm to Fork*; WRAP: Bunbury, UK, 2020.

6 General discussion

Nutrition can be described as a link between human and planetary health, especially in the context of dietary compositions changing towards greater meat components (TILMAN and CLARK, 2014). Curbing meat demand, especially in countries with persistently high per capita meat consumption levels (STOLL-KLEEMANN and SCHMIDT, 2017), and reducing wasted food quantities, could significantly contribute to achieving global sustainability goals (WILLETT et al., 2019; WBAE, 2020).

By assessing the current meat consumption level, meat waste out-of-home, and meat purchasing patterns of individual consumer groups in Germany this dissertation presents important implications for researchers, policy makers, and market participants. First, a regular monitoring of meat consumption at the population level is a prerequisite to assessing long-term developments (FEHRENBACH et al., 2016) and to providing initial indications concerning related political intervention (THAR et al., 2020). Reliable information on total and per capita meat consumption is therefore an essential part of a comprehensive national nutrition monitoring as required by the WBAE (WBAE, 2020). Second, measures need to consider individual consumer groups in order to manage meat demand through legislative interventions or to effectively implement marketing strategies that shift consumption patterns away from meat-oriented towards more plant-based eating (APOSTOLIDIS and MCLEAY, 2016). Detailed consumer profiles provide insights into heterogeneity in this context. Third, wasted meat quantities need to be measured regularly in order to assess the environmental footprint of meat demand (KARWOWSKA et al., 2021). A differentiated contemplation of individual stages of the value chain, arising points, and waste types allows to identify hotspots of meat waste and to subsequently derive targeted prevention and reduction measures.

Against this background and based on three contributing articles, this dissertation addresses three overarching research questions:

RQ I What is the average meat consumption in Germany based on a market balance approach?

RQ II What are meat purchasing patterns and characteristics of related consumer groups in Germany?

RQ III Are there options to reduce meat waste at different arising points in German Hospitality and Food Service businesses?

After having presented the conceptual framework in chapter 4, the following chapter discusses the main findings of the three articles in relation to relevant literature and suggests options for future research.

RQ I What is the average meat consumption in Germany based on a market balance approach?

The average per capita meat consumption determined for the year 2018, comprises 34.8 kg pork, 11.5 kg beef, and 15.8 kg poultry with a total average meat consumption of 64.7 kg per capita. The uncertainty of the estimated meat consumption level is determined to be 20% by means of a sensitivity analysis. Particularly, modified assumptions on food waste at the consumer level including cooking losses, lower the estimated results to 51.6 kg.

Food-based dietary guidelines are an integral component of national food policies and primarily provide nutritional recommendations from a health perspective. FISCHER and GARNETT (2016) revealed that 24% of national dietary guidelines emphasise a modest or reduced meat intake, especially of processed and red meat (i.e., beef, pork, and lamb). Individual food guidelines (e.g., Sweden and Germany) even suggest certain environmental effects of overconsumption concerning animal sourced foods and therefore generally strive for “win-win” diets which are beneficial for both environmental and human health (FISCHER and GARNETT, 2016).

Referring to the prepared meat quantity, an average annual per capita level of 52 kg exceeds the 31 kg recommended by the German Nutrition Society (DGE) as a maximum meat intake needed for maintaining good health (DGE, 2020b). Other national directives provide similar benchmarks. Finland and Sweden suggest an annual meat intake 26 kg per capita and year; Austria urges people not to eat more than 23 kg of meat a year; and Belgium recommends a level of 31 kg (FAO, 2021b). The World Cancer Research Fund Network (WCRF) and the American Institute for Cancer Research (AICR) recommend not to eat more than 26 kg of cooked meat per capita and year, with the intake of processed meat reduced to a minimum amount (WCRF and AICR, 2018).

The meat consumption level determined in article (1) is also not reconcilable with “planetary health diets” on a global level. To comply with the Paris Agreement, WILLETT et al. (2019) put the globally compatible average meat consumption at only 16 kg. They used various indicators to define planetary boundaries (i.e., greenhouse gas emissions, nitrogen application, phosphorus application, consumptive water use, extinction rate, and cropland use). WILLETT et al. (2019) also assumed a doubling of the consumption of fruit and vegetables, while halving FLW.

Whether the results of article (1) provide a sufficient rationale for profound legislative intervention would have to be further examined in consideration of economic theory. Meat-heavy diets might lead to market failure for three reasons. Externalities of meat consumption arise in connection with negative environmental effects, but also in relation to intensive animal husbandry systems if animal welfare is considered a public good. Additionally, health risks of heavy meat eaters have a negative influence on the entire society because of the "collective nature" of the health care system (BONNET et al., 2020). In light of these three domains, meat has been characterised as a potential "demerit" good by a majority of German economists, who therefore justify distinct regulatory efforts (AHLHEIM et al., 2020).

However, without an internalisation of externalities in the market it can hardly be ascertained whether current supply and demand levels lead to a socially desirable outcome (MORAN, 2021). Due to missing "first-best" solutions for agricultural livestock farming, "second-best" consumption taxes on domestic and imported meat products might mitigate the multiple externality issue (FUNKE et al., 2022). In the course of a compensation, external costs would initially have to be monetised according to the "polluter-pays principle" (MITTIGA, 2018). There is further need for research especially with regard to the "real costs" of biodiversity loss and animal-welfare issues in this context (FUNKE et al., 2022).

In agreement with existing scientific literature (RODRIGUES et al., 2007; NASKA et al., 2009; DEL GOBBO et al., 2015; FAO, 2017), findings of article (1) suggest a mismatch between results of market balance approaches, individual dietary surveys (IDS), and household budget surveys (HBS). According to the NVS II, average annual meat intake of adult meat consumers amounted to 43 kg per capita between 2005 and 2007 (KOCH et al., 2019; STRAßBURG et al., 2019). As described in chapter 2.2, information on fresh meat purchases of private households is also provided by GfK with an average meat purchasing level of 33 kg per capita, expressed as product weight in 2018 (AMI, 2020). Conforming to expert information, the market coverage of the respective GfK household panel lies between 75% and 90% due to unrecorded meat components contained in convenience products or lacking purchase data (e.g., from weekly markets). Out-of-home consumption accounts for an additional 36% of the total meat consumed (author's own calculation based on results of article (1)). Against this background and considering cooking losses of approximately 20% (SHOWELL et al., 2012), average meat consumption per capita would amount to approximately 55 kg based on the demand-side and revealed preferences.

However, consumption indications based on FBS, HBS, and IDS are only partially comparable, because they represent different value chain stages (SERRA-MAJEM, 2001) and use divergent food group compositions or methodological concepts (RODRIGUES et al., 2007). Hence, these data sources should rather be used in a complementary way (RODRIGUES et al., 2007; AMO et al., 2016). IDS and HBS allow for an analysis of the

behaviour of individual consumer groups as demonstrated in the course of article (2). Answering RQ I by referring to the coefficients presented in article (1) enables the identification of dietary trends in connection with the annually calculated domestic meat supply at population level.

The estimation technique proposed in article (1) represents an update compared to the original approach, as meat-type specific marketing channels as well as loss and waste quantities for individual value chain stages are considered. The procedure takes up methodological claims raised in scientific literature. DOWLER and SEO (1985) argued that mass flows along food value chains need to be captured to derive human consumption of specific foods. SERRA-MAJEM (2001) and NASKA et al. (2009) asked to consider consumer waste when calculating human food consumption. In addition, the proposed method considers meat sold for pet-food production, mentioned by THAR et al. (2020) as a potential limitation of FBS information since pet-food might still be included in specified consumption levels.

An analysis of foreign trade data in edible offal and by-products and a subsequently revised allocation of the CN-codes related to beef and pork also allows for a more accurate calculation of meat consumption. There is a need for further research in this context, as incorrect allocations of CN-codes are most likely also to be found for other EU Member States. Both domestic supply and the consumption level calculated are influenced by incorrect quotas. This is why consultations on the assignment of CN-codes for meat, edible offal, and by-products with reference to official trade statistics would make an important contribution towards improved consistency of the EU FBS.

Despite the evaluation of three sensitive parameters (i.e., the share of production exported or sold for pet-food production as well as assumptions on consumer waste), further limitations must be considered in the course of interpreting the results of article (1). Per capita values are calculated by means of official statistics of population size (BLE, 2021) which does not include tourists consuming meat in Germany. Further limitations are related to the sample size at slaughterhouse level. Businesses with low slaughter capacities are not part of the sample and may have divergent sale channels. Seasonal effects are also not mapped, but are minimised by querying two reference years. Commodity flows between the individual value chain stages (processing - wholesale - food retail - export - import - consumption at-home and out-of-home) are not systematically revealed and are also likely to be transitory. Participating slaughterhouses indicate that marketing shares change in the course of a single year. Nevertheless, profound shifts between marketing channels or at-home and out-of-home consumption might still emerge rather successively as changes in domestic meat supply are gradual with regard to meat types and quantity (BLE, 2021). A

temporary validity of the estimated coefficients can therefore be assumed, however, surveys at slaughterhouse level would have to be repeated at regular intervals.

Expert assessments are obtained since representative meat loss ratios at the processing and wholesale level related to respective available meat quantities are not available. These information gaps should be filled in order to more precisely map the environmental effects of meat consumption. The corresponding research gap regarding meat waste in the HaFS sector is addressed by answering RQ III as part of this dissertation.

As mentioned by DOWLER and SEO (1985), the notion of food consumption depends on the scientist's objective. Authors and policy makers therefore need to clarifying whether they refer to the actually ingested quantity (meat intake), the quantity intended for human consumption or the domestic meat supply.

Due to an overestimation of waste, losses and non-food uses, meat consumption in Germany has so far been underestimated by 4 kg per capita based on the current supply-side approach. Overall, a meat consumption level of 64.7 kg per capita on average is not compliant with national health (DGE, 2020b) or international environmental goals (WILLETT et al., 2019). This is why there is certainly an even greater need for further political coordination regarding a desirable consumption level in the course of a national food strategy.

RQ II What are meat purchasing patterns and characteristics of related consumer groups in Germany?

Article (2) demonstrates the heterogeneity of meat purchasing behaviour among German households. A segmentation based on meat product purchases of private households reveals four household clusters which significantly differ in relation to their product portfolio and purchased meat quantities. A large segment of *pork and beef traditionalists* (59% of the total sample; 1.95 kg monthly meat purchase per capita) and three smaller segments described as *poultry lovers* (25%; 1.54 kg per capita), *premium red meat lovers* (5%; 1.71 kg per capita), and *convenience-oriented pork buyers* (11%; 1.62 kg per capita) are identified.

A direct comparison of the results with previous scientific studies is not possible since revealed product-based preferences have not yet been used for a segmentation of German meat consumers. CORDTS et al. (2014) also found heterogeneity among German meat buyers but based their segmentation on self-reported total meat quantities in addition to the sustainability and health orientation of participants.

According to the results of article (2), the majority of German households can still be described as "classic meat eaters". *Pork and beef traditionalists* purchase 0.48 kg of fresh

meat per week which accounts for approximately one third of their total meat consumption (AMI, 2020, author's own calculation based on article 1). This is in contrast to representative surveys indicating that a flexitarian diet is already more prevalent among the German population. According to a survey conducted by Forsa, 55% of the respondents reported to abstain from meat at least three times a week (FORSA, 2020). Findings of article (2) therefore confirm main statements of article (1) and further reveal the existence of a citizen-consumer dichotomy. The importance of revealed-preference data in order to draw conclusions about purchase patterns is underpinned by the small share of *premium red meat lovers* that actually show a "willingness to pay" (WTP) well above average unit values. This finding also contradicts survey-based studies, typically indicating higher WTP for sustainability characteristics such as animal welfare (EC, 2016).

A characterisation of individual household clusters gives additional insights into purchasing patterns that allow for the derivation of options and challenges when aiming for a dietary change.

In order to achieve a more rapid nutritional transformation overall, *pork and beef traditionalists* would need to cut down on meat-eating. This would be especially desirable due to their high level of fresh meat purchases and the nutrient composition of purchased pork products. Associated reference persons are of advanced age, which is why their eating behaviour is likely to be habitual (BROMBACH et al., 2015). Households report to be price sensitive when purchasing food and pay rather low average prices for meat. Intermediate to high net incomes decrease the chance of belonging to *pork and beef traditionalists*. Therefore, increased meat prices through meat taxation could cause a drop in their meat demand as studies usually observe increased price sensitivity together with more limited financial resources (PARK et al., 1996; NI MHURCHU et al., 2013; PELTNER and THIELE, 2021).

However, in view of their deeply anchored food habits, it remains unclear to what extent a profound and long-term change can be sustainably controlled by legislative intervention. Significant price increases might be needed to cause a real change for *pork and beef traditionalists*. Also, because price elasticities of meat demand, which indicate anticipated effects of meat taxes (WBAE, 2020), are comparatively low for high-income countries (FEMENIA, 2019). PELTNER and THIELE (2021) determined a price elasticity of -0.67 for meat demand (including fish and eggs) and low-income German households.

The Competence Network on Animal Husbandry ("Borchert Kommission") is in favour of introducing an excise tax to finance improved animal husbandry conditions in Germany (KNW, 2020). ROOSEN et al. (2022) found that a per-unit CO_2-eq tax of 93 € per ton CO_2 in order to internalise external costs could lead to a reduction in per capita consumption of 21% for beef, 13% for pork, and 9% for poultry (ROOSEN et al., 2022).

The WBAE advocates raising the value-added tax (VAT) rate on animal products from 7% to 19% as only a transitional solution towards meat demand management (WBAE, 2020). This taxation is in most cases likely to result in lower changes in demand. According to DEBLITZ et al. (2021), a corresponding adjustment of the VAT rate would only lead to a reduced consumption of 6% for beef, 5% for pork, and 4% for chicken meat. ROOSEN et al. (2022) estimated demand effects of -11% for beef, -12% for pork, and -11% for poultry.

A direct comparison of both tax designs through an increased VAT rate to 14% and a CO_2-eq tax of 37 € per ton CO_2 conducted by ROOSEN et al. (2022) illustrates that the excise tax is more effective with a view toward environmental goals and causes lower welfare costs for all households.

Nevertheless, and for both options, the resulting social issues caused by the financial burden on economically less privileged groups are key challenges (KNW, 2020; WBAE, 2020). Furthermore, the effects of different financial incentives would need to be analysed in more detail, e.g., by estimating demand systems for the consumer segments identified in article (2). Substitution effects between meat categories and alternative products need to be considered in order to assess possible rebound effects and the anticipated total effect of meat taxation. ROOSEN et al. (2022) have already illustrated noticeable responses to price variations across household groups differentiated by age and income. Interestingly, they reported lower price elasticities for households with a high per capita meat consumption level. However, their results most likely depict reactions of demand due to temporary price changes caused by seasonality, price discounts, or product promotions. These effects would need to be factored in when conducting further research in order to reflect long-term changes in meat consumption as a result of long-term price changes through fiscal approaches.

Individuals can change their behaviour by adapting to the norms of others (CIALDINI, 2007) and transformation processes based on social tipping points can be triggered by minorities of consumers (OTTO et al., 2020). It therefore seems reasonable to examine consumer segments that already deviate from traditional dietary habits. Two of the clusters found already buy meat quantities below the total samples average and are comprised of rather young household reference persons. They account for 36% of all households.

Female-headed single households of *poultry lovers* consume a rather healthy assortment of meat types, state to be quality-conscious, and pay comparatively high unit values for meat. Male-headed *convenience-oriented pork buyers* express being less quality-motivated with rather limited financial resources while favouring easy-to-prepare pork products.

Changes in the meat demand of younger consumers compared to “traditional dieters” have already been identified by existing scientific literature. ZÜHLSDORF et al. (2021) found

that 40% of young adults, especially female consumers, reconsider their meat consumption level with environmental consequences as a particular driving factor. In this context, KUŹNIAR et al. (2021) identified rising consumer awareness as a promising measure among millennials. NADERI and VAN STEENBURG (2018) found that "rational and self-oriented motives" caused millennials to behave in a more environmentally-friendly way. Target-oriented marketing measures that are aiming to encourage consumers' choices for healthier and more climate-friendly meat, hybrid meat substitutes, or meat alternatives should take this behavioural motivation into account.

In addition to increased meat prices, personalised price promotions (PPP) of plant-based alternatives might encourage a more balanced diet of the price-conscious *convenience-oriented pork buyers.* Positive financial incentives evoke less negative emotional response than negative financial incentives (JUST and HANKS, 2015). NGUYEN et al. (2019) regarded PPP as an effective measure to stimulate purchases of foods with health benefits. The dietary behaviour of *convenience-oriented pork buyers* is not yet well-established and they are unlikely to respond to informative measures due to a lack of interest in quality signals. This is why positive financial incentives might contribute to a long-term adoption of plant-based meat alternatives for this segment. Comparatively high purchases of meat substitutes in combination with reduced meat purchases among the younger age groups (see chapter 2.1) highlights the potential for a more flexitarian diet-style among German consumers overall.

The cluster of *premium red meat lovers* would initially have to be targeted by policies from an environmental perspective due to the climate effects of meat types favoured by this segment (CLUNE et al., 2017). However, looking at their financial standing, their expenditure on meat and taste for high-priced premium products and due to their low price-sensitivity, financial incentives might not bring about a sufficient behavioural change in this case. A shift towards a more sustainable dietary behaviour might rather be achieved through further qualitative change. Information campaigns or governmental multilevel labelling, as envisaged by the WBAE (WBAE, 2020), could promote meat with less climate effect or produces under improved animal welfare conditions. In this context, animal welfare might be used as a unique selling point in relation to meat quality (DERSTAPPEN et al., 2021) since quality seems to be an important buying criterion for *premium red meat lovers*. By the same token and with a view toward *poultry lovers*, informative measures could promote organic meat as a more sustainable alternative which is associated with slightly enhanced animal welfare as well as improved water conservation, biodiversity, and soil fertility (SANDERS and HEß, 2019).

Market coverage is a relevant limitation of the results presented in article (2). The used dataset comprises exclusively fresh meat purchases. Future research may include

processed meat and meat products. Along the same line, the meat consumed out-of-home for which revealed-preference data with regard to quantity, type, and origin of meat is lacking is not considered. Also, the analysis of meat purchasing behaviour is household-based and thus carried out at an aggregated level. A regular collection of the corresponding information at an individual or at household level would contribute to an adequate database for national monitoring of nutrition.

Results of article (2) imply that different approaches are needed instead of using one single silver bullet in order to achieve a more sustainable meat demand in Germany. A correspondingly tailored product range including plant-based products or hybrid meat substitutes may be accompanied by target-oriented communication and effective pricing measures to facilitate healthier and environmentally friendly every-day food choices. This could bring about a change in the "food environment" covering "exposure and access" to as well as "choice and consumption" of food (WBAE, 2020).

RQ III Are there options to reduce meat waste at different arising points in German Hospitality and Food Service businesses?

In line with articles (1) and (2), a quantification of meat waste in HaFS businesses differentiated by individual points of waste arising in the course of article (3) calls for further action. The estimated annual meat waste is 85,800 tons for the German HaFS sector, encompassing 72% avoidable waste quantities. Leftovers account for 50% of the total meat waste, whereas meat waste in the course of storage and processing is less severe (i.e., accounts for 12% and 37%, respectively). Since a considerable share of wasted meat is linked to prepared meals and thus to behavioural issues, there is a potential for meat waste reduction through more waste-aware behaviour among guests and staff. This is further supported by the fact that accepting mean waste ratios of the lower quartile (bottom 25%) of each of the four segments as a feasible benchmark would potentially reduce wasted meat quantities by 77%.

Meat waste ratios vary at a business-type level and significantly differ between the first three segments (i.e., *gastronomy, communal catering,* and *accommodation*) and *further HaFS businesses*. The highest total (7.8%) and avoidable (5.8%) mean waste ratio is found for the *gastronomy* segment. Although a direct comparison with existing literature is difficult due to different reference units being used and prevailing framework conditions, the found mean meat waste ratios (3.7-7.8%) deviate only slightly from the results of PAPARGYROPOULOU et al. (2019) who calculated a meat waste ratio of 2.3-2.6% within the Malaysian HaFS sector. Considering total quantities, the *gastronomy* and *communal catering* segments would have to be addressed specifically. A study conducted by the

Waste & Resources Action Programme (WRAP) likewise saw the greatest potential for overall waste reduction for restaurants (classified as *gastronomy* within this thesis), Quick Service Restaurants (QSRs), pubs and services (classified as *communal catering*) (WRAP, 2013).

Leftovers are identified as a hot spot compared to the remaining arising points. They make up the largest share of total waste in *gastronomy* (45%) and *accommodation* (55%) and account for 75% of the meat wasted in *communal catering*. Although leftovers include overproduction in the kitchen, at the buffet, and plate waste, an accordingly large potential for waste reduction through improved matching of served and actually eaten dishes has been identified by other authors. TOMASZEWSKA et al. (2021) found that the share of plate waste in hotel food services made up nearly 50%. PAPARGYROPOULOU et al. (2019) and WRAP (2013) estimated customer plate waste to account for up to one-third of wasted food quantities out-of-home.

The comparably high share of unavoidable processing waste within *gastronomy* is not verifiable by previous literature. KUNTSCHER et al. (2020) observed a high number of convenience meat products within *communal catering*. It was therefore to be expected that *gastronomy* businesses under comparable conditions would also purchase pre-processed meat and report less unavoidable waste. There is a need for further research as the utilisation of non-edible components at early value chain stages (e.g., in slaughterhouses or at meat processing) would most likely be beneficial for reasons of economies of scale, and considering the waste hierarchy, to ensure environmentally compatible waste management (EC, 2008).

Considering the above conducted classification of the determined waste ratios, the approach presented describes an effective way to quantify meat waste and establish corresponding benchmarks. The results of article (3) might therefore provide important indications for the implementation of the German National Strategy for Food Waste Reduction (BMEL, 2019b). Based on a voluntary agreement resolved within the “Dialogue Forum on Away-from-Home Consumption”, food waste is supposed to be regularly measured using comparable methodological techniques and reference units (BMEL, 2019b). According to the Delegated Decision 2019/1597 of the European Commission (i.e., the legal basis for national monitoring), a differentiation between product categories or waste types is not compulsory (EC, 2019). At least a more differentiated data collection at national level is recommended in the course further explanations on the Dialogue Forum´s target agreement (FRIEDRICH and BORSTEL, 2021) and should also be aimed for given varying climate effects of individual food products (CLUNE et al., 2017).

A perception-related bias is a potential limitation of the study related to an underestimation of overall meat waste quantities. However, for economic reasons, the

respondents' appraisal skills can be expected to be adequate regarding weekly purchased, processed, and sold meat quantities. Vegetarian and vegan restaurants are not part of the sample, but are considered for extrapolation of waste quantities. This might cause a slight overestimation of meat waste quantities. In contrast, prisons, correctional facilities, and the recreational sector are not included in the sample.

Appropriate legal framework conditions and private sector solutions could contribute to considerable levels of waste reduction. Donations of overproduction via (social) distribution organisations prove to be a promising waste prevention measure. However, several participating businesses indicate that the collaboration with food banks is complicated and difficult due to legal hygiene requirements. Facilitating food donations is also subject to the National Strategy for Food Waste Reduction (BMEL, 2019b). In this context, the Federal Council of Germany has additionally proposed to examine the limitation of legal liability for donated foodstuffs (BR, 2021). Clarifying that the liability for shelf life and the quality of leftover food lies with guests or customers could reduce barriers for the donation of edible meat dishes and ease concerns about food scandals.

The results of article (3) suggest that the offering of doggy bags to reduce leftovers depends on operating conditions and is only common in the *gastronomy* segment. Rising awareness among customers and reducing socially negative attitudes towards the use of doggy bags is also needed to encourage diners to use them (MIROSA et al., 2018).

Corresponding communicative measures should address kitchen staff, managers as well as guests. Measuring food waste on a regular basis might enable improved purchase planning and reduce overproduction within the kitchen (KUNTSCHER et al., 2020). A prevention of unsold meat quantities, especially in terms of premium cuts, is most likely an even greater economic incentive for food waste prevention at business level than discounted sales of surplus portions.

TOMASZEWSKA et al. (2021) proposed to emphasise the environmental effects of food waste when communicating with consumers, which could particularly raise moral concerns among younger guests. ZÜHLSDORF et al. (2021) demonstrated that the environmental footprint led young consumers to reconsider their demand for meat. Accordingly, they might also be willing to reduce plate waste when eating out-of-home.

In the context of promoting more sustainable nutrition, the Federal Ministry of Food and Agriculture (BMEL) announced the implementation of climate-friendly menus in federal canteens (BMEL, 2020). The DGE quality standards for communal catering seek to offer meals containing meat two times a week and to use an increased share of meat from improved husbandry conditions. They further recommend to offer small portions trying to achieve less wasteful behaviour among guests (DGE, 2020a). The benefits of food and meat waste prevention could be highlighted even more clearly in this context. A nationwide

information campaign “Zu gut für die Tonne” (Too good for the bin) has already sought to raise public awareness for the issue (BMEL, 2019a). Whether such informative measures are successful in the long term needs to be verified based on regularly collected waste quantities.

In the course of article (3), individual measures for meat waste reduction within the German HaFS meat supply chain are specified. Considering economic theory, there is certainly space for additional research.

Since the implementation of reduction measures comes at a cost and restaurant operators act as profit maximisers (GOLAN et al., 2020), individuals will initially reduce food and meat waste until their marginal costs equal marginal benefits (MOUNTER et al., 2019). A certain quantity of uneaten meat may therefore be already an optimal market outcome based on market constraints, including imperfect information (GOLAN et al., 2020). Due to the unpredictable number of guests, avoiding the “stockout-problem”, which has mainly been analysed at retail levels (SANCHEZ-RUIZ et al., 2018; TELLER et al., 2018), might, for example, be an additional cause of overproduction within HaFS businesses.

Future studies should look more closely into operational conditions analysing the efficiency of individual business types (e.g., by Stochastic Frontier Analysis) and consider budget-constraints to clarify the actual feasibility of waste reduction. REFED (2016), HANSON and MITCHELL (2017) and CRISTÓBAL et al. (2018) already carried out economic evaluations of individual reduction measures. Further assessment could be particularly interesting, as results of article (3) reveal varying waste ratios at a business-type level.

RUTTEN (2013) illustrated that overall welfare gains associated with FLW reduction depend on the scale of FLW in relation to the respective market size, FLW types (i.e., avoidable or unavoidable), and interactions between supply chain participants in addition to reduction costs and food prices. As mentioned earlier, in terms of meat consumption and considering corresponding externalities, the individual level of meat waste might, however, not correspond to the societal optimal outcome (GOLAN et al., 2020).

Overall, this illustrates the importance of a detailed and regular measurement of FLW prior to developing cost-effective actions through whole-chain private-sector solutions or the justification of governmental intervention. Results of article (3) illustrate the scope of the meat waste issue within the German HaFS value chain, but also suggest that improvement seems feasible by behavioural changes at the business-type level.

Overarching conclusions as well as implications for policy makers, market participants, and scientists that can be drawn from the findings of this dissertation against the background of the three research questions are presented in the course of chapter 7. The following section also suggests further research, putting the results of the three contributing articles into a broader perspective.

7 Conclusions and implications

Sustainable diets are defined as "[…] diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations […]" (BAUMUNG and HOFFMANN, 2012). In this context, policy recommendations of the German Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE) refer to a reduced consumption of animal products from a health perspective but also call for minimising food waste to preserve planetary health (WBAE, 2020).

The three contributing articles of this dissertation call for action with a view toward consumption levels and wasted quantities when aiming for a more sustainable meat demand. On average, German meat consumption is well above environmental and health guidelines; almost two-thirds of German households have not yet turned away from traditional meat consumption habits; and leftovers are a hotspot for meat waste within the German HaFS sector.

A revised estimation of meat consumption based on a market balance approach and following a mass flow analysis conducted in article (1) reveals a per capita consumption level of 65 kg for the year 2018. Even when referring to prepared meat quantities, this result exceeds national recommendations for a balanced diet by 68% (DGE, 2020b). It is also twice as high as the maximum consumption level of red and processed meat suggested by the World Cancer Research Fund Network (WCRF) and the American Institute for Cancer Research (AICR), while putting a special focus on cancer risk (WCRF and AICR, 2018). A household segmentation illustrates that per capita fresh-meat purchases of all consumer segments determined in article (2) would at global level not be compliant with planetary health, according to the Eat-Lancet Commission (WILLETT et al., 2019). Substantial changes in terms of healthy and environmentally-sound diets would be required especially for 59% of German households, labelled as *pork and beef traditionalists*. The urgency for a change in meat demand behaviour is underpinned by a quantification of meat waste in article (3). 85,800 tons of meat are wasted in Hospitality and Food Service (HaFS) businesses annually, whereby the prevailing share corresponds to avoidable meat waste. A less wasteful behaviour of staff and guests considering leftover meat, especially within *gastronomy* and *communal catering* could contribute to diminishing the environmental footprint of the meat value chain.

7.1 Indications to develop a more comprehensive monitoring of nutrition with regard to meat demand

As outlined in chapter 6, comprehensive national monitoring needs to cover meat consumption and wasted meat quantities along the entire value chain in order to derive policies and allow for ex-post evaluation of implemented actions. This dissertation makes an important contribution in the context of an enhanced data base, capturing both measures.

The revision of the procedure for estimating human meat consumption presented in article (1) additionally provides indications for a subsequent evaluation of environmental effects due to the consideration of meat-type specific marketing channels and corresponding loss and waste quantities. A regular monitoring of meat utilisation based on the supply-side would therefore be desirable from multiple perspectives but will depend on the commitment of stakeholders. Up to now, legal bases only allow for a regular recording of slaughter weights and prices according to commercial grades (i.e., § 59 AgrStatG). The results of article (1) further suggest that consultations on a consistent calculation of meat balance sheets among EU Member States should first of all focus on the assignment of CN-codes with regard to meat, edible offal, and by-products in official trade statistics to provide for improved transparency.

For a more comprehensive response to dietary issues, the Federal Ministry of Food and Agriculture (BMEL) should strive for a regular collection of individual dietary data. The German National Nutrition Survey II was conducted 15 years ago (KOCH et al., 2019); more recent results are not yet available. Article (2) illustrates the relevance of regularly collected revealed-preference data which must cover meat purchases intended for at-home and out-of-home consumption. The recently established “Gesellschaft für Konsumforschung” (GfK) consumer panel on out-of-home consumption refers to purchased dishes (GFK, 2022). The derivation of meat quantities would therefore require additional assumptions concerning meat components in meals.

Comparable product related information on meat waste quantities, differentiated by avoidable and unavoidable waste would supplement the required database. However, simply meeting the specifications defined by the Delegated Decision 2019/1597 of the European Commission and thus reporting total food loss and waste (FLW) quantities on a national basis (EC, 2019) might not be adequate in order to assess the effectiveness of reduction efforts. Moreover, the lack of uniform FLW definitions and measurement procedures has been named a more general challenge by the scientific community as it leads to difficulties when assessing the effects of implemented FLW reduction measures in international supply chains (LEVERENZ et al., 2021).

7.2 Proposals for policy measures and private sector solutions to curb meat consumption and address meat waste

The findings of the contributing articles indicate that different governmental and private approaches are required, addressing individual consumer groups by changing their "food environment" and focusing on the identified meat waste hot spots.

There is a common understanding that a reduction in meat consumption can significantly contribute to accomplishing sustainability goals (WBAE, 2020). However, the steering effect achieved by increasing the value-added tax (VAT) rate on animal products from 7% to 19%, as requested by the WBAE (WBAE, 2020), is likely to be small (DEBLITZ et al., 2021). In order to attain a dietary transformation at a reasonable pace, target group-oriented concepts are needed. *Beef and pork traditionalists* need to be especially focused on by policy makers. Meat price increases through fiscal approaches might curb meat consumption of these "traditional" consumers. It is not clear, however, how pronounced and how long-lasting the reduction in their meat demand turns out to be as a result of an increased VAT rate or by introducing an environmental tax.

Findings of this dissertation provide essential insights into meat purchasing patterns of different household segments and thus into consumer heterogeneity as a condition for a more targeted meat demand management. These results can help to support and prepare policy decision-making. This must incorporate potential trade-offs between entrepreneurial freedom, consumer sovereignty and social contradictions on the one hand, and emerging externalities as well as related overall societal costs on the other hand. Such a comprehensive, holistic examination would, however, go far beyond the scope of this thesis.

Nevertheless, a change in the diet of younger consumers towards more flexitarian diets appears to be already underway in particular looking at *poultry lovers* and *convenience-oriented pork buyers*. Meat alternatives that are compelling for each of the consumer segments regarding taste, quality, and convenience could in the long run contribute even more to less meat-heavy diets.

Due to its small market share (AMI, 2020), organic meat can be seen as an example of how corresponding marketing measures primarily reach consumers who, as a matter of principle, pursue more sustainable consumption. Although results demonstrate that only a minority of German consumers (i.e., *premium red meat lovers*) actually reveal a willingness to pay (WTP) above average unit values, more target-oriented marketing strategies might increase sales of meat produced under improved husbandry conditions and, also organic meat to bring about a "qualitative" shift especially for *premium red meat lovers*, but also for *poultry lovers*.

In order to prevent a substantial quantity of meat from going uneaten within the HaFS meat supply chain, measures should primarily be aimed at reducing leftovers. Achieving

reduced meat waste ratios against the background of prevailing market conditions and constraints would increase resource-efficiency. Leftover meat and food need to be challenged with internal business solutions and government actions. Since managers, kitchen staff, and guests must be addressed and made more aware of waste prevention, communicative measures might have an additional multiplying effect. In this context, the scale of meat waste should be illustrated based on the potential savings in greenhouse gas emissions, land use, and energy when communicating with stakeholders. Communicating environmental effects might especially induce younger guests to exhibit less wasteful behaviour in educational canteens. They might prove to be a suitable setting for the implementation of new social norms with regard to meat waste prevention, in addition to more conscious meat consumption (WBAE, 2020).

A more precise definition of benchmarks in the wake of political objectives might facilitate the development of a common narrative that influences food habits. The German Nutrition Society (DGE) from a health point of view suggests a maximum permissible per capita meat intake of 31 kg (DGE, 2020b). However, a specific desirable meat consumption level in relation to a given time frame is not yet on the political agenda. Wasted food quantities are to be halved at retail and consumer levels by 2030 as part of the National Strategy for Food Waste Reduction and according to the Sustainable Development Goal (SDG) 12.3 (BMEL, 2019b). This target does not include the level of primary production, processing, and wholesale and disregards the requirement for any product-specific or resource-efficient waste management (KOESTER and GALAKTIONOVA, 2021). Indeed, the actual potential for meat waste reduction would have to be further analysed in view of cost-benefit-ratios of businesses while considering “true” costs of meat waste and looking at interactions between stakeholders in order to sharpen the national political goal setting.

Whether higher meat prices achieved through legislative interventions also result in lower meat waste might be assessed by further research. Nevertheless, the results presented in article (3) already indicate that donations of edible overproduction need to be facilitated. This issue has been identified in the course of the National Strategy for Food Waste Reduction and the sector-specific Dialogue Forum (BMEL, 2019b), but was also the subject of requests by the Federal Council (BR, 2021). The effect of legal adjustments regarding the liability for shelf life and for the quality of leftover food in the context of food donations, should be evaluated based on a regularly conducted waste monitoring.

7.3 Broader perspectives and own reflections

Comprehensive and long-term dietary strategies need to consider animal welfare in addition to human health and environmental aspects (WBAE, 2020). This turns the "diet-environmental-health trilemma" (TILMAN and CLARK, 2014) into an issue with even four dimensions. There is a need for integral policies as the simultaneous pursuit of all sustainability goals exceeds the breadth of individual purchasing decisions due to at least three conflicting goals (WBAE, 2020):

i) Efforts regarding more animal-welfare friendly livestock systems in Germany do not directly ensure a reduction of animal husbandry (BMEL, 2019c). Notwithstanding, livestock population determines the global environmental burden of dietary behaviour (FUNKE et al., 2022).

ii) In view of human health, the meat intake of each individual cannot exceed the recommended levels (DGE, 2020b). Indeed, against the background of climate planetary boundaries (WILLETT et al., 2019), average national meat consumption levels have to be assessed, rather than setting individual limits.

iii) Resource-efficiency would simultaneously require efficient production systems which contradict animal welfare ambitions (WBAE, 2020).

Ultimately, these trade-offs can only be defused by reducing the consumption of animal products (WBAE, 2020). This cumulative thesis contributes to improving the monitoring and suggests individual options to change meat purchasing behaviour, as described above. Chapters 4, 6 and article (1) explain the importance of a market based perspective as an appropriate way to assess total meat consumption, corresponding overall long-term developments and effects of market based instruments. The identification of consumer segments in article (2) considers socio-economic characteristics of individual households' purchasing patterns, but only at an aggregated level without in-depth insights into meat consumption motives.

Manifold aspects are related to dietary changes, particularly to the reduction of meat consumption, e.g., social norms, perceived benefits or barriers and environmental concerns (CHEAH et al., 2020). These might also be drivers for a particularly high meat consumption level of individual consumers. Due to the fact that this information is not captured by GfK household panels, such influencing factors are not assessed in the course of this thesis. Ultimately, a knowledge of meat eating motives at the micro level is required in order to "fine-tune" the transformation of food environments and change individual habit-formed

dietary behaviour. Due to the complexity of food choices, the analysis of consumer responses to a mix of measures requires the application of various scientific disciplines, including behavioural and social economics as well as psychology and ethics. This holistic approach exceeds the scope of a single dissertation and emphasises the need for an interdisciplinary research design.

Looking beyond the focus of this thesis, any national solution can only describe a partial solution in view of the global burden of eating behaviour. Low-income and emerging countries that currently have more plant-based diets (see ***Figure 1***) need to be considered to ensure sustainable food systems at global level, but in relation to their individual nutritional situation (UN NUTRITION, 2021). However, it remains unclear how different food strategies, i.e., reduced meat consumption levels in one country and the promotion of animal proteins in another could be coordinated internationally. Naturally enough and most likely, this poses difficulties for the implementation. Moreover, agricultural livestock farming contributes substantially to the agricultural value chain (FAO, 2018b) and secures farmers' livelihoods where non-arable land can only add to food production through animal husbandry (JANZEN, 2011). This is why demand-side measures are not the single silver bullet for climate protection. Any comprehensive solution must also take supply-side measures into account.

References

AHLHEIM, M., K. GRÜNDLER, L. KÄHN, M. MOSLER, N. POTRAFKE and F. RUTHARDT (2020): *Brauchen wir staatliche Eingriffe in den Fleischmarkt? (Do we need government intervention in the meat market?)*. In: Ifo Schnelldienst 73 (8): 60–63.

AMI (2020): *AMI analyses based on the GfK household panel*. Bonn, Germany.

AMO, E., F. ESCRIBANO, M.-J. GARCÍA-MESEGUER and I. PARDO (2016): *Are the eating habits of university students different to the rest of the Spanish population? Food availability, consumption and cost*. In: Spanish Journal of Agricultural Research 14 (2): e0103.

APOSTOLIDIS, C. and F. MCLEAY (2016): *Should we stop meating like this? Reducing meat consumption through substitution*. In: Food Policy 65: 74–89.

ARMSTRONG, J. S. and P. SOELBERG (1968): *On the interpretation of factor analysis*. In: Psychological Bulletin 70 (5): 361–364.

BACKHAUS, K., B. ERICHSON, W. PLINKE and R. WEIBER (2018): *Multivariate Analysemethoden (Multivariate analysis techniques)*. Eine anwendungsorientierte Einführung. 15th ed. Springer Gabler, Berlin, Germany.

BATTAGLIA RICHI, E., B. BAUMER, B. CONRAD, R. DARIOLI, A. SCHMID and U. KELLER (2015): *Health Risks Associated with Meat Consumption: A Review of Epidemiological Studies*. In: International Journal for Vitamin and Nutrition Research 85 (1-2): 70–78.

BAUMUNG, R. and I. HOFFMANN (2012): *Animal genetic diversity and sustainable diets*. In: Burlingame, B. and S. Dernini (Eds.): Sustainable diets and Biodiversity - Directions and solutions for policy, research and action. Proceedings of the International Scientific Symposium BIODIVERSITY AND SUSTAINABLE DIETS UNITED AGAINST HUNGER, 3–5 November 2010, FAO Headquarters. Rome, Italy: 83–92.

BERETTA, C. and S. HELLWEG (2019): *Potential environmental benefits from food waste prevention in the food service sector*. In: Resources, Conservation and Recycling 147: 169–178.

BLAND, J. M. and D. G. ALTMAN (1995): *Multiple significance tests: the Bonferroni method*. In: BMJ (Clinical research ed.) 310 (6973): 170.

BLE (2021): *Fleisch und Geflügel. Versorgungsbilanzen. Versorgung mit Fleisch in Deutschland seit 1991. (Meat and poultry. Supply balances. Supply with meat in Germany since 1991).* Excel files. In: https://www.ble.de/DE/BZL/Daten-Berichte/Fleisch/fleisch_node.html. Call: 10.3.2022.

BMEL (2019a): *Bundesweite Strategie „Zu gut für die Tonne!“*. (The „*Too good for the bin!*“ initiative). In: https://www.zugutfuerdietonne.de/. Call: 10.3.2022.

BMEL (2019b): *National Strategy for Food Waste Reduction*. Berlin. In: https://www.bmel.de/SharedDocs/Downloads/EN/_Food-and-Nutrition/Strategy_FoodWasteReduction.pdf?__blob=publicationFile&v=3. Call: 10.10.2021.

BMEL (2019c): *Nutztierstrategie. Zukunftsfähige Tierhaltung in Deutschland. (Livestock Husbandry Strategy. Sustainable animal husbandry in Germany)*. Bundesministerium für Ernährung und Landwirtschaft, Berlin. In: https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/Nutztierhaltungsstrategie.pdf;jsessionid=D6F6E978997E251BEA70721E5029ED06.live851?__blob=publicationFile&v=9. Call: 10.3.2022.

BMEL (2020): *Konzept zur Förderung einer nachhaltigen Ernährung (Concept for the promotion of sustainable nutrition)*. Bundesministerium für Ernährung und Landwirtschaft, Berlin. In: https://www.bmel.de/SharedDocs/Downloads/DE/_Ernaehrung/Nachhaltige-Konsum/konzept-nachhaltige-ernaehrung.pdf?__blob=publicationFile&v=3. Call: 1.12.2021.

BONNET, C., Z. BOUAMRA-MECHEMACHE and T. CORRE (2018): *An Environmental Tax Towards More Sustainable Food: Empirical Evidence of the Consumption of Animal Products in France*. In: Ecological Economics 147: 48–61.

BONNET, C., Z. BOUAMRA-MECHEMACHE, V. RÉQUILLART and N. TREICH (2020): *Viewpoint: Regulating meat consumption to improve health, the environment and animal welfare*. In: Food Policy 97: 101847.

BR (2021): *Ausgewählte Tagesordnungspunkte der 1008. Sitzung am 17.09.2021 (Selected agenda items of the 1008th meeting on 17.09.2021)*. Top 17 Lebensmittelverschwendung. In: https://www.bundesrat.de/DE/plenum/bundesrat-kompakt/21/1008/1008-pk.html. Call: 8.3.2022.

BROMBACH, C., S. BARTSCH and G. WINKLSER (2015): *Ernährungsverhalten im Verlauf von drei Generationen (Dietary behaviour over the course of three generations)*. In: Schweizer Zeitschrift für Ernährungsmedizin 5: 20–24.

BZL (2019): *Umrechnungsfaktoren für Innereien (Conversion factors for edible offal). The Federal Centre for Agriculture. Department for Market Information, Critical Infrastructure Agriculture. Written communication received at 31.01.2019.*

CAMERON, C. A. and P. K. TRIVEDI (2009): *Microeconometrics Using Stata.* Stata Press, College Station, TX, USA.

CASINI, L., C. CONTINI, C. ROMANO and G. SCOZZAFAVA (2015): *Trends in food consumptions: what is happening to generation X?* In: British Food Journal 117 (2): 705–718.

CHEAH, I., A. SADAT SHIMUL, J. LIANG and I. PHAU (2020): *Drivers and barriers toward reducing meat consumption*. In: Appetite 149: 104636.

CHRISTOPH-SCHULZ, I. and A.-K. ROVERS (2020): *German Citizens' Perception of Fattening Pig Husbandry-Evidence from a Mixed Methods Approach*. In: Agriculture 10 (8): 342.

CIALDINI, R. B. (2007): *Descriptive Social Norms as Underappreciated Sources of Social Control*. In: Psychometrika 72 (2): 263–268.

CLEFF, T. (2015): *Deskriptive Statistik und explorative Datenanalyse (Descriptive statistics and exploratory data analysis).* 3rd ed. Gabler Verlag, Wiesbaden, Germany.

CLUNE, S., E. CROSSIN and K. VERGHESE (2017): *Systematic review of greenhouse gas emissions for different fresh food categories*. In: Journal of Cleaner Production 140: 766–783.

CORDTS, S., N. DUMAN, H. GRETHE, S. NITZKO and A. SPILLER (2014): *Potenziale für eine Verminderung des Fleischkonsums am Beispiel Deutschland und Auswirkungen einer Konsumreduktion in OECD-Ländern auf globale Marktbilanzen und Nahrungsmittelpreise (Potentials for a reduction of meat consumption using the example of Germany and effects of a reduction of consumption in OECD countries on global market balances and food prices)*. In: Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e. V (49): 209–222.

CRIPPA, M., E. SOLAZZO, D. GUIZZARDI, F. MONFORTI-FERRARIO, F. N. TUBIELLO and A. LEIP (2021): *Food systems are responsible for a third of global anthropogenic GHG emissions*. In: Nature Food 2 (3): 198–209.

CRISTÓBAL, J., V. CASTELLANI, S. MANFREDI and S. SALA (2018): *Prioritizing and optimizing sustainable measures for food waste prevention and management*. In: Waste Management (New York, N.Y.) 72: 3–16.

DEBLITZ, C., J. EFKEN, M. BANSE, F. ISERMEYER, C. ROHLMANN, H. TERGAST, P. THOBE and M. VERHAAGH (2021): *Politikfolgenabschätzung zu den Empfehlungen des Kompetenznetzwerks Nutztierhaltung (Policy impact assessment on the recommendations of the Competence Network on Animal Husbandry)*. Thünen Working Paper No. 173. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://literatur.thuenen.de/digbib_extern/dn063574.pdf. Call: 1.2.2022.

DEL GOBBO, L. C., S. KHATIBZADEH, F. IMAMURA, R. MICHA, P. SHI, M. SMITH, S. S. MYERS and D. MOZAFFARIAN (2015): *Assessing global dietary habits: a comparison of national estimates from the FAO and the Global Dietary Database*. In: The American Journal of Clinical Nutrition 101 (5): 1038–1046.

DERSTAPPEN, R., I. CHRISTOPH-SCHULZ and M. BANSE (2021): *An empirical analysis of the export potential of pork produced under higher animal welfare standards*. Thünen Working Paper No. 184. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://literatur.thuenen.de/digbib_extern/dn064254.pdf. Call: 1.3.2022.

DESTATIS (2021): *Einkommens- und Verbrauchsstichprobe (EVS) (The Sample Survey of Income and Expenditure (EVS)*. Statistisches Bundesamt. In: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Einkommen-Konsum-Lebensbedingungen/Einkommen-Einnahmen-Ausgaben/Methoden/einkommens-verbrauchsstichprobe.html. Call: 12.3.2022.

DGE (2020a): *DGE-Qualitätsstandard für die Verpflegung in Betrieben (DGE quality standard for catering in companies)*. Deutsche Gesellschaft für Ernährung, Bonn, Germany. In: https://www.jobundfit.de/fileadmin/user_upload/medien/DGE-QST/DGE-Qualitaetsstandard_Betriebe.pdf. Call: 10.3.2022.

DGE (2020b): *Die Nährstoffe. Bausteine für Ihre Gesundheit (The nutrients. Modules for your health)*. Deutsche Gesellschaft für Ernährung e.V., Bonn, Germany.

DOWLER, E. A. and Y. O. SEO (1985): *Assessment of energy intake: Estimated of food supply v measurement of food consumption*. In: Food Policy 10 (3): 278–288.

DVF (1987): *Ergebnisbericht (Report on results).* Arbeitskreissitzung des Bundesmarktverbandes für Vieh und Fleisch im BML am 14. Januar 1987, 14.00 bis 17.00 Uhr. Ermittlung realistischer Fleischverzehrswerte. Frankfurt am Main, Germany.

EC (2005): *Attitudes of consumers towards the welfare of farmed animals*. Special Eurobarometer 229. European Commission, Brussels, Belgium. In: http://www.vuzv.sk/DB-Welfare/vseob/euro_barometer25_en.pdf. Call: 10.3.2022.

EC (2008): *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives*. In: Official Journal of the European Union, L 312/3.

EC (2016): *Attitudes of Europeans towards Animal Welfare*. Special Eurobarometer 442. European Commission, Brussels, Belgium. In: https://www.bioecoactual.com/wp-content/uploads/2016/03/Eurobarometer-2016-Animal-Welfare.pdf. Call: 7.3.2022.

EC (2018): *Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste*. In: Official Journal of the European Union, L 150/109.

EC (2019): *Commission Delegated Decision (EU) 2019/1597 of 3 May 2019 supplementing Directive 2008/98/EC of the European Parliament and of the Council as regards a common methodology and minimum quality requirements for the uniform measurement of levels of food waste.* (EU) 2019/1597. In: Official Journal of the European Union, L248/77.

EC (2020): *Farm to Fork Strategy*. For a fair, healthy and environmentally-friendly food system. European Commission, Brussels, Belgium. In: https://ec.europa.eu/food/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf. Call: 13.2.2022.

ENNEKING, U., R. KLEINE-KALMER, A. DAUERMANN and R. VOLGT (2019): *Kaufbereitschaft bei verpackten Schweinefleischprodukten im Lebensmitteleinzelhandel. Realexperiment und Kassenzonen-Befragung (Willingness to buy packaged pork products in the food retail sector. Real-life experiment and checkout zone survey)*. Osnabrück, Germany. In: https://www.hs-osnabrueck.de/fileadmin/HSOS/Homepages/Personalhomepages/Personalhomepages-AuL/Enneking/Tierwohlstudie-HS-Osnabrueck_Teil-Realdaten_17-Jan-2019.pdf. Call: 3.3.2022.

EU (2021): *Inception Impact Assessment*. Summary of feedback. EU Platform on Food Losses and Food Waste. European Union, Brussels, Belgium. In: https://ec.europa.eu/food/system/files/2021-11/fw_eu-platform_20211118_flw_pres_02.pdf. Call: 9.3.2022.

FAO (2011): *Global food losses and food waste – Extent, causes and prevention*. Food and Agriculture Organization of the United Nations, Rome, Italy. In: https://www.fao.org/3/i2697e/i2697e.pdf. Call: 2.1.2022.

FAO (2017): *Guidelines for the compilation of Food Balance Sheets*. Food and Agriculture Organization of the United Nations, Rome, Italy. In: http://www.cisstat.com/gsagr/GS-FBS-Guidelines-ENG-completo-03.pdf. Call: 10.9.2021.

FAO (2018a): *Sustainable food systems: Concept and framework*. Food and Agriculture Organization of the United Nations. In: https://www.fao.org/3/ca2079en/CA2079EN.pdf. Call: 11.11.2021.

FAO (2018b): *World Livestock: Transforming the livestock sector through the Sustainable Development Goals*. Food and Agriculture Organization of the United Nations, Rome. 222 pp. https://doi.org/10.4060/ca1201en. Licence: CC BY-NC-SA 3.0 IGO.

FAO (2019): *Moving forward on food loss and waste reduction*. The state of food and agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. In: https://www.fao.org/3/ca6030en/ca6030en.pdf. Call: 9.10.2021.

FAO (2021a): *Food Balances*. Agriculture Organization of the United Nations (FAO). In: https://www.fao.org/faostat/en/#data/FBS. Call: 9.3.2022.

FAO (2021b): *Food-based dietary guidelines*. Agriculture Organization of the United Nations (FAO). In: http://www.fao.org/nutrition/education/food-based-dietary-guidelines. Call: 2.2.2022.

FEHRENBACH, K. S., A. C. RIGHTER and R. E. SANTO (2016): *A critical examination of the available data sources for estimating meat and protein consumption in the USA*. In: Public Health Nutrition 19 (8): 1358–1367.

FEMENIA, F. (2019): *A meta-analysis of the price and income elasticities of food demand*. [University works] Inconnu.: 78 p. hal-02103880.

FERRARI, S. and F. CRIBARI-NETO (2004): *Beta Regression for Modelling Rates and Proportions*. In: Journal of Applied Statistics 31 (7): 799–815.

FISCHER, C. G. and T. GARNETT (2016): *Plates, pyramids, planet*. Developments in national healthy and sustainable dietary guidelines: a state of play assessment. Food and Agriculture Organization of the United Nations and The Food Climate Research Network at The University of Oxford, Rome, Italy, Oxford, UK. In: https://www.fao.org/3/I5640E/i5640e.pdf. Call: 22.12.2021.

FLICK, U., E. von KARDORFF and I. STEINKE (2007): *Was ist qualitative Forschung? Einleitung und Überblick (What is qualitative research? Introduction and overview)*. In: Flick, U., E. von Kardorff and I. Steinke (Eds.): Qualitative Forschung (Qualitative Research). Ein Handbuch. Rowohlt Taschenbuch Verlag, Reinbeck, Germany: 13–29.

FORSA (2020): *Ernährungsreport 2021 (Nutrition Report 2021)*. Ergebnisse einer repräsentativen Bevölkerungsbefragung. forsa Politik- und Sozialforschung GmbH, Berlin, Germany. In: https://www.bmel.de/SharedDocs/Downloads/DE/_Ernaehrung/forsa-ernaehrungsreport-2021-tabellen.pdf?__blob=publicationFile&v=2. Call: 1.2.2022.

FRIEDRICH, S. and T. von BORSTEL (2021): *Erläuterung zur Beteiligungserklärung der Zielvereinbarung (Explanation of the participation declaration of the target agreement)*. Reduzierung von Lebensmittelabfällen in der Ausser-Haus-Verpflegung. World Wide Fund For Nature (WWF) Germany, Berlin, Germany. In: https://www.wwf.de/fileadmin/fm-wwf/PublikationenPDF/Landwirtschaft/Beteilgungserklaerung-Reduzierung-von-Lebensmittelabfaellen-in-der-Ausser-Haus-Verpflegung.pdf. Call: 10.10.2021.

FUNKE, F., L. MATTAUCH, I. VAN DEN BIJGAART, C. GODFRAY, C. HEPBURN, D. KLENERT, M. SPRINGMANN and N. TREICH (2022): *Is Meat Too Cheap? Towards Optimal Meat Taxation*. In: Review of Environmental Economics and Policy. Forthcoming.

GEIBEL, I., F. FREUND and M. BANSE (2021): *The Impact of Dietary Changes on Agriculture, Trade, Environment and Health: A Literature Review*. In: German Journal of Agricultural Economics 70 (3): 139–164.

GERBER, P. J., H. STEINFELD, B. HENDERSON, A. MOTTET, C. OPIO, J. DIJKMAN, A. FALCUCCI and G. TEMPIO (2013): *Tackling climate change through livestock - A global assessment of emissions and mitigation opportunities*. Food and Agriculture Organization of the United Nations, Rome, Italy.

GERHARDT, C., F. ZIEMßEN, M. WARSCHUN, G. SUHLMANN, D. DONNAN and J.-H. KÜHLE (2019): *How will cultured meat and meat alternatives disrupt the agricultural and food industry?* A.T. Keanrey, Chicago, USA.

GERTEN, D., V. HECK, J. JÄGERMEYR, B. L. BODIRSKY, I. FETZER, M. JALAVA, M. KUMMU, W. LUCHT, J. ROCKSTRÖM, S. SCHAPHOFF and H. J. SCHELLNHUBER (2020): *Feeding ten billion people is possible within four terrestrial planetary boundaries*. In: Nature Sustainability 3 (3): 200–208.

GFK (2022): *Erläuterung der Möglichkeit, den Fleischverzehr mit Hilfe des GfK in- und out-of-home-panel zur ermitteln (Explanation of the possibility to determine meat consumption with the help of GfK at-home and out-of-home-panel). Written communication received at 21.01.2022*.

GODFRAY, H. C. J., P. AVEYARD, T. GARNETT, J. W. HALL, T. J. KEY, J. LORIMER, R. T. PIERREHUMBERT, P. SCARBOROUGH, M. SPRINGMANN and S. A. JEBB (2018): *Meat consumption, health, and the environment*. In: Science (New York, N.Y.) 361 (6399).

GOLAN, E., T. MINOR and S. THORNSBURY (2020): *Loss and waste*. Are we really measuring a problem? In: Minor, T., S. D. Thornsbury and A. K. Mishra (Eds.): The economics of food loss in the produce industry. Routledge Taylor & Francis Group, New York, US: 14–24.

GÖTZE, F. and T. A. BRUNNER (2021): *A Consumer Segmentation Study for Meat and Meat Alternatives in Switzerland*. In: Foods 10 (6): 1273.

HAFNER, G., D. LEVERENZ, J. BARABOSZ and D. RIESTENPATT (2014): *Lebensmittelverluste und Wegwerfraten im Freistaat Bayern (Food losses and throwaway rates in the Free State of Bavaria)*. Universität Stuttgart, Institute für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft, Lehrstuhl für Abfallwirtschaft und Abluft and Arbeitsbereich Ressourcenmanagement und Industrielle Kreislaufwirtschaft, Stuttgart, Germany.

HAIR, J. F., W. C. BLACK, B. J. BABIN and R. E. ANDERSON (2019): *Multivariate data analysis.* 8th ed. Cengage Learning, Hampshire, UK.

HALLSTRÖM, E., E. RÖÖS and P. BÖRJESSON (2014): *Sustainable meat consumption: A quantitative analysis of nutritional intake, greenhouse gas emissions and land use from a Swedish perspective*. In: Food Policy (47): 81–90.

HANSON, C. and P. MITCHELL (2017): *The business case for reducing Food Loss and Waste*. Report on behalf of Champions 12.3. Washington, D.C., US. In: http://flwprotocol.org/wp-content/uploads/2017/05/Champions123-Report_-business-case-for-reducing-food-loss-and-waste.pdf. Call: 5.5.2021.

HERZBERG, R., T. G. SCHMIDT and F. SCHNEIDER (2020): *Characteristics and Determinants of Domestic Food Waste: A Representative Diary Study across Germany*. In: Sustainability 12 (11): 4702.

HÖLKER, S., H. STEINFATH, M. von MEYER-HÖFER and A. SPILLER (2019): *Animal-Ethical Intuitions in Germany: Developing a Measuring Instrument to Capture Domain-Specific Values in the Context of the Human-Animal Relationship*. In: German Journal of Agricultural Economics 68 (4): 299–315.

JANZEN, H. H. (2011): *What place for livestock on a re-greening earth?* In: Animal Feed Science and Technology 166-167: 783–796.

JUST, D. R. and A. S. HANKS (2015): *The Hidden Cost of Regulation: Emotional Responses to Command and Control*. In: American Journal of Agricultural Economics 97 (5): 1385–1399.

KAISER, H. F. (1970): *A second generation little jiffy*. In: Psychometrika 35 (4): 401–415.

KARPENSTEIN, U., F. FELLENBERG, SCHINK, A., C. JOHANN, K. DINGEMANN, M. KOTTMANN, EN DROIT, M., J. AUGUSTIN and B. GAUSING (2021): *Machbarkeitsstudie zur rechtlichen und förderpolitischen Begleitung einer langfristigen Transformation der deutschen Nutztierhaltung (Feasibility study for legal and funding policy support of a long-term transformation of the German livestock sector)*. Berlin/Bonn/Kraainem/Herne, Germany. In: https://www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Nutztiere/machbarkeitsstudie-borchert.pdf?__blob=publicationFile&v=11. Call: 5.1.2022.

KARWOWSKA, M., S. ŁABA and K. SZCZEPAŃSKI (2021): *Food Loss and Waste in Meat Sector—Why the Consumption Stage Generates the Most Losses?* In: Sustainability 13 (11): 6227.

KAYSER, M., NITZKO, S. and A. SPILLER (2013): *Analysis of differences in meat consumption patterns*. In: International Food and Agribusiness Management Review 16 (2): 43–56.

KNW (2020): *Empfehlungen des Kompetenznetzwerks Nutztierhaltung (Recommendations of the Competence Network on Animal Husbandry)*. Berlin, Germany. In: https://www.bmel.de/SharedDocs/Downloads/DE/_Tiere/Nutztiere/200211-empfehlung-kompetenznetzwerk-nutztierhaltung.pdf;jsessionid=362390985258F076C1D7EF5CF7952F88.live842?__blob=publicationFile&v=3. Call: 13.1.2022.

KOCH, F., T. HEUER, C. KREMS and E. CLAUPEIN (2019): *Meat consumers and non-meat consumers in Germany: a characterisation based on results of the German National Nutrition Survey II*. In: Journal of Nutritional Science 8: e21.

KOESTER, U. and E. GALAKTIONOVA (2021): *FAO Food Loss Index methodology and policy implications*. In: Studies in Agricultural Economics: 1–7.

KRUSKAL, W. H. and A. WALLIS (1952): *Use of Ranks in One-Criterion Variance Analysis*. Published online: 11 Apr 2012. In: Journal of the American Statistical Association 47 (260): 583–621.

KUNTSCHER, M., T. SCHMIDT and Y. GOOSSENS (2020): *Lebensmittelabfälle in der Außer-Haus-Verpflegung - Ursachen, Hemmnisse und Perspektiven (Food waste in out-of-home catering - causes, obstacles and perspectives)*. Thünen Working Paper. No. 161. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://literatur.thuenen.de/digbib_extern/dn063075.pdf. Call: 15.2.2022.

KUŹNIAR, W., T. SURMACZ and B. WIERZBIŃSKI (2021): *The Impact of Ecological Knowledge on Young Consumers' Attitudes and Behaviours towards the Food Market*. In: Sustainability 13 (4): 1984.

KVAN, P. H. and B. VIDAKOVIC (2007): *Nonparametric Statistics with Applications to Science and Engineering.* John Wiley & Sons, Hoboken, NJ, USA.

LAMNEK, S. and C. KRELL (2016): *Qualitative Sozialforschung.* 6th ed. Beltz Verlag, Weinheim, Basel, Switzerland.

LEVERENZ, D., F. SCHNEIDER, T. SCHMIDT, G. HAFNER, Z. NEVÁREZ and M. KRANERT (2021): *Food Waste Generation in Germany in the Scope of European Legal Requirements for Monitoring and Reporting*. In: Sustainability 13 (12): 6616.

MACQUEEN, J. (1967): *Some methods for classification and analysis of multivariate observations*. In: Proceedings of the fifth Berkeley symposium on mathematical statistics and probability 5.1: 281–297.

MAIO, F. G. (2007): *Income inequality measures*. In: J Epidemiol Community Health: 849–852.

MALEK, L., W. J. UMBERGER and J. ROLFE (2018): *Segmentation of Australian meat consumers on the basis of attitudes regarding farm animal welfare and the environmental impact of meat production*. In: Animal Production Science 58 (3): 424.

MAYRING, P. (2000): *Qualitative Content Analysis*. In: Forum Qualitative Sozialforschung / Forum: Qualitative Social Research 1 (2): Art. 20.

MAYRING, P. and T. FENZL (2019): *Qualitative Inhaltsanalyse (Qualitative content analysis)*. In: Baur, N., Blasius, J. (Eds.): Handbuch Methoden der empirischen Sozialforschung (Handbook Methods of Empirical Social Research). Springer Fachmedien, Wiesbaden, Germany: 633–648.

MIROSA, M., Y. LIU and R. MIROSA (2018): *Consumers' Behaviors and Attitudes toward Doggy Bags: Identifying Barriers and Benefits to Promoting Behavior Change*. In: Journal of Food Products Marketing 24 (5): 563–590.

MITTIGA, R. (2018): *Allocating the Burdens of Climate Action: Consumption-Based Carbon Accounting and the Polluter-Pays Principle*. In: Edmondson, B. and S. Levy (Eds.): Transformative Climates and Accountable Governance. Springer International Publishing, Basel, Switzerland: 157–194.

MORAN, D. (2021): *Meat market failure*. In: Nature Food 2 (2): 67.

MOUNTER, S., E. FLEMING, G. GRIFFIT and S. ROHR (2019): *Using welfare economics to analyse food waste as a negative externality in a food value chain*. In: https://www.une.edu.au/__data/assets/pdf_file/0011/164927/aares_seminar.pdf. Call: 10.3.2022.

NADERI, I. and E. VAN STEENBURG (2018): *Me first, then the environment: young Millennials as green consumers*. In: Young Consumers 19 (3): 280–295.

NASKA, A., M.-A. BERG, C. CUADRADO, H. FREISLING, K. GEDRICH, M. GREGORIC, C. KELLEHER, E. LESKOVA, M. NELSON, L. PACE, A.-M. REMAUT, S. RODRIGUES, W. SEKULA, M. SJÖSTROM, K. TRYGG, A. TURRINI, J. L. VOLATIER, G. ZAJKAS and A. TRICHOPOULOU (2009): *Food balance sheet and household budget survey dietary data and mortality patterns in Europe*. In: The British Journal of Nutrition 102 (1): 166–171.

NGUYEN, M. T. T., A. EMBERGER-KLEIN and K. MENRAD (2019): *A Systematic Review on the Effects of Personalized Price Promotions for Food Products*. In: Journal of Food Products Marketing 25 (3): 257–275.

NI MHURCHU, C., H. EYLES, C. SCHILLING, Q. YANG, W. KAYE-BLAKE, M. GENÇ and T. BLAKELY (2013): *Food prices and consumer demand: differences across income levels and ethnic groups*. In: PloS one 8 (10): e75934.

OECD (2021): *Joint Working Party on Agriculture and Trade*. Aglink Cosimo Model Documentation. Unpublished.

OECD and FAO (2020): *OECD-FAO Agricultural Outlook 2020-2029*. FAO, Rome/OECD Publishing, Paris, https://doi.org/10.1787/1112c23b-en. FAO and OECD.

OECD and FAO (2021): *OECD-FAO Agricultural Outlook (Edition 2021)*. OECD Agriculture Statistics (database). Call: 14.12.2021.

OTTO, I. M., J. F. DONGES, R. CREMADES, A. BHOWMIK, R. J. HEWITT, W. LUCHT, J. ROCKSTRÖM, F. ALLERBERGER, M. MCCAFFREY, S. S. P. DOE, A. LENFERNA, N. MORÁN, D. P. VAN VUUREN and H. J. SCHELLNHUBER (2020): *Social tipping dynamics for stabilizing Earth's climate by 2050*. In: Proceedings of the National Academy of Sciences of the United States of America 117 (5): 2354–2365.

PAPARGYROPOULOU, E., J. K. STEINBERGER, N. WRIGHT, R. LOZANO, R. PADFIELD and Z. UJANG (2019): *Patterns and Causes of Food Waste in the Hospitality and Food Service Sector: Food Waste Prevention Insights from Malaysia*. In: Sustainability 11 (21): 6016.

PAPKE, L. E. and J. M. WOOLDRIDGE (1996): *Econometric methods for fractional response variables with an application to 401 (k) plan participation rates.* In: Journal of Applied Econometrics 11: 619–632.

PARK, J., R. HOLCOMB, K. RAPER and O. CAPPS (1996): *A demand system analysis of food commodities by US households segmented by income*. In: American Journal of Agricultural Economics 78 (2): 290–300.

PELTNER, J. and S. THIELE (2021): *Elasticities of Food Demand in Germany – A Demand System Analysis Using Disaggregated Household Scanner Data*. In: German Journal of Agricultural Economics 70 (1): 49–62.

REFED (2016): *Roadmap to reduce US food waste by 20 percent*. Long Island City, NY, US. In: https://staging.refed.org/downloads/ReFED_Report_2016.pdf. Call: 20.1.2022.

RODRIGUES, S. S. P., C. LOPES, A. NASKA, A. TRICHOPOULOU and M. D. V. de ALMEIDA (2007): *Comparison of national food supply, household food availability and individual food consumption data in Portugal*. In: Journal of Public Health 15 (6): 447–455.

ROOSEN, J., M. STAUDIGEL and S. RAHBAUER (2022): *Demand elasticities for fresh meat and welfare effects of meat taxes in Germany*. In: Food Policy 106: 102194.

RUBY, M. B. (2012): *Vegetarianism. A blossoming field of study*. In: Appetite 58 (1): 141–150.

RÜCKERT-JOHN, J. and M. KRÖGER (2019): *Vorwort*. In: Rückert-John, J. and M. Kröger (Eds.): Fleisch. Vom Wohlstandssymbol zur Gefahr für die Zukunft (Meat. From symbol of prosperity to threat towards the future). Nomos Verlagsgesellschaft, Baden-Baden, Germany: 5–7.

RUSSO, V., L. NANI COSTA, C. SERMONETA, A. AMICI, P. DANIELI, A. de ANGELIS, C. CAVANI, FRANCI. O., L. GASCO, D. P. LO FIEGO, A. MELUZZI, V. MORETTI, F. V. NICASTRO, G. PARISI, G. PICCOLO, A. SERRA and E. TREVISI (2016): *Estimation of real per capita consumption of meat in Italy*. Proceedings ICAS VII Seventh International Conference on Agricultural Statistics, Rome 24-26 October 2016.

RUTTEN, M. M. (2013): *What economic theory tells us about the impacts of reducing food losses and/or waste: implications for research, policy and practice*. In: Agriculture & Food Security 2 (1).

SÄLL, S. and I.-M. GREN (2015): *Effects of an environmental tax on meat and dairy consumption in Sweden*. In: Food Policy 55: 41–53.

SANCHEZ-RUIZ, L., B. BLANCO and A. KYGUOLIENĖ (2018): *A Theoretical Overview of the Stockout Problem in Retail: from Causes to Consequences*. In: Management of Organizations: Systematic Research 79 (1): 103–116.

SANDERS, J. and J. HEß (2019): *Leistungen des ökologischen Landbaus für Umwelt und Gesellschaft (Benefits of organic farming for the environment and society)*. Thünen Report 65. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_65.pdf. Call: 6.2.2022.

SCHMIDT, T. G., F. SCHNEIDER, D. LEVERENZ and G. HAFNER (2019): *Lebensmittelabfälle in Deutschland - Baseline 2015 (Food loss and waste in Germany - Baseline 2015)*. Thünen-Report 71. Johann Heinrich von Thünen Institute, Braunschweig, Germany. In: https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_71.pdf. Call: 4.2.2022.

SCHRANZHOFER, A., R. ROCKENBAUER, F. TRAGNER, V. HALA, M. HRAD, R. OTTNER, G. OBERSTEINER, F. SCHNEIDER, S. LEBERSORGER, A. M. MANHART and C. MARONNIER (2015): *Vermeidung von Lebensmittelabfall in Gastronomie, Beherbergung und Großküchen (Prevention of food waste in gastronomy, accommodation, and canteen kitchens)*. Wien, Austria. In: https://united-against-waste.at/wp-content/uploads/2015/05/Endbericht_UAW_ABF_tatwort_final_ARA.pdf?eb6772. Call: 7.1.2022.

SCOZZAFAVA, G., A. M. CORSI, L. CASINI, C. CONTINI and S. M. LOOSE (2016): *Using the animal to the last bit: Consumer preferences for different beef cuts*. In: Appetite 96: 70–79.

SEARCHINGER, J., R. WAITE, C. HANSON and J. RANGANATHAN (2018): *Creating a sustainable food future*. A menu of solutions to feed nearly 10 billion people by 2050. World Resource Institute, Washington, D.C., US. In: https://files.wri.org/d8/s3fs-public/wrr-food-full-report.pdf. Call: 8.1.2022.

SERRA-MAJEM, L. (2001): *Food availability and consumption at national, household and individual levels: implications for food-based dietary guidelines development*. In: Public Health Nutrition 4 (2B): 673–676.

SHOWELL, B. A., J. R. WILLIAMS and M. DUVALL (2012): *USDA Table of Cooking Yields for Meat and Poultry*. U.S. Department of Agriculture, Agricultural Research Service, Beltsville Human Nutrition Research Center, Nutrient Data Laboratory, Beltsville, Maryland, US. In: https://www.ars.usda.gov/ARSUserFiles/80400525/data/retn/usda_cookingyields_meatpoultry.pdf. Call: 10.3.2022.

SPRINGMANN, M., M. CLARK, D. MASON-D'CROZ, K. WIEBE, B. L. BODIRSKY, L. LASSALETTA, W. de VRIES, S. J. VERMEULEN, M. HERRERO, K. M. CARLSON, M. JONELL, M. TROELL, F. DECLERCK, L. J. GORDON, R. ZURAYK, P. SCARBOROUGH, M. RAYNER, B. LOKEN, J. FANZO, H. C. J. GODFRAY, D. TILMAN, J. ROCKSTRÖM and W. WILLETT (2018): *Options for keeping the food system within environmental limits*. In: Nature 562 (7728): 519–525.

SPRINGMANN, M., H. C. J. GODFRAY, M. RAYNER and P. SCARBOROUGH (2016): *Analysis and valuation of the health and climate change cobenefits of dietary change*. In: Proceedings of the National Academy of Sciences of the United States of America 113 (15): 4146–4151.

STOLL-KLEEMANN, S. and U. J. SCHMIDT (2017): *Reducing meat consumption in developed and transition countries to counter climate change and biodiversity loss: a review of influence factors*. In: Regional Environmental Change 17 (5): 1261–1277.

STRAßBURG, A., M. EISINGER-WATZL, C. KREMS, A. ROTH and I. HOFFMANN (2019): *Comparison of food consumption and nutrient intake assessed with three dietary assessment methods: results of the German National Nutrition Survey II*. In: European Journal of Nutrition 58 (1): 193–210.

TELLER, C., C. HOLWEG, G. REINER and H. KOTZAB (2018): *Retail store operations and food waste*. In: Journal of Cleaner Production 185: 981–997.

THAR, C.-M., R. JACKSON, B. SWINBURN and C. N. MHURCHU (2020): *A review of the uses and reliability of food balance sheets in health research*. In: Nutrition Reviews 78 (12): 989–1000.

THORNTON, P. K. (2010): *Livestock production: recent trends, future prospects*. In: Philosophical transactions of the Royal Society of London. Series B, Biological Sciences 365 (1554): 2853–2867.

TILMAN, D. and M. CLARK (2014): *Global diets link environmental sustainability and human health*. In: Nature 515 (7528): 518–522.

TOMASZEWSKA, M., B. BILSKA, A. TUL-KRZYSZCZUK and D. KOŁOŻYN-KRAJEWSKA (2021): *Estimation of the Scale of Food Waste in Hotel Food Services-A Case Study*. In: Sustainability 13 (1): 421.

TUKKER, A., R. A. GOLDBOHM, A. de KONING, M. VERHEIJDEN, R. KLEIJN, O. WOLF, I. PÉREZ-DOMÍNGUEZ and J. M. RUEDA-CANTUCHE (2011): *Environmental impacts of changes to healthier diets in Europe*. In: Ecological Economics 70 (10): 1776–1788.

UN (2015): *Resolution adopted by the General Assembly on 25 September 2015 (70/1)*. Transforming our world: the 2030 Agenda for Sustainable Development. United Nations, New York, NY, USA.

UN NUTRITION (2021): *Livestock-derived foods and sustainable healthy diets*. Discussion paper. UN Nutrition, Rome, Italy. In: https://cgspace.cgiar.org/bitstream/handle/10568/113923/UN_nutrition_paper.pdf?sequence=1&isAllowed=y. Call: 18.1.2022.

UNEP (2021): *Food Waste Index*. Report 2021. United Nations Environment Programme, Nairobi, Kenya. In: file:///C:/Users/thies/AppData/Local/Temp/FoodWaste.pdf. Call: 15.2.2022.

V. HAL, O., I. J. M. DE BOER, A. MULLER, D. DE VRIES, S. DE VRIES, K.-H. ERB, C. SCHADER, W.J.J. GERRITS, H.H.E. VAN ZANTEN (2019): *Upcycling food leftovers and grass resources through livestock: Impact of livestock system and productivity.* In: Journal of Cleaner Production: 485-495.

VILARIÑO, M. V., C. FRANCO and C. QUARRINGTON (2017): *Food Loss and Waste Reduction as an Integral Part of a Circular Economy*. In: Frontiers in Environmental Science 5: 21.

WARD, J. H. (1963): *Hierarchical Grouping to Optimize an Objective Function*. In: Journal of the American Statistical Association 58 (301): 236–244.

WBAE (2020): *Politik für eine nachhaltigere Ernährung (Policies for a more sustainable diet)*. Eine integrierte Ernährungspolitik entwickeln und faire Ernährungsumgebungen gestalten. Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz (WBAE) beim BMEL, Berlin, Germany. In: https://www.bmel.de/DE/Ministerium/Organisation/Beiraete/ Texte/AgrVeroeffentlichungen.html. Call: 22.1.2022.

WCRF and AICR (2018): *Continuous Update Project Expert Report 2018.* Recommendations and public health and policy implications. World Cancer Research Fund and American Institute for Cancer Research, London, UK. In: https://www.wcrf.org/wp-content/uploads/2021/01/Recommendations.pdf. Call: 19.1.2022.

WEIBLE, D., I. CHRISTOPH-SCHULZ, P. SALAMON and K. ZANDER (2016): *Citizens' perception of modern pig production in Germany: a mixed-method research approach*. In: British Food Journal 118 (8): 2014–2032.

WILLETT, W., J. ROCKSTRÖM, B. LOKEN, M. SPRINGMANN, T. LANG, S. VERMEULEN, T. GARNETT, D. TILMAN, F. DECLERCK, A. WOOD, M. JONELL, M. CLARK, L. J. GORDON, J. FANZO, C. HAWKES, R. ZURAYK, J. A. RIVERA, W. de VRIES, L. MAJELE SIBANDA, A. AFSHIN, A. CHAUDHARY, M. HERRERO, R. AGUSTINA, F. BRANCA, A. LARTEY, S. FAN, B. CRONA, E. FOX, V. BIGNET, M. TROELL, T. LINDAHL, S. SINGH, S. E. CORNELL, K. SRINATH REDDY, S. NARAIN, S. NISHTAR and C. J. L. MURRAY (2019): *Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems*. In: The Lancet 393 (10170): 447–492.

WRAP (2013): *Overview of Waste in the UK Hospitality and Food Service Sector*. Waste & Resources Action Programme, Banbury, UK. In: https://wrap.org.uk/sites/default/files/2020-10/WRAP-Overview%20of%20Waste%20in%20the%20UK%20Hospitality%20and%20Food%20Service%20Sector%20FINAL.pdf. Call: 10.10.2021.

XUE, L., N. PRASS, S. GOLLNOW, J. DAVIS, S. SCHERHAUFER, K. ÖSTERGREN, S. CHENG and G. LIU (2019): *Efficiency and Carbon Footprint of the German Meat Supply Chain*. In: Environmental Science & Technology 53 (9): 5133–5142.

ZKL (2021): *Zukunft Landwirtschaft. Eine gesamtgesellschaftliche Aufgabe (The future of agriculture. A task for the whole of society)*. Empfehlungen der Zukunftskommission Landwirtschaft. Zukunftskommission Landwirtschaft, Berlin, Germany. In: https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/abschlussbericht-zukunftskommission-landwirtschaft.pdf;jsessionid=A9A87DE717559B1E013C48A58A683A91.live922?__blob=publicationFile&v=15. Call: 10.3.2022.

ZÜHLSDORF, A., K. JÜRKENBECK, M. SCHULZE and A. SPILLER (2021): *Politicized Eater: Jugendreport zur Zukunft nachhaltiger Ernährung (Politicized Eater: Youth Report on the Future of Sustainable Food)*. Göttingen, Germany. In: https://www.uni-goettingen.de/de/document/download/ecc93c87045b061c7e7f61ff5f5f206f.pdf/Jugendreport%20zur%20Zukunft%20nachhaltiger%20Erna%CC%88hrung.pdf. Call: 11.3.2022.

List of Legislations

Gesetz über Agrarstatistiken (Agrarstatistikgesetz - AgrStatG), *in der Fassung der Bekanntmachung vom 17. Dezember 2009 (BGBl. I S. 3886), das zuletzt durch Artikel 109 des Gesetzes vom 20. November 2019 (BGBl. I S. 1626) geändert worden ist*.

Tierschutzgesetz (TierSchG), *in der Fassung der Bekanntmachung vom 18. Mai 2006 (BGBl. I S. 1206, 1313), das zuletzt durch Artikel 105 des Gesetzes vom 10. August 2021 (BGBl. I S. 3436) geändert worden ist*.

Appendices

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