

Article

## Cutting Food Waste through Cooperation along the Food Supply Chain

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**Abstract:** Food produced but not used for human consumption is a waste of natural resources. In order to prevent and reduce food waste, the main causes have to be identified systematically along the food supply chain (FSC). The aim of this study is (1) to shed light on the causes and effects of food waste through the analysis of 44 qualitative expert interviews examining the processes and intermediaries along the German food chain and (2) to find methods to reduce it. Results indicate that food waste occurs at all stages in the food chain. Thus, there is no single culprit to be blamed. Besides, the identified reasons for food waste differ between product groups; not a single solution can cause notable change. Furthermore, the analysis demonstrates that the causes and effects of food waste are to be found at different stages of the value chain. Hence, it is of high importance to improve communication and to raise a new appreciation for food among all stakeholders of the food supply chain in order to develop a more sustainable food system. Information on the topic of food waste needs to be shared among all actors of the supply chain. They need to share responsibility and work together to reduce food waste.

**Keywords:** understanding food waste; avoiding food waste across the food chain; qualitative expert interviews

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## 1. Introduction

Food which is produced for human consumption but not used for this purpose is a waste of natural resources such as land, energy or water [1–3] and leads to unnecessary CO<sub>2</sub> emissions [3]. On the one hand, almost one third of globally produced food is lost or wasted from farm to fork [3]. On the other hand, food must be produced to meet the needs of a growing world population of about 9 billion people by 2050 [4]. With increasing prosperity, however, people demand both more varied and simultaneously more resource intensive nutrition [5]. Thus, minimising food waste is fundamental to obtain a sustainable food system since food waste affects economic, social, ecological and health-related domains.

The competition for resources such as land, water and energy further increases the sensitivity of this issue. Thus, the coverage of global demand for food commodities is increasingly difficult, and the effects of anthropogenic induced environmental impact and climate change threaten the livelihood of future generations. For example, the value chain for food and drinks (food supply chain—FSC) in the European Union (EU) is responsible for about 17% of direct greenhouse gas emission and about 28% of the consumption of material resources [6]. Luckily, globally, the awareness of the positive impacts on reducing food waste is rising [7,8].

To face these challenges, the European Commission has formulated its “Roadmap to a Resource Efficient Europe” to reduce resource input into the food chain by 20%—while at the same time, halving food waste [6]. A more sustainable system of food production and management must be aspired to. In particular, this includes the prevention of food loss and food waste which is a complex problem with, among other, structural obstacles rooted in the modern lifestyle of the Western world. The basis for optimising the management of food is an inventory and analysis of the status quo of food waste and its main causes [9]. This includes, as far as possible, an investigation along the whole FSC primarily of food flow but also the use of resources and their impact on the environment. In the analysis of subsystems—such as single levels of the value chain, food categories, *etc.*—the interfaces to the overall system are of significance. The generic FSC is unique and different from any other supply chain due to the complexity of the logistic processes, manufacturing and processing, distribution and consumption of food especially with regard to quality, safety, sustainability and logistic efficiency [10,11]. In the investigation of subsystems, the origin, pathways and fate of food, raw materials and other resources are also of concern—both within the subsystem investigated and beyond to show the complexity of the interactions in the FSC. There already exists initial research into this at the European level and in some Western countries [4,8,12–19]. The focus is mostly on estimating the amount of food thrown away within a specific study area but also the causes for food waste along the FSC are shown [4,8,15–17]. Previous research about the causes and the source of food waste as well as measures to reduce it along the food supply chain in Germany does not exist. The Institute for Sustainable Nutrition and Food Production (iSuN) at the University of Applied Sciences Münster conducted a study for the German state of North Rhine-Westphalia in order to assess the amount of food waste in Germany; it also showed the

causes and effects of food waste along the food chain and methods of reducing it [16]. The study consists of four research components:

*Research component A* analyses the causes of food waste within the four relevant product groups and deduces implicit possibilities for recommended procedure.

*Research component B* performs an analysis of face-to-face interviews and anonymous online-interviews in private households.

*Research component C* analyses the available statistics in order to produce data on the amount of food waste.

*Research component D* shows that the creation of food waste leads to considerable social, economic and ecologic effects.

In this paper, the *main results of research component A* are presented.

The study was conducted to serve as a basis to develop action to reduce food waste and enhance the appreciation of food in the German state of North Rhine-Westphalia.

First, the causes for food waste are presented for FSC of four different product groups, which were selected according to their relevance to the issue and the country in which the study took place. Then, the explanation of cause–effect relationships follows; this occurs across product groups and indicates that cause and effect of food waste are to be found at different stages of the value chain. Finally, derived from the results, recommendations on how to act are demonstrated. Other countries like the UK, the United States or the Nordic countries (Denmark, Finland, Norway and Sweden) [4,8,12–19] have already published several studies on this issue, so comparisons are drawn between these studies and the results in Section 3.

## **2. Qualitative Case-by-Case Approach to Identify Processes, Interfaces and Causes for Food Waste along the Food Chain**

A qualitative case-by-case approach [20] was conducted (1) to identify the processes and interfaces along the food chain where food waste occurs; and (2) to study the causes of this loss. The approaches are based on interviews with various representatives from different companies; experts such as external advisors and a veterinary surgeon in the food chain of four product groups were also interviewed:

Plant-based food:

- (1) Vegetable
- (2) Bread and bakery

Animal food:

- (3) Milk and dairy products
- (4) Meat and sausages

The food groups included in the study were selected in terms of their importance for North Rhine-Westphalia [21] as well as their relevance to the generation of waste [4] and the associated resources. The study examined the food chain—agriculture, handicraft/industry (processing) and trade. Consumers were studied in a separated research module [22]. The hospitality sector was not considered further as it is subject of a current investigation.

The method of qualitative cause analysis was chosen [20,23] since it is able to face the complexity of the question, to identify influencing factors which cause food loss across the FSC and especially at the interfaces as well as to interpret cause-effect relationships.

To ensure reliability and to facilitate the comparability of the interviews, *semi-structured, open interview guidelines* were developed and tailored to the specific product group and level of the food chain. The interviews examined all information and the material flow in the process from procurement to quantity and quality management, distribution and production to disposal and recycling channels in companies. The core issue was:

*Which food waste is generated at which stage of the food chain and for which reason?*

### 2.1. Data Collection

In order to decide which companies should be interviewed, *theoretical sampling* based on predefined criteria [24] was employed. To ensure a reasonable spread of information for an exploratory approach the *heterogeneous nature of the study participants* was important, and so the criteria to choose the interview partners were enterprise-size, the level of food chain, production systems (organic and conventional) and product groups. In order to obtain a comprehensive picture of emerging food waste in North Rhine-Westphalia, an additional interview with two experts (a consultant from the Chamber of Agriculture and a veterinary surgeon) was conducted. The willingness of experts and company representatives to give interviews was crucial, so especially in the retail sector it was difficult to find interview partners.

In total, 44 interviews were conducted in October and November 2011. The interviewees were *representatives of the companies* mostly from management level such as managing director, production manager, and quality manager or from other management positions. In addition to the interviews, in most enterprises, the statements were supported by *company tours* and *informal interviews* with employees.

The structure of the surveyed companies is shown in Figure 1.

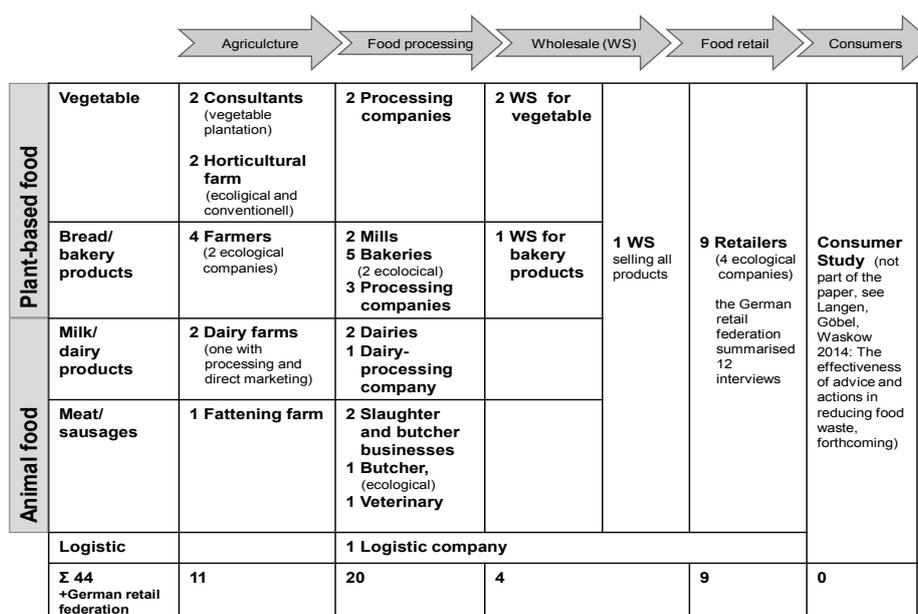


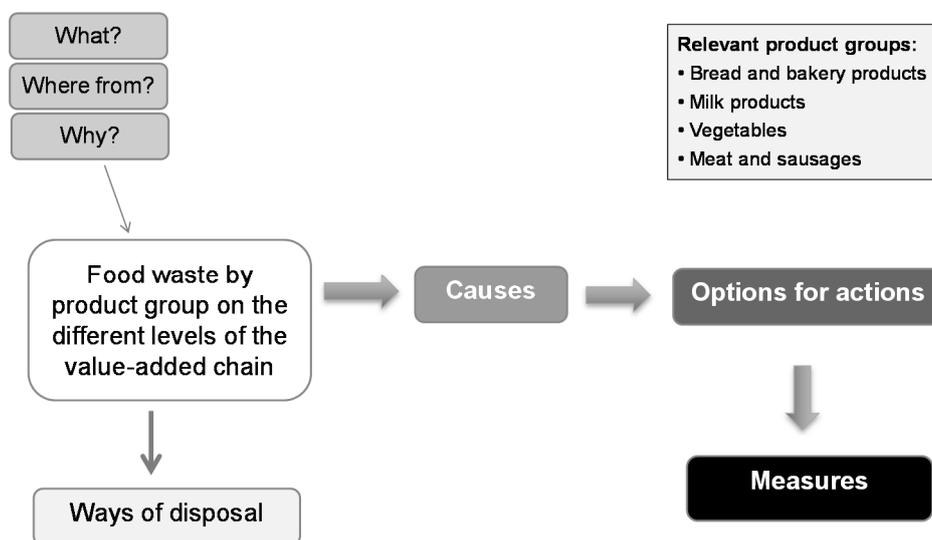
Figure 1. 44 Expert-interviews along the value-added chain (WS = wholesale).

The interviews were carried out by two researchers; one interviewer conducted an open guideline interview with the interviewee while the other interviewer took notes. Through the open dialogue, detailed and fundamental questions could also be clarified and a cause analysis through exchange was developed. The interviews were recorded and took between 45 and 120 min. Partially relevant places and processes of the enterprises involved were inspected by the researcher after the interview.

## 2.2. Data Analysis

To prepare the data for analysis, the “recorded interviews” were made anonymous, transcribed and partially summarized. After this, the data was analyzed with the methods of *qualitative content analysis* [23]. The statements in the interviews were structured into categories and coded to gain information on processes, the causes of food waste and the recycling routes at different levels of the value chain for different product groups as well as already used measures to reduce food waste. To guarantee the *objectivity* different researchers defined the categories together and double checked the interpretation of the analyzed interviews. Moreover the qualitative content analysis is a systematic approach which follows precise rules. So the analysis is transparent and can be checked by third parties [23].

Finally, an overview with the key aspects for each product group was developed, and this also shows correlation between the individual interviews. The causes for and data of food waste at each level or interface of the food chain were interpreted in critical comparison with existing data. Moreover, the results were discussed and validated during an interdisciplinary workshop with experts in order to decide on appropriate action. Figure 2 gives an overview of the analyzing process.



**Figure 2.** Qualitative research along the value-added chain: procedure for analysis.

## 3. Results

Previous research on the causes and the source of food waste as well as the measures to reduce it along the food supply chain in Germany did not exist. Other countries like the United Kingdom, the United States or the Nordic countries (Denmark, Finland, Norway and Sweden) have already published several studies, and so it is possible to draw comparisons between these studies as is done below.

### 3.1. Causes for Food Waste for the Respective Food Supply Chain

In each of the four FSC examined for plant-based and animal food, different main causes for food waste were found during the interviews conducted.

Plant-based food:

(1) vegetable, main reason: standards

For the *vegetable product group*, marketing/retailer product quality standards as well as product specifications were identified as the main causes of food waste as is also shown for Nordic countries by Stenmarck *et al.* [18] and for industrialized countries in general by Gustavsson *et al.* [4]. In order to meet high quality standards, retailers offer products in a way they believe consumers want them to be presented. Furthermore, consumers receive food in the right appearance, weight, size and shape, so farmers waste large portions of their crops instead of delivering them to the retail [4]. Standardized packaging additionally contributes to the problem of food waste in the vegetable sector. From interviews with experts in the vegetable supply chain, it became clear that direct marketing with vegetable leads to less waste than other channels of distribution. This is due to the fact that direct marketing involves fewer middle-men between grower and consumer, and so there are fewer quality checks, fewer restrictions on quality and less transport which might damage food.

(2) bread and bakery, main reason: freshness

A central problem within the group of *bread and bakery* is the limited freshness of such products. This fact is contrary to the consumers' wishes to buy fresh products even until late in the evening; this was also found by Stenmarck *et al.* [18]. Buzby *et al.* [19] pointed out that the demand for fresh products at all times also exists in other product groups.

Animal food:

(3) milk and dairy, main reason: production process

With *dairy products*, many causes for the discarding of goods in the earlier FSC are linked to technical issues (wastage through defects in machinery, which also occurs in other sectors) or other deficiencies such as loss through the cleaning of machines [4]). In later stages of the FSC, products which have a short residual shelf-life will often be rejected by retailers and sometimes returned to product suppliers. The best-before date also has an important effect on customer sales—especially with dairy products—because consumers do not buy products which are close to the expiry date. They wish to have fresh products with the longest shelf life [25,26].

(4) meat and sausages, main reason: health and cost pressure

The industrialized value added chain for products in the categories of *meat and sausages* undergoes substantial time and cost pressure. Two of the interviewees from the category “meat and sausage” stated that it is not economical to increase work levels or time to reduce waste during meat processing: “There is always still meat on the bone which has to be thrown away because of the time factor. It is too expensive to pay someone to remove the flesh from the bone or the pig's head, so it is thrown away” (manager from a slaughter and butcher business). Moreover, food from this product group has a high risk to health since not keeping close to product specifications with regard to quality, optical-characteristics,

texture and temperature automatically leads to food waste. In addition, there are product rejections which also lead to food waste [26].

In all product groups, seven *central potential causes* were identified:

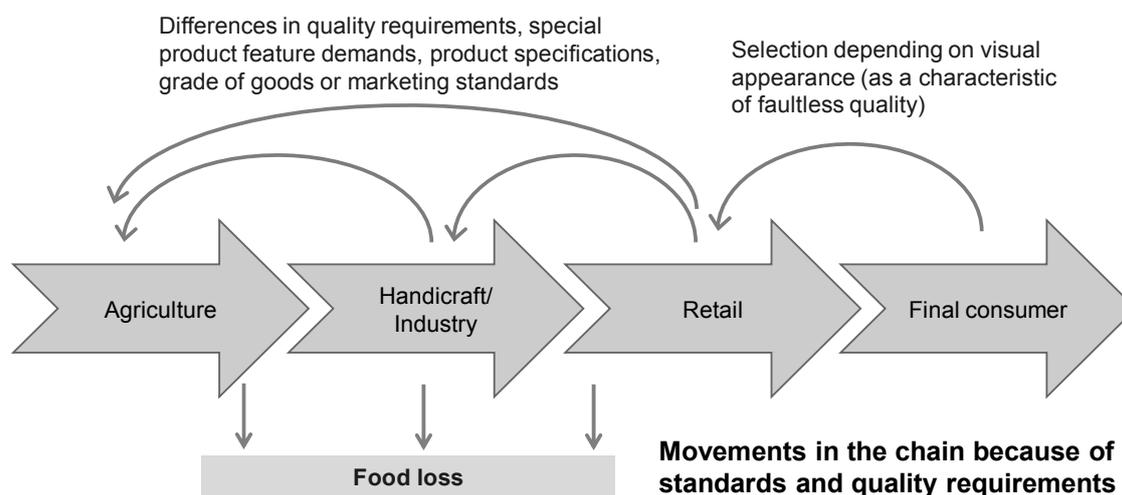
- (1) The definition of process- and market-induced standards and quality requirements
- (2) Legal framework requirements; especially regulations to guarantee food safety
- (3) Market convention
- (4) Human error
- (5) Technical issues
- (6) Hold-ups within logistics
- (7) Cultural influence

### 3.2. Cause–Effect Relationship for Food Waste across the FSC

The analysis of inter-dependency shows that causes and effects can be assigned to different stages of the value chain. Demands on products as well as the selection of goods create waste in stages that differ from the stage in which these demands are made.

#### 3.2.1. Process- and Market-Induced Standards and Quality Requirements

Firstly, it was found that product specifications and demands on quality on later value-added steps, especially for products in the vegetable group, cause food waste to get downshifted within the value chain as demonstrated in Figure 3. The cause–effect relationship leads to food loss at the early stages of the FSC.



**Figure 3.** Process- and market-induced standards and quality requirements.

Although the number of product specific marketing standards for fruit and vegetables were reduced by about two thirds—from 36 to 10 product standards (Regulation EC No. 1580/2007 [27])—trade and processing enterprises continue to classify products according to high standards. If a retailer requires a class subdivision, producers relate to *standards of the United Nation Economic Commission for Europe*

(UNECE) which is an international recommendation. It provides no legal classification, but allows the categorization of products into different quality levels or classes of trade [28], so products fit into a single package, the quality is uniform or the optical impression meets the customers' requirements. The UNECE standards reflect an important function for the specification of ingredients, and allow a smooth conduct of business between retailers and their precursors. Since quality requirements are not mandatory, there is the possibility for retailers to make their own regulations on acceptable quality [29].

In addition to the minimum quality requirements of general marketing, further standards exist and apply to shape and size. The established and proven practice of formulating product requirements for commercial classes is not questioned by the actors. Because according to the statements of the experts interviewed, also products with small optical defects or damaged packaging are not bought by customers. Thus, quality is measured by impeccable appearance and good taste is secondary. Moreover, the interviews illustrated that, according to market conditions, different conditions apply. When supply is sufficient even products with minor defects are rejected (with reference to standards) whereas in situations of reduced supply, products which would normally not be acceptable are accepted. Subcontractors also partly work for retailers to check products at delivery ensuring strict quality control. In addition, the food industry requires higher product specifications than before such as the fat content in meat (summarized result from the interviews conducted in the retail sector).

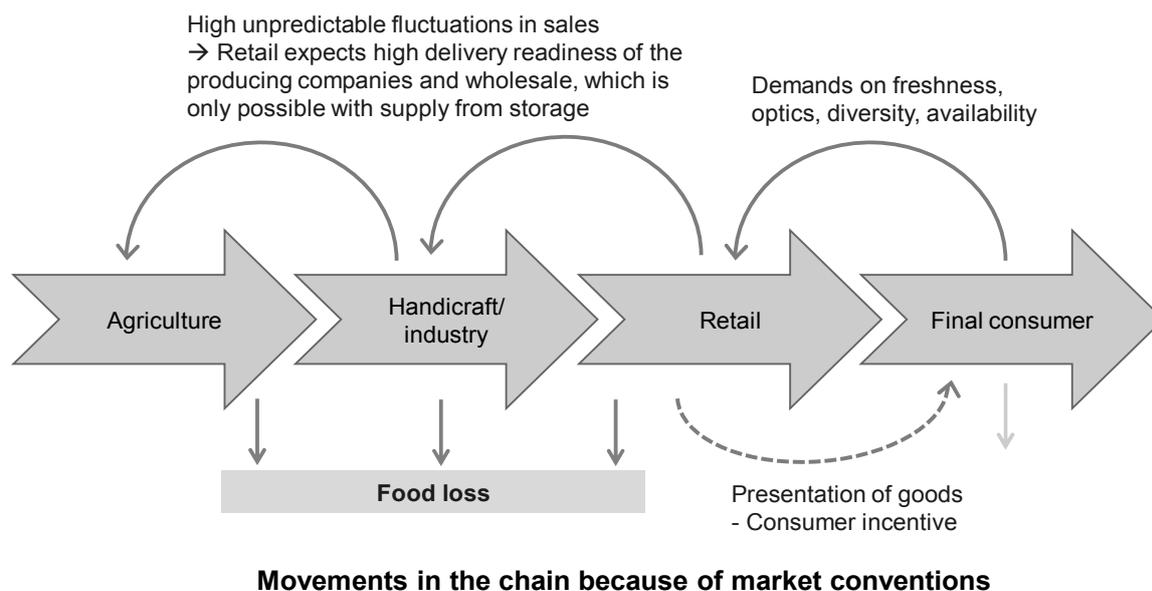
When selling fresh products, the appearance plays a crucial role. Products with small optical defects are difficult to sell even in organic markets; this suggests that consumers use the standardized appearance of the product as an indicator of quality (summarized result from the interviews conducted in the retail sector). This raises the question whether the optical requirements of consumers affect the requirements of trade and processing plants, or *vice versa*?

The findings show that the understanding of quality, which is responsible for rejecting food, is based on regulations and international standards, not on issues of nutritional value or enjoyment.

When products are rejected because they do not conform to the specifications of the particular customer, there is a need for a clear distinction of the causes of waste between the prevention of health risks (such as non-compliance with hygiene regulations, interruption of the cold chain or high pesticide exposure), standardization for reasons of cost (packaging) or because of marketing strategy (optical quality). To avoid waste resulting from low quality, the products that are discarded because of health risks also have to be considered since this means there has already been errors in the FSC. Accordingly, they have to be removed from the value chain for human consumption. Yet, the current framework and conditions for health protection were not called into question by the interviewees. The latest study of Priefer *et al.* [30] points out that “current regime of food safety regulations should be reviewed in order to identify norms that are not mandatory to protect human life, but lead to unnecessary food waste” (p. 127).

### 3.2.2. Market Conventions

Other aspects which show changes in causes and effects along the FSC are market conventions. The constant availability of fresh and diverse goods has become a central prerequisite in the Western markets—and leads to food waste in the early stages of the value added chain. Demands on freshness, variety and availability as a cause of food waste and the effects resulting from these are shown in the Figure 4.



**Figure 4.** Market conventions (freshness, variety and availability).

The interviews clearly show that the demands of consumers, or rather consumer demands as regarded by retailers, lead to food waste all along the FSC. A key statement in one of the interviews was “on the one hand, the consumer requires guaranteed supply at a high standard of quality; on the other hand, he does not guarantee demand. This together with miss-assessment of the market is one of the key causes for food waste. Perhaps, it is the most important one!” (Interview with the veterinary surgeon). The interesting point is that these demands not only influence the stage of the value chain at which products are wasted, but also lead to problems at earlier stages.

Compared with other countries, Germany has a high concentration of discount stores and strong price competition. Like in other saturated markets, the consequence is price dumping between dealers, leading to low food prices [31,32].

This is the reason why people in industrialized countries can afford to waste food [4]. It might be concluded that loss of food can be compensated quickly and inexpensively. A key reason for the loss along the entire food chain is the high expectation of constant availability of a broad range of fresh products. To withstand market competition, meet customer requirements and not lose customers because of sold out products, freshness, variety and the availability of food is a high priority along the entire value chain. In the following, the aspects of product availability, variety and freshness are presented in more detail.

#### *Availability*

Wholesale is at the centre of the FSC for commercialization if the food is not sold through direct marketing. The important role of an intermediary is to control a needs-based procurement through a precise management of volume.

The interviews show that because of the short-term order possibilities of retailers, intermediaries need to have permanent availability of goods with a high delivery capacity. Likewise, Stenmarck *et al.* [18] pointed out that customers of Nordic countries demand full shelves and a broad variety of products just before closing time. In addition, Lebersorger and Schneider [33] identified the same demand by

customers in Austria. There is an implicit danger of creating a surplus at the wholesale or manufacturing level if there is unexpected fluctuation in sales or miscalculation in the quantity ordered at subsequent stages of the FSC. Anyway, there is always some fluctuation in sales to final consumers, but also in the quantity ordered by retailers. Regardless of the season, this is considered in the procurement of goods, sales fluctuation which are because of public holidays, school holidays or short-term change in the weather. Especially in bakeries, rainy weather is seen as a trigger for the waste of goods because resale is lower (interview results of present study [34]).

From the retailer's viewpoint, the possibility of ordering short-term is positive because goods can be obtained which meet specific needs. Regarding the supplier's perspective, there is the necessity of a short-term and high delivery capability (interview results of present study).

### *Variety*

During food shopping, consumers are presented a variety of constantly available, aesthetically perfect looking food, convenient products and ready-to-eat dishes, as is also shown by Stenmarck *et al.* [18] in Nordic countries.

This demonstration of “plenty” is achieved for some products (products in the refrigerated section or bakery products) through a large range of products and a broad product mix. For other products (fruits and vegetables), this is obtained by the amount of goods offered and the way they are presented. This representation of “full shelves” is thereby guaranteed until closing time. The buying behavior of consumers is stimulated by visual sales incentives. These facts lead to the assumption that the presentation of goods increases consumer buying beyond necessary demand, consumers buy different products to those they actually need and, finally, they do not consume them at home but dispose of them [8,13,35]. The dotted line between retailer and consumer in Figure 4 represents this assumption.

### *Freshness*

In retail packaged products such as bread, milk and dairy, products are removed and disposed of shortly before reaching the best before date (see Section 3.1), so that consumers are offered fresh products and still have time to consume this food at home.

According to German food labeling regulations (Lebensmittelkennzeichnungsverordnung, [36]) packaged products require a best before date by law. The German best before date (Mindesthaltbarkeitsdatum—MHD) provides information on the date up to which product characteristics are guaranteed. These properties do not necessarily say anything about the microbiological shelf life of a product, and products must not be disposed of at the end of MHD [36]. During every day business, the MHD is often interpreted as an indicator of freshness—the MHD terms here are often determined more by marketing than by product requirements. The result is that every customer chooses products with the longest MHD to obtain the freshest products [18,25]. The interviews revealed that the MHD maturity is used as an organizational tool for volume control and indicates whether a product is still purchased, sold off or can be delivered.

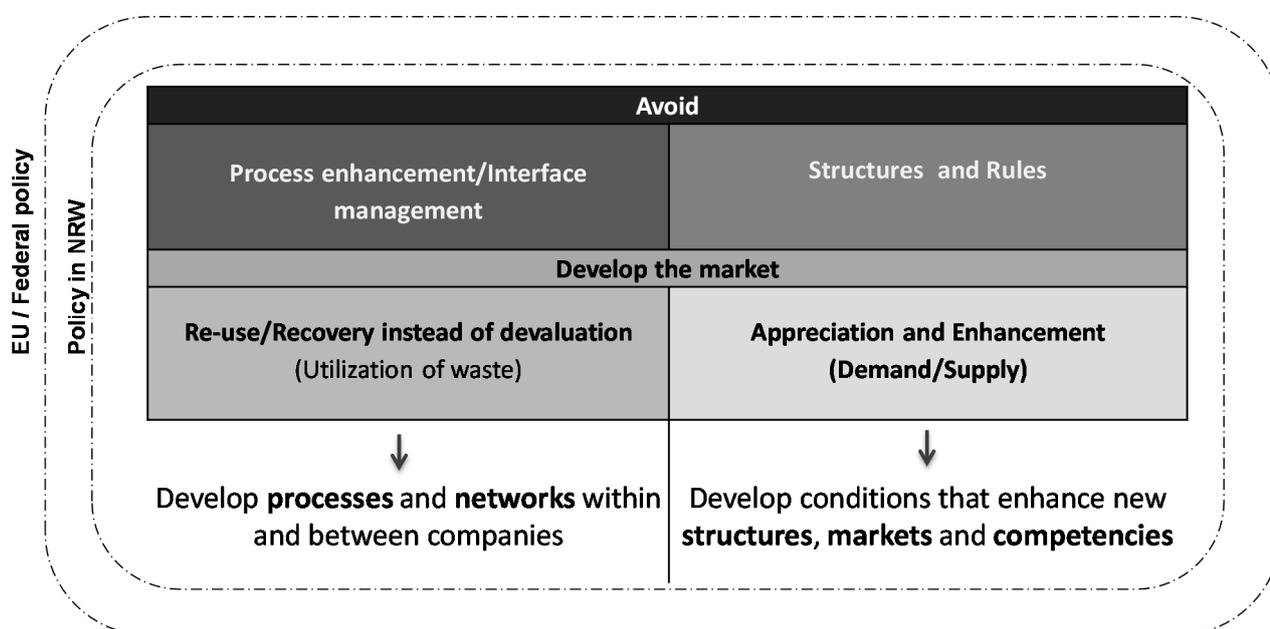
In addition, at the consumer level, the preparation of food at home is partly replaced by convenience products [37], whereby the basic skills of cooking and knowledge of food are neglected [38]. In this context, presumably, the appreciation of food decreases which encourages the throwing away of food.

### 3.3. Central Fields of Action to Reduce Food Waste

Four central fields of action resulted from the interview conclusion, workshops and expert-discussions. The study recommends courses of action for reducing and avoiding food waste in the German state of North Rhine-Westphalia in the four categories:

- Process enhancement/interface management
- Structures and rules
- Re-use/recovery instead of devaluation
- Appreciation and enhancement (see Figure 5).

These four fields of activity along with the results from the study allow the development of practical measures, ways of reducing food waste and identify “new markets” for the subsequent use of food waste.



**Figure 5.** New appreciation for food—four central fields of action (for an explanation of the categories please see the text).

#### 3.3.1. Process Enhancement Interface Management

In the category “*Process enhancement/Interface management*”, the problem of insufficient cooperation and cooperation across production stages leads to a lot of food waste. Today, foods are produced within a global network. Each single company which takes part in the production process will try to optimize their own processes, but at the same time, accept that their actions may lead to an accumulation of food waste at earlier stages (less stock-keeping but at the same time demanding a permanent stock availability of suppliers transfers the risk of spoilage to an earlier stage of production). The study therefore recommends an optimization of value added chains, focused on waste avoidance. Segrè *et al.* (2009) also described that there are different reasons for the production of a growing quantity of food surplus at each level of the FSC, so that a “Last Minute Market” could link the surplus (supply) and deficit

(demand) to counterbalance the food market [39]. Besides, the focus of this study should be the prevention of waste and not the usage.

### 3.3.2. Structures and Rules

The examination of commercial operational structures in the category “*Structures and Rules*” points out, that the rules which regulate food production lead to food waste which would usually be classified as avoidable waste. Product quality categories, standards *etc.* simplify the cooperation of partners in trade and serve as a method of quality control. At the same time, these standards and norms create a situation in which a product that does not fit in with standards cannot be put to its intended use. The study recommends a multi-stakeholder dialogue which critically deals with the use of and need for norms, rules, specifications, quality expectation and habits with particular regard to the reduction of food waste. The aspects of consumer protection and food safety have to be taken into account [30].

### 3.3.3. Re-Use/Recovery Instead of Devaluation

Causes for food waste are often linked to the lack of concepts for subsequent use and or insufficiently utilized ways of disposal. These causes are named in the category “*Re-use/Recovery instead of devaluation*”. Food is often wasted even though prospective buyers are available, and often in close proximity. The study recommends regional initiative and model projects for innovative waste management, focused on the re-use of waste and the development of supporting services.

### 3.3.4. Appreciation and Enhancement

The category *Appreciation and Enhancement* lists causes for food waste that are rooted in the way consumers appreciate food, in the knowledge of foods and the ability of preparing or storing food. Moreover, people who are acting along the whole FSC are taken into account in this category and need to develop a new appreciation for food. In order to minimize food waste linked to these causes, the study recommends informing and educating actors of the supply chain and consumers on the topic of food waste. Lehmann (2011) also called for embedding *zero-waste* ideas in education curricula and raising awareness through research and education as well as refocusing research agendas to bring about attitudinal change and the reduction of wasteful consumption [40]. At the same time, innovations and services should be promoted that focus on relieving consumers from some of their complex daily routines, because this will aid the consumer with the chance to better match and manage shopping, food preparation and consumption.

By putting these options into practice, the ecological effects of the different product groups have to be taken in account. The upstream chain footprints of meat products as well as of dairy are more relevant than vegetable or bread and bakery products. So, product groups rank differently when categorized according to the resources that are lost within their upstream chains from the way they rank when categorized by the total quantity of food waste they account for [16,41]. This is why examination and management of food waste should always consider indicators for utilization of resources and other environmental impacts of related upstream chains [16].

#### 4. Conclusions

To prevent or reduce food waste, its main causes have to be identified systematically throughout the whole FSC. Most studies conducted so far focused either on estimating the amount of food thrown away or the reasons within a specific study area. A comprehensive approach taking into account the whole FSC in Germany was lacking. We suppose that it is very important not only to analyze processes in e.g., single enterprises but, in particular, the interfaces between the levels of the value chain. Through the analysis of qualitative information along the FSC, the study shed light on some important open questions related to the issue of food waste. So, the study design is characterised by an openness of the survey and evaluation methodology and enabled to explore the context of food waste generation along the whole supply chain.

The results reveal that food waste is produced at all stages of the value chain. The causes differ from stage to stage and also are product group specific. A remarkable insight is that practices which lead to food waste often take effect across various levels of the food chain, so quality standards and requirements of the later stages of the FSC cause a downshifting of food waste along the FSC towards the earlier stages of the FSC. Thus, the food waste found at the e.g., farmers level is caused by standards requested by the retail. Furthermore, the findings show that the understanding of quality, which is responsible for rejecting food, is based on regulations and international standards and not on issues of nutritional value or enjoyment. This understanding affects e.g., the choice of varieties in the plant and livestock production at the farmers' level resulting in reduced biodiversity. It becomes clear that the complex system of FSCs with different actors and actions relate to each other even in creating food waste.

Thus, the analysis of the causes of food waste clearly demonstrates that there is not a single culprit who can be blamed for the current situation. It also becomes obvious that there is not a single solution to bring forth notable changes. This is in line with recent developments in "Sustainable Food Supply Chain Management" published in the special issue of *Int. J. Production Economics* in 2014 [11]. Hence, it is of high importance to raise a new appreciation for food among all stakeholders of the food supply chain in order to arrive at a more sustainable food system. Although every stage in the food chain is effective for itself, all actors have to be informed on this topic and united in the approaches towards a reduction of food waste. Only by doing so, the many causes of wastefulness within the different sectors of food industry can be eliminated and, hence, as few foods as possible will be discarded. Courses of action for a reduction of food waste should be taken within each company but also in interaction with other stages of the value chain, especially the interdependencies of each firm with the general framework, the interactions on the markets as well as with its social environment and with the appreciation of foods. Also, the examination and management of food waste should consider indicators for utilization of resources and other environmental impacts of related upstream chains. To reduce food waste, the solution can only be to share responsibility across the supply chain in which all stakeholders' behaviors are to such an extent connected that each activity has an impact on all other actors in the chain, regionally and globally.

The insights into four product categories reveal the importance for more comprehensive studies on sustainable food systems. To reduce food waste along the entire FSC, further in depth research is needed for a better understanding of the relationships and automatisms in the FSC.

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## Author Contributions

All of the named co-authors were mainly involved in the development of the research design and the discussion and preparation of the data for publication as well as writing the results down in a report. Christine Göbel and Nina Langen prepared and summarized the data for this paper and mainly wrote this paper under the leadership of Prof. Petra Teitscheid and Prof. Guido Ritter, who were also responsible for the research project. Moreover, Christine Göbel and Antonia Blumenthal conducted data collection and analyzes. All authors read and approved the final manuscript.

## Conflicts of Interest

The authors declare no conflict of interest.

## References and Notes

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