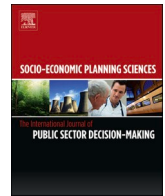




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Generation and prevention of food waste in the German food service sector in the COVID-19 pandemic – Digital approaches to encounter the pandemic related crisis

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ABSTRACT

The COVID-19 pandemic has affected the food service processes and operations in many ways, such as the use of contactless payment methods or ordering systems has increased. Despite the pandemic-related obstacles the sector faces, SDG12.3, halving food waste at the retail and consumer levels by 2030, needs to be achieved. This study therefore examines the two questions: How far has the pandemic affected the generation of food waste and the implementation of prevention measures? How does the use of digital technology, which has been increasingly accessed since the beginning of the pandemic, offer opportunities to further reduce food waste in the sector? Two online surveys were conducted. In the first survey, 84% of the 170 respondents indicated not to implement further food waste reduction measures since the start of the pandemic, while 11% do. They engaged in more targeted purchasing activities based on more conscious planning of the production volume, the reduction of menus offered, and the standardisation of menu components. In total, 91 food service companies provided data on the food wasted (in %) before and since the pandemic. Of the 179 entries made for the different waste categories, 47% indicated waste had not changed, while 42% and 11% indicated an increase/decrease, respectively. In the context of the ongoing digitalisation of the sector, possible fields of action for digital applications were identified, which are helpful in combating food waste in general and specifically during the pandemic. In this study, a classification scheme for digital food waste reduction approaches was developed. These approaches are systemised into four categories: forecasting, waste analysis, redistribution, and measures catalogue. Further, the process steps in which the applications are applied are indicated and direct and indirect effects on the generation of food waste are provided.

1. Introduction

Every year, 12 million tonnes of food are wasted in Germany [1]. Approximately 14% of this amount is attributed to the food service sector (FSS) [1]. Considering that nearly 690 million people worldwide suffer from hunger, wasting food is not only uneconomical but also ethically unacceptable [2]. Moreover, the resources needed to produce food, such as energy for transport, processing and storage or the use of artificial fertilisers pollute the environment [3].

One of the UN's 17 Sustainable Development Goals, SDG 12.3 aims to halve food waste at the retail and consumer level and reduce food losses along the food value chain. The German government has adopted the UN's SDG 12.3 and has committed itself to the EU's objective of

meeting said targets. To reach the SDG 12.3 goal, the German cabinet adopted the National Strategy for Food Waste Reduction [4] in February 2019. This strategy focuses on the causes of food waste in the food value chain, taking the production (post-harvest) up to the consumption in private households into account. To reduce food waste, the strategy introduced four fields of action: politics, business, changing behaviour of all actors involved, and potential of research and digitalisation.

The COVID-19 pandemic presents the FSS with unprecedented challenges, threatening the existence of food service businesses. In Germany, the first lockdown required a closure of food businesses, therefore the food service companies had to suspend their regular operations. In the current lockdown (04/2021), selling food is exclusively allowed through take away or delivery. It is not yet possible to predict

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how long the businesses will have to continue operating under the restricted conditions.

Lockdowns and stay-at-home measures resulted in a change in consumer behaviour. A growing relevancy of digital tools could be observed in multiple sectors during the pandemic: almost half of all Germans used delivery service during stay-at-home orders [5]. According to a study by the German Federal Ministry of Food and Agriculture (BMEL), 8% used delivery services more than they did before the pandemic [6]. Abay et al. (2020) described a drop in google searches for “restaurant” and “hotel”, while searches for “delivery” became much more frequent [7]. Further, the use of digital technologies helps adhering to contact restrictions and hygiene regulations [8].

The strict hygiene regulations applied to the companies to ensure food safety and reduce the potential transmission of the virus [9,10], also mitigate the compliance with sustainable business practices, as the share of food waste as well as already established measures against food waste might be affected. Further, food delivery increases the use of plastic packaging [11]. Several value-added processes might be taken under a reconfiguration due to the change in consumer behaviour and needs.

While studies have already been published on changes of food waste caused in private households in Spain, Italy, and England due to the pandemic [12–15], according to the authors’ knowledge there is no evidence on changes in food waste generated in the FSS to date. Therefore, this paper investigated how the pandemic affects the generation of food waste and its prevention.

The prevention of food waste is stated as the prioritised measure in the food waste hierarchy and should be targeted [16,17]. Reducing food surplus and waste has the strongest effect on sustainability long-term, as already the next favourable option in the hierarchy contributes to greenhouse gas emissions [17]. One field of action of the German National Strategy for Food Waste Reduction is given by means of digitalisation. Currently, there is insufficient scientific knowledge about the potential that digitalisation provides for food waste reduction in the FSS. Accordingly, this paper further aims to examine how digitalisation offers opportunities to reduce food waste and to better cope with the pandemic-related crisis, supporting the resilience of this sector.

2. Objectives and theoretical framework

The main objectives of this study are first to assess how the pandemic affects the generation of food waste in the FSS; and second how to avoid food waste using digital applications to help companies better manage the crisis. This study adds to existing literature as it delivers information on the effect of the pandemic on food waste generated in the FSS in Germany and on the potential that digitalisation provides for food waste reduction. To achieve this, the study aims to obtain answers to the following research questions:

1. How much food was wasted before the pandemic and what is the influence of the pandemic?
2. What were the most frequently implemented food waste reduction measures before the pandemic and how are they affected?
3. How does the digital transformation affect business activity?
4. How widespread is the use of digital technologies in the food service sector and what is the influence of the pandemic?
5. How can digital technologies be used to reduce food waste in the food service process?

The terms food waste and digital technologies were defined by the authors to set a theoretical framework for the subsequent desk research and online surveys.

2.1. Food waste

According to the European project FUSIONS (2014), food waste is

any food and inedible part of food removed from the food supply chain to be recovered or disposed [18]. Food waste refers to food appropriate for human consumption, which is being discarded, whether or not after it is kept beyond its expiry date or left to spoil.

In the FSS food waste can be categorised according to its origin: as receiving waste, when acceptance of raw materials is refused at the incoming goods inspection; storage waste which arises from spoiled goods or goods whose best-before date has expired; preparation waste, resulting from trimming of food or errors from cooking; safety margin waste, comprising food which is overproduced and does not leave the kitchen; serving waste, which does not reach the guests’ plates; and plate waste, which consists of food leftover on the plates [19,20]. In this study, no restriction is made to one of the categories of waste.

2.2. Digital technologies

Digital technologies underlay an inconsistent definition and classification in the literature. The commonly used acronym SMACIT describes the different digital and social contexts in which the technologies are applied: social, mobile, analytic, cloud and Internet of Things [21, 22]. Different usage scenarios of digital technologies are intermingled in this classification.

The present paper refers the term digital technologies to: the provision of information and to the collection or processing of digital data within a company or in exchange with its customers, suppliers or other stakeholders. Additionally, related terms such as digital solution, digital innovation, digital application and digital tool can be categorised:

- first, by their type of technology,
- second, by their place of application along the value chain of the FSS,
- third, by their overall benefit for food service businesses in terms of their food waste reduction potential.

Considering this categorisation, the digital tools included in this study range from basic hardware solutions to different forms of software such as apps, internet driven technology (e.g. online platforms) up to artificial intelligence.

3. Methodological approach

The study was carried out in three steps (see Fig. 1). First, the research questions (see Section 2), which are related to the main topics *digitalisation* and *food waste*, were stated.

After that, a methodological approach was carried out in three phases. In the initial phase, a desk research was conducted, covering internationally available literature and concept papers. The topics searched for comprised: digitalisation in the FSS, digital applications used for the reduction of food waste, business operations in the FSS during COVID-19, and the influence of the pandemic on the occurrence of food waste and on counteracting measures.

In the second phase, the geographical focus was narrowed down from an international perspective to a national focus on the German food service market. The results of the desk research were used as the basis to set up an online survey (online survey 1), investigating the business activities of the Germany FSS before and during the pandemic. The participants were asked about their usage of marketing instruments and food waste measures as well as the occurrence of food waste. It was the objective of this phase to obtain missing information and to verify the results of the first phase specifically for the German market. This survey was complemented by a second survey (online survey 2) on the issue of food waste during the pandemic.

For online survey 1, a standardised online questionnaire was used, which covered the following topics: monitoring of food waste, implementing reduction measures, applying digital tools before and during the pandemic, recommendations for tackling the pandemic crisis, and general information (number of guests, type of facility). To specify the

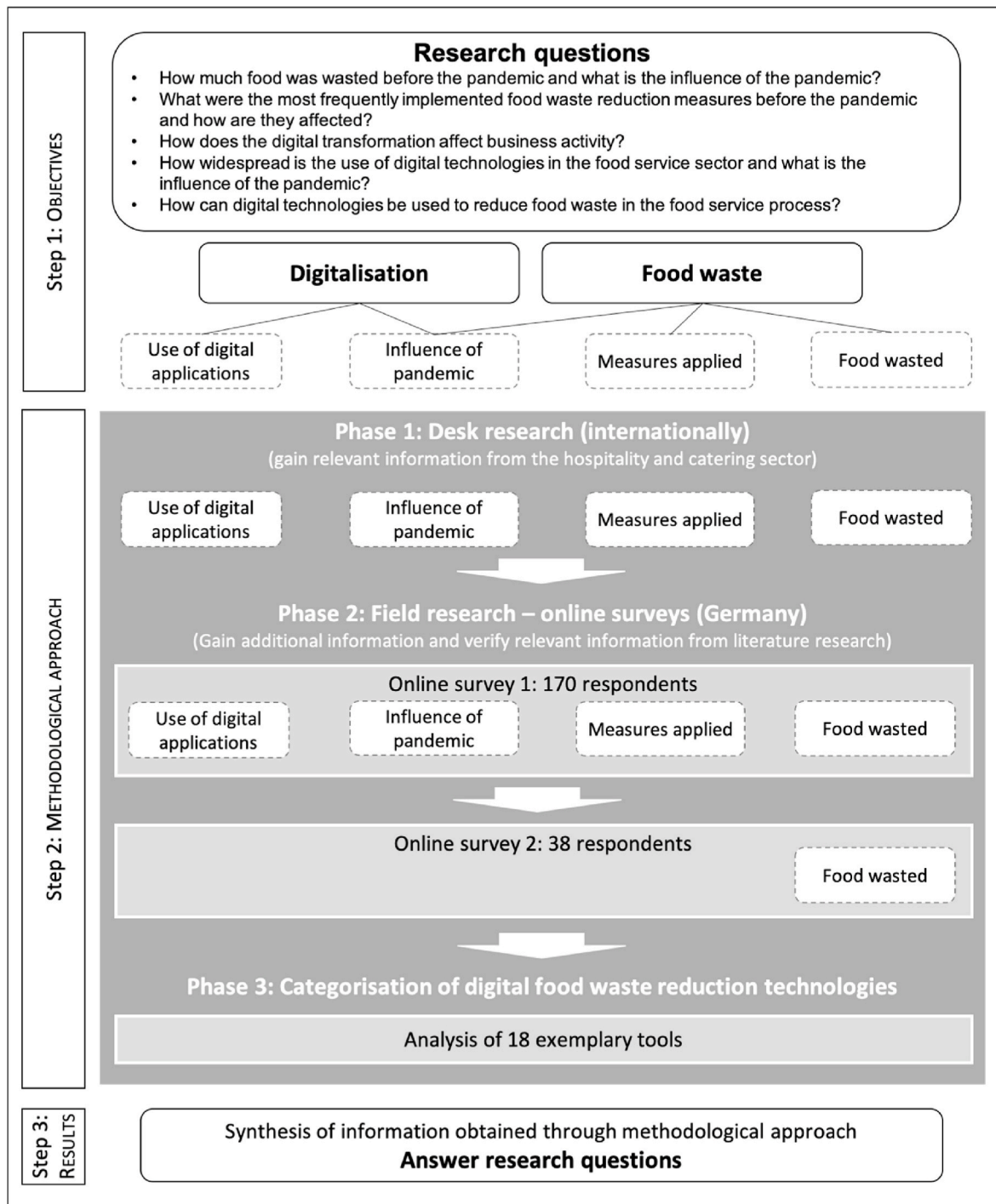


Fig. 1. Steps and methodological approach of the study (Source: Authors' own illustration).

term digital tools in the questionnaire, participants were asked about digital marketing instruments (e.g. delivery services) and other digital tools (e.g. from the areas of planning, purchasing or production). The questionnaire comprised closed questions with single and multiple answers, scaling questions and open questions. The scaling questions contained exclusively verbal scales. Filter questions were used to heighten information gain. The survey was designed based on the recommendations of Kornmeier (2007): it was structured in such a way that the processing time was as short as possible, it contained mostly closed questions, and included an incentive (lottery of cookbooks) [23]. There were no mandatory questions in the questionnaire. Three pre-tests were completed to identify and adjust possible sources of error. For the

descriptive statistics analysis of the closed questions, the IBM SPSS Statistics 24 programme was used, while the open questions were analysed by an inductive category-based approach according to Kuckartz et al. (2009) [24].

The target group of the survey were kitchen managers and decision makers of the German FSS. Participants were recruited by e-mail. The contact data of a representative sample of 10,000 companies was provided by a market research institute, which specialises in the FSS. The representative sample included public caterers, from the sectors education, business, and care, as well as restaurants, hotels, cafes, and system caterers. The survey was open to respondents for a 4-week period, beginning October 01, 2020. Online survey 1 was completed

by 170 respondents ($N = 170$, response rate $< 2\%$). The sample comprised 65% restaurants and hotels, 18% cafes, 7% business caterers, 6% system caterers and 4% others.

Online survey 2 was set up to gain additional information on how food waste was affected by the pandemic. The second survey consisted of the two closed questions: how surplus (overproduction + serving waste) and plate waste, respectively, had been affected by the pandemic. There were three optional answers: the respective waste increased, decreased, or remained constant. These questions were submitted to 38 caterers (business, student, hospital and conference catering), who participated in workshops related to sustainable nutrition offered by the authors' institution.

In the third phase of the methodological approach, 18 exemplary digital food waste reduction technologies from the European area were analysed. The objective of this stage was to derive a categorisation scheme for the applications. The digital technologies were examined according to their application in process steps of food business operations, groups of users, and type of digital technology. The users of the digital tools may differ depending on their application in the food service process. They comprise users within the company, such as the management of the kitchen and from superior levels, kitchen staff; but also external users, such as guests, food service companies, or non-profit organisations. After the examination, a categorisation of the technologies was established, based on commonalities according to food waste reduction potential.

In the last phase, the synthesis step, the information obtained through the different methods were compiled to answer the five research questions.

4. Results

Each of the following subsections presents the results obtained during the three phases of the methodological approach (see Fig. 1). In this section, the five research questions (see section 2) are answered one by one.

4.1. How much food was wasted before the pandemic and what is the influence of the pandemic?

The desk research revealed that in Sweden, Norway, Finland, and Germany, around 20% of food served is wasted in various food service companies [19]. Waste per portion varies widely among the food service companies, ranging from 50.1 ± 9.4 g/portion for canteens to 192 ± 30 g/portion for restaurants [19]. Eriksson et al. (2017) analysed food waste quantities in 30 public kitchens in Sweden, detecting that wasted food consisted of 64% serving waste, 33% plate waste and 3% other food waste [25]. Food waste data from Germany shows overproduction occurring frequently with 25–55%. A considerable amount of food ends up as plate waste (25–30%), while 20–35% of food is wasted in production [26].

In Germany, 1.22 of the 1.69 Mt wasted food annually in the FSS could be avoided through improved storage, planning or time management [1]. The cost associated with food waste amounts to around 4 euros per kilogram [26]. This means that the cost of food waste to the FSS, which accounts for 14% of total food wasted, is 6.8 billion euros per year [1,26].

Only few studies have dealt with the effects of the pandemic on food waste in the FSS. Filimonau (2020) listed and categorised short-term, medium-term and long-term effects [11]. Because lockdowns were ordered in a rather spontaneous fashion, food service companies could not adequately prepare to shut down and store their already stocked, perishable products [11,27]. As storage and freezing space is often limited, this causes food waste as a short-term effect.

The COVID-19 crisis made customer behaviour less predictable. During lockdown, foodstuff needed for takeout and delivery orders was difficult to plan. This also led to increased food waste as another short-

term effect of the pandemic [11].

The decreased number of operating food service companies and customers overall led to a decreased demand for foodstuff, causing food waste in primary production in form of a ripple effect [11]. The ripple effect is defined as: "The propagation of a disruption through an SC [Supply Chain] and its associated impact (...)" [28]. Farmers had to waste overproduced food as demand from the food service industry fell [27,29,30]. According to Filimonau (2020), this might last longer in form of a medium-term effect [11]. This effect is possibly amplified by storing food, as the interaction of stakeholders along the food value chain (farmers, deliverers, producers) was aggravated due to the pandemic. Therefore, such emergency food supplies could help to ensure food security [9,31,32].

Results of online survey 1 and 2

In both surveys, the participating food businesses were asked to indicate, whether they have noticed a decrease, an increase or a stagnation in the share of food waste in the course of COVID-19. As the companies were able to enter more than one answer, the total amount of entries differs from the number of participants. Table 1 summarises the results of the two surveys regarding these changes in food waste due to the pandemic. The following statement of numbers refer to the amount of entries given by food service companies.

Online survey 1 showed that 31% of the participants (53 out of 170) monitor food waste. These participants who track food waste, were asked to estimate the share of food waste (in %, related to the amount of food produced) in their businesses. On average (based on 33 answers), they waste 12% of the food produced. Regarding the changes in food waste quantities, 24 out of the 53 respondents stated, that the share of food wasted in the kitchen and production area had not changed due to the pandemic; whereas 22 and 6 of the respondents stated that they had experienced a decrease or an increase, respectively. Regarding serving waste, 24 respondents indicated that the share of food waste had not changed, while 18 and 4 respondents indicated a decrease/increase, respectively. For plate waste, 28 respondents indicated no change, whereas 16 and 3 businesses indicated a decrease/increase, respectively.

In online survey 2, a total of 38 food service companies took part. To the question, if surplus waste (safety margin and serving waste) changed, 16 answers were given. A total of 17 businesses provided an answer to the other question, if plate waste had changed due to the pandemic. Out of the total number of 33 answers, according to 4 and 2 food service companies each, surplus and plate waste increased, respectively. In contrast 9 and 3 of the food businesses indicated surplus and plate waste decreased, respectively. No change of surplus and plate waste had been observed by a number of 3 and 4 of the participating companies, respectively.

All in all, of the 179 entries provided by the respondents of both surveys (146 for survey 1 and 33 for survey 2) 11% (19 businesses) revealed an increase in food waste, while 42% (76 businesses) indicated a decrease, and 47% (84 businesses) stated food waste had not changed.

Online survey 1 included an optional open question, in which the respondents were asked to state the reasons for the change in share of food wasted. The 23 answers given (see Table 2) can be categorised according to the following steps of the food service process: menu planning, production planning, and distribution & serving. 17 answers relate to the menu planning (smaller number of menus, fewer components) as well as to production planning (quantities cooked, timing of cooking). While in 12 cases better and more conscious planning led to less waste; in 2 cases, it also caused more waste. This occurred, if the management decided to offer the complete menus despite the reduced number of customers. In other cases, the safety margin calculated to avoid running out of meals was too large due to the unpredictable number of guests. 3 respondents stated that the reduced number of customers has led to a reduction in food waste.

There were different statements concerning the changed form of

Table 1

Change of food waste due to pandemic (+increase, - decrease, = same, N/A no answer given) (Source: Authors' own elaboration).

Waste category/Change	Online survey 1 (N = 53)				N/A	Online survey 2 (N = 38)				N/A
	+	-	=	Entries		+	-	=	Entries	
Plate waste	3	16	28	47	99	2	11	4	17	16
Safety margin + Serving w.						4	9	3	16	17
Serving waste	4	18	24	46	100					
Preparation waste	6	22	24	52	94					
Total	13	56	77	146	293	6	20	7	33	33

Table 2

Reasons for increasing/decreasing share of food waste (Source: Authors' own elaboration).

Aspects of food service process	More waste	Less waste
Menu planning		<ul style="list-style-type: none"> • Menus are reduced (smaller variety and less components, e. g. no salad on offer) (5)
Production planning	<ul style="list-style-type: none"> • Overproduction to avoid running out of offer (1) • Production of all meals despite small number of customers (1) 	<ul style="list-style-type: none"> • Production volume is planned more conscious and food is cooked on demand (5) • reduced number of customers (3) • Better planning through pre-order requirement (2)
Distribution & serving	<ul style="list-style-type: none"> • Pre-composed menus on plates (1) 	<ul style="list-style-type: none"> • Self-service with gloves at buffet, instead of pre-portioned plates (1) • Smaller amounts served on buffets (1) • Menus served on plate (1) • Proportioning of breakfast (1) • Sell via APP (Too Good To Go) (1)

serving food. While 1 respondent said that pre-portioning on plates led to more waste, 2 companies said that waste had decreased due to this change of the serving form. This is in line with the statement of 2 respondents, who indicated that in their organisation, waste was reduced by serving food in buffet form.

4.2. What were the most frequently implemented food waste reduction measures before the pandemic and how are they affected?

As revealed by desk research, there are various measures to reduce food waste in the FSS. All of them need to be adapted to the organisation-specific constraints, such as the production and serving system or the given personnel and financial resources [33,34]. Nevertheless, there are recommendations and measures which are generally applicable. In the following, general prevention measures for the FSS are mentioned.

Managing and preventing food waste in the FSS requires a holistic approach [35,36]. To achieve this, Filimonau and Coteau (2019) propose a managerial framework for food service businesses [37]. Key activities for reducing food waste are prevention (demand forecasting, pro-active stock management, social marketing), re-use/redistribution (dynamic discount pricing, technology, food donations), recycling (on-site food separation, on-site composting), recovery (on-site anaerobic digestion) and disposal (food waste sent to landfill) [17,37].

Some more specific recommendations for the prevention of waste are given by Clowes et al. (2017), who analysed data from 114 restaurants across 12 countries and identified key strategies for reducing food waste [38]. These were to measure food waste, engage staff, reduce food overproduction, rethink inventory and purchasing practices, and

repurpose excess food. The authors define internal enablers, like corporate policies, managerial and staff attitudes, as well as external enablers, e.g., national policies, consumer behaviour, relationships with suppliers. All those can cause a positive change regarding food waste in the FSS.

Derqui et al. (2018) identified the most important overall factor for the implementation of measures in the field of school catering as the attitude of the entire workforce [39]. Increasing the awareness on food waste is one finding of Diaz-Ruiz et al. (2019) as well [40]. In their study, 48 food waste measures got discussed by various stakeholders from the food supply chain. Stakeholders assigned high values to all measures overall. Seven measures were perceived as very effective, all of them were aimed at increasing food waste awareness and improving food redistribution and access to food [40].

In Germany, the official dietary guidelines are developed by the German Nutrition Society (DGE). Sustainability has been incorporated in the guideline of the FSS for several years. The guideline "On the way to more sustainability in food service companies" (translated) gives general advice on reducing and monitoring food waste [41]. The suggested measures involve little or no investment and are easy to integrate into everyday workplace routines. Like Strotmann et al. (2017) and Heikkilä et al. (2016), the DGE recommends a holistic food-waste-management approach, which begins with measuring food waste and analysing processes in order to identify appropriate measures [35,36,41].

Results of online survey 1

The participants of online survey 1 who stated to monitor food waste were asked to check off boxes with measures they had already implemented in their businesses before the pandemic. Results show that the most frequent measures were improvement in storage (76%), meal planning (84%) or preparation of meals (75%). The further use of overproduced foodstuffs in other meals was also mentioned (71%). Results coincide with the findings of literature.

In addition, the participants were asked to indicate how the implementation of measures has been affected by the pandemic. In total, 84% of the respondents reported that their measures to prevent food waste have not changed. 11% indicate that additional measures were taken (see Table 3). The most frequently listed measure was more targeted purchasing, purchasing smaller amounts (7 respondents), followed by a reduction of the offered menus and standardising the menu components (4 respondents), using products with longer shelf life and pre-packaged components (2 respondents), and changing the serving system to individual table service instead of self-service (2 respondents). The measures that could no longer be implemented due to the pandemic referred to the reuse of surplus food, which was no longer possible due to hygiene restrictions (3 respondents). Moreover, exact production planning was said to be negatively affected as the number of guests could no longer be predicted reliably.

4.3. How does the digital transformation affect business activity?

During the COVID-19 pandemic, policies such as lockdowns change the socio-technical system. Contact restrictions advocate the use of

Table 3

Changes to the implementation of measures against food waste caused by the pandemic (number of answers) (Source: Authors' own elaboration)).

Measures	no longer implemented	Implemented additionally
Procurement		<ul style="list-style-type: none"> • more targeted purchasing/smaller amounts (7)
Menu planning		<ul style="list-style-type: none"> • more testing of menu components before they are offered to all customers and strictly refer to optimised recipe • reduced portion sizes and offer refill (1) • reduced offer and standardised menu composition (3) • more pre-packaged food, food with longer shelf-life and smaller packaging size (2)
Production planning	<ul style="list-style-type: none"> • Exact production planning (difficult due to unpredictable number of guests) (1) 	<ul style="list-style-type: none"> • better production planning due to required pre-ordering (1) • more detailed analysis to plan production volume (1) • sticking closer to planned production (1) • more targeted cooking (cook on demand if pre-produced quantities are not enough due to longer eating times) (1)
Serving		<ul style="list-style-type: none"> • individual table service instead of self-service (2)
Disposal	<ul style="list-style-type: none"> • reuse of surplus food restricted due to hygiene regulations (3) 	

digital technologies thus also inducing a shift in consumer needs. In combination with a persisting development of disruptive innovations, it is essential for companies to continuously adapt to the digital environment and to thrive for a re-organisation of economic business activity towards a more digital business [42,43].

In order to fulfil customer needs like contactless orders or payment [8,44] and to promote the resilience of the food system in time of the pandemic, food companies have to be taken under a digital transformation [31]. Summarising the diverse perspectives from the differentiated definitions of the term digital transformation [21,22] to a general proposition, digital transformation has the potential to coalesce business and society, creating new ecosystems. In the new-born competitive environment, economic sectors such as food service need to reposition themselves. The process of digital transformation will affect all value-adding processes of a company, from core processes to supporting activities up to strategic alignment [21,22,45,46].

Considering said transformational process, the use of digital technologies becomes more significant from being a constituent part to representing a key driver of the transformation process. Therefore, the implementation of digital technologies can be seen as an incremental process to revolutionize single value-added processes towards a digital business model [21,31].

Digitalising the business can have multidimensional leveraging effects on the business activities [22]. An increase in productivity and cost efficiency can be achieved [47,48] and the use of digital technologies can help to stay agile [49,50], which is of great significance in the vulnerable environment of COVID-19. At the same time, the pandemic acts as a barrier, restricting the potential of digital transformation [42]. Additionally, internal obstacles such as labour resistance towards digitalisation are likely [22], as labour not only needs to adapt to new technologies, but also to a shift in process workflows. Svahn et al. (2017) highlighted that the cause for such an aversion by employees towards digital technologies can arise because the benefits of such digital tools are not perceived or communicated [51].

4.4. How widespread is the use of digital technologies in the food service sector and what is the influence of the pandemic?

To understand the possible fields of action digital technologies offer in the FSS, Fig. 2 illustrates the core and supporting processes of an exemplary food service business value chain. The processes derive from a company and from a customer perspective. Further, possible linkages between the different processes are shown.

As can be seen in Fig. 2, the fields of action for digital applications are wide. They cover processes taking place within the company. These are the business core processes, such as menu or production planning, food

procurement, storage, processing, distribution and serving or disposal as well as the required supporting processes, for instance related to cleaning, accounting, or marketing activities. In addition, they relate to process activities of the customer taking place outside of the company. Not only because of the wide-ranging fields of application, describing "digitalisation" is difficult. Moreover, when it comes to digitalisation, there are no commonly used concepts to indicate digital maturity levels of economic sectors or companies across any country nor industry.

What can be observed for the FSS is the fact that due to the pandemic, there are numerous studies and surveys documenting an increase in delivery services, digital menus, digital payment methods, social media use, etc. Of food service companies. As COVID-19 prevention measures have limited human contact and gatherings of strangers such as crowds in restaurants or in workplace cafeterias, the use of digital marketing instruments in the German FSS grew. 16% of Germans used food delivery instead of going out to minimize contact [52]. Overall, 48% of Germans used food delivery services during lockdown [5].

In a German study by Wilkesmann and Wilkesmann (2020), the authors revealed that the pandemic caused 24% of chefs to organize a take-away service, 12% implemented a delivery service [44]. Although revenues from such services do not outbalance losses due to COVID-19 closures and restrictions [44], some costs can still be covered this way [53]. Over half of the sector's employees see a delivery or take-away service as important during the pandemic, but also in the following years [54].

As has been shown in a current study by the market analyst techconsult (2021), the pandemic sped up digitalisation in the FSS and hotels: 32% of the participating businesses digitalised crucial processes because of the pandemic [55]. 70% see a positive influence of digitalisation on cost reduction and almost two-thirds say that digital measures improve internal business processes. The study also showed that one fifth of the food service businesses want to further strengthen their digitalisation efforts in 2021, but one third admits their reliance on government funding or other forms of help for such plans [55].

Results of online survey 1

Online survey 1 revealed that 157 respondents (92%) do not use digital solutions for marketing purposes. 5% use digital marketing instruments, such as websites, Instagram and Facebook, delivery services (Lieferando and Smoother) or their own webshop since the start of the pandemic.

Regarding digital solutions used for other internal processes, the situation is similar. 79% state not to use other digital solutions. The digital applications used mainly comprise complete enterprise resource planning (ERP) systems (9 respondents), procurement software (4

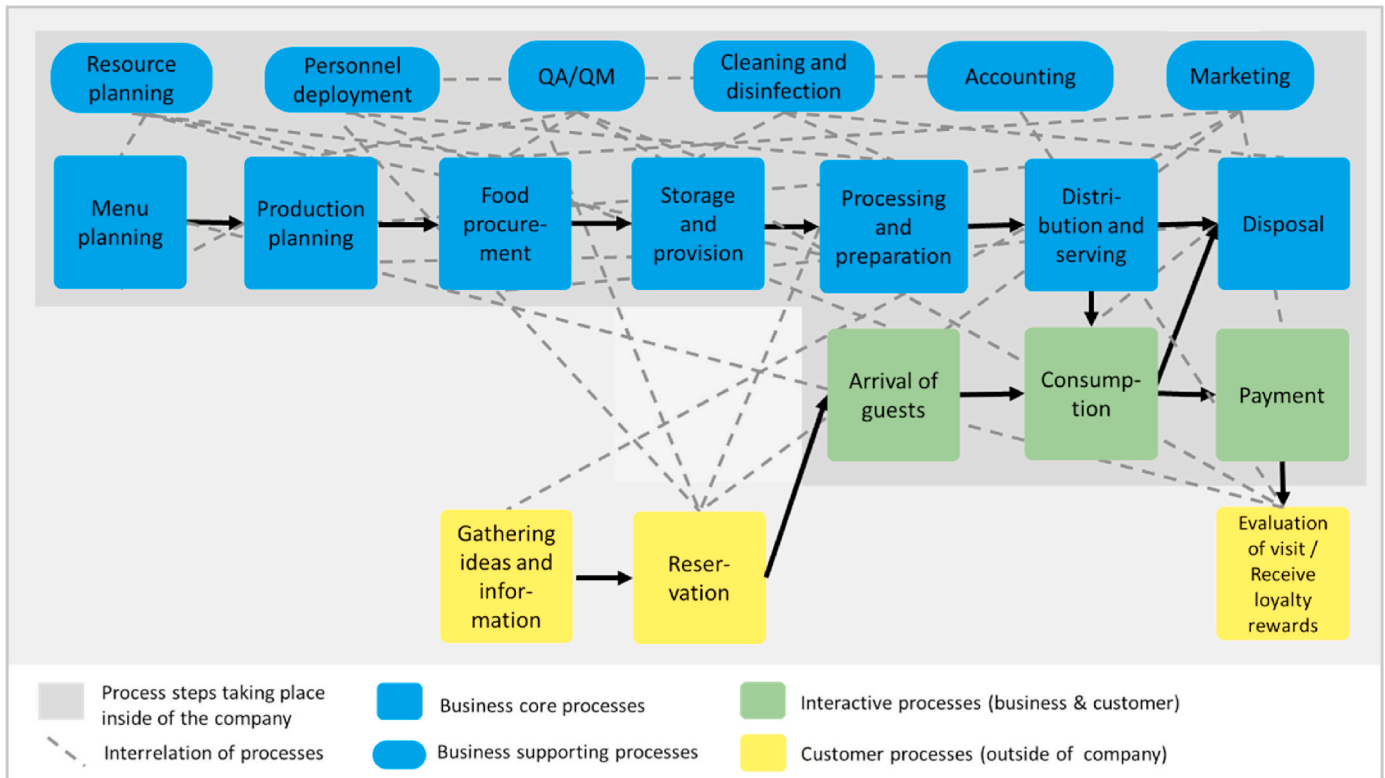


Fig. 2. Digital fields of action in an exemplary food service setting (Source: Authors' own illustration).

respondents), or solutions for production planning (4 respondents). Digital menus and order taking systems were applied by two respondents each, whereas digital applications for stockkeeping and recipe management were each mentioned once. 5% started using other digital solutions since the pandemic, for example a digital menu or an application for registering guests.

4.5. How can digital technologies be used to reduce food waste in the food service process?

The analysis of the digital food waste reduction technologies was carried out in phase 3 of the methodological approach. As outlined in the previous chapter, there are several fields of action in which digital technologies can be applied in the FSS (Fig. 2). In order to understand how digital technologies can be used to reduce food waste in the food service process, the authors derived a categorisation scheme. This scheme is based on a selection of 18 digital food waste reduction technologies available in the European area. Tools were selected that have a direct impact on food waste and whose reduction function is explicitly advertised as such by the institutions offering them. Digital applications that only have an indirect impact on food waste, such as ERP systems, cash register systems or cooking equipment were not considered.

Annex A 1 provides an overview of the 18 tools selected. It shows the general utility and the type of technology of each tool based on the information given by its provider. Additionally, it identifies the relevant group of users in different fields of application.

After reviewing the tools, the following processes proved to be important starting points for food waste prevention in the food service business: menu planning, production planning, food procurement, storage and provision of raw material, processing and preparation, distribution and serving, consumption, and disposal. The operating

range of the digital innovations can vary from a single core process up to a wider range of applications along the value chain. In upstream processes, the tools are mostly used by the management level. Downstream, operational processes require use by kitchen staff. The application of the tools is mostly related to the process of disposal, as food waste monitoring is a main utility within most of the reviewed technologies. In contrast, the process of food procurement is the least directly affected process. The tools can be applied by a single user or multiple user groups in each process.

The reviewed digital food waste technologies provide different approaches to food waste reduction and to promote the digitalisation within the FSS. In addition to their specialised fields of application along the food service processes (see Annex A 1), the evaluated technologies can have a leveraging effect, indirectly influencing upstream or downstream processes. The analysis of the tools revealed that the application of such digital technologies can be roughly clustered in the following four scenarios:

- *Forecasting tools*, mostly intelligent software based on data analysis. A demand forecast can be established by analysing data from past business activities in combination with external data (such as weekday, season, weather condition) with the help of algorithms. Demand forecasts improve planning reliability, with the potential of affecting multiple key processes. This may result in a modification of strategic decisions, optimising the handling of food. The constant data analysis can lead to continuous process optimizations and an increase of efficacy in strategic and operational business activities.
- *Waste analysis tools*, mostly based on a combination of hardware and software solutions with a focus on the distribution process of food service businesses. A retrospective analysis of the accrued amount and type of food waste can be provided, based on the collected data

by measuring the quantity and categorising the origin of food surplus. *Waste Analysis tools* can facilitate the detection of the major sources of food waste, whether caused by storage deficiencies/issues, overproduction, or serving and plate leftovers. They can increase sensibility on the level of management, kitchen and customer towards food waste. Measures to reduce food waste can be evaluated and established in the causal processes, preventing and reducing further food waste.

- *Redistribution tools*, focus on reselling food surplus at a reduced rate or donating to other businesses, institutions or customers. A *redistribution* of food surplus can increase the distribution network of food service businesses by establishing new distribution channels and strengthening the connection between actors of the FSS. Further, the consciousness towards accrued food leftovers by customers is affected, as they perceive the offers and amount of food surplus.
- *Measure catalogues*, providing practical support for handling food. The measures range from recipe ideas for leftovers up to educational content for staff and customers. Measure catalogues can support the strategic leadership down to operational processes by providing an overview of food waste reduction principles and supportive digital tools. Thus, they help to identify optimisation potential in several processes.

As a result of this analysis phase, the categorisation scheme for digital food waste reduction applications was derived (Table 4). In this scheme, applications can be structured according to the production processes in which they are used and by the usage scenarios described above. Benefits of the applications as well as the direct and indirect effects on food waste along the process steps are listed. The respective group of users for each process step are included.

5. Discussion of the results

The results provide information on the two main thematic topics of this study: Food waste and digitalisation in the FSS and the effect of the COVID-19 pandemic, respectively.

Regarding food waste, both online surveys revealed that food waste mostly either remained constant or was even reduced since the start of the pandemic. That said, it must be considered that the results are based on a limited number of participants. The comprehensive online survey 1 was sent out to 10,000 contacts. However, the response rate was only 1.7% (170 responses). Addresses of food businesses have been purchased in order to increase the number of the sample. The lack of direct relation to the companies might be a possible reason for the low response rate. Additionally, the participation rate might be low due to the pandemic, as working time is strained due to changes in operational activities.

The investigation of the change of food waste in private households due to the pandemic has indicated heterogenous results. On the one hand, there has been a tendency to stock up and to overbuy, which might lead to more food waste. On the other hand, shopping for groceries has become a more thoughtful process and food planning has increased as each grocery store visit is seen as a risk for infection [15]. The pandemic and lockdowns were an opportunity to cook more at home and to value food. This also aligns with the emerging ideal of sustainability [73], which might have led to a decrease of customers in the FSS as well.

As online survey 1 of this study was set up to obtain large amounts of data with little effort for respondents, technical terms could not be clarified in detail. Although the questionnaire was tested beforehand, there might have been misunderstandings in the terminology used in the survey. The pandemic-related reduction of guests and, accordingly, of the amount of food produced lead to lower absolute waste quantities.

For this reason, the companies were asked to indicate if their share of food waste in relation to the amount of food produced had changed. The respondents might have mixed up the share of food wasted (in % of the production volume) with the amount of food wasted (in kg), or they interpreted the term digital tool differently. Considering further, that these companies possibly measure the share of food waste visually, it can be assumed that waste data is not accurate as visual measurement errors are likely [74].

Related to digitalisation, the pandemic has also affected the use of digital technology in the FSS sector. The application of digital marketing instruments in the German FSS grew as COVID-19 prevention measures included limited human contact in restaurants or in workplace cafeterias. There is very limited data available outlining the current status of digitalisation in the FSS. Other studies agree that the pandemic accelerated the implementation of digital tools in the sector and in general [9, 75].

16% of Germans used food delivery instead of going out to minimize contact [52]. Overall, 48% of Germans used food delivery services during lockdown [5]. Despite the increase of such applications, online survey 1 revealed that only 5% of the respondents use marketing tools and only 21% stated to use other digital applications. Considering these low values, digital approaches offer a high potential in the field of food waste reduction. This statement is supported by a survey conducted by the market analyst techconsult in which 70% of the participants see a positive influence of digitalisation on cost reduction and almost two-thirds say that digital measures improve internal business processes.

A categorisation scheme for digital food waste technologies was derived based on an analysis of 18 digital food waste reduction approaches. In the scheme, the approaches can be differentiated by their process step of application along the catering process. Further, direct and indirect effects on food waste are shown. For instance, a waste tracker may directly show the amount and origin of food surpluses, or dishes less liked by the customers. Indirectly, this can trigger the optimisation of processes, such as offering other food components preferred by the customers, adjusting portion sizes, or increasing the employees' or customers' awareness for food waste.

Structuring the tools led to four systematization categories: forecasting, waste analysis, redistribution, and measures catalogue. Since only 18 applications, representing a selective snapshot, were used to derive the classification scheme, other tools might exist which have not been taken into consideration. The resulting scheme offers a generally applicable solution, which can be used to structure food waste prevention tools to better identify solutions fitting in an organisation-specific context.

A common feature of the reviewed digital tools is their revealing nature, exposing the causes of food waste. Whether the insights are driven by the analysis of generated data or simply by an increased awareness of food surplus, new principles can be set. The implementation of such digital tools in line with digital transformation within the food service business reshapes established value-adding and supporting activities. Thus, it can help to adapt to the changes in the food service economic system.

6. Conclusion

This study has dealt with the effect the pandemic has on food waste and on reduction measures implemented in the FSS. Moreover, it sheds light on the ongoing digital transformation in the sector and discusses how far digital approaches, specifically those targeted at the reduction of food waste, can be applied in the FSS. It contributes to existing knowledge as it delivers empirical information from the sector related to

Table 4

Categorisation of digital food waste reduction technologies and their effects (direct & indirect) on business activities (Source: Authors' own elaboration based on [57–72]).

Category	Example of digital tool	Benefit of application for the share of food waste	Menu planning	Production Planning	Effects of digital food waste reduction tools on business activities					
					Food procurement	Storage and provision of raw material	Processing and preparation	Distribution and serving	Consumption	Disposal
FORECASTING	Delicious Data, Mitakus, Prognolite	Optimisation of planning accuracy	Management: Selection of food components/dishes favoured by customers	Management: optimised planning of food quantities	Management: correct type and amount of food supplies		Kitchen Staff: Adapted quantities of food/meal	Kitchen Staff: Offering adjusted portion sizes		Kitchen Staff: Offering adjusted portion sizes
WASTE ANALYSIS	Kitro, Kitchenmonitor, Leanpath, Matomatic, Waste Tracker, App Waste, Analysis Tool, Winnow Waste, Monitor, Winnow Waste AI	Detection of food surplus origin	Management: Selection of food components/dishes favoured by customers	Management: optimised planning of food quantities and portion sizes	Management: Order of the correct type and amount of food supplies		Kitchen Staff: Adapted quantities of food/meal	Kitchen Staff: Offering adjusted portion sizes	Customer: higher awareness for food waste	Kitchen staff: Higher sensibility towards food waste (amount and components)
REDISTRIBUTION	Foodsharing, Regusto App, Regusto, Platform ResQ, ToGoodToGo	Enlargement of distribution channels; Consolidation of B2B and B2C relations						Hospitality Business/NPO/ Customer: further utilisation and consumption of surplus	Customer: higher awareness for food waste	Kitchen staff: Higher sensibility towards food waste (amount and components)
MEASURE CATALOGUE	Food Save App, LAV Platform	Educational approach; collection of materials/tools targetig food waste	Management: Selection of food components/dishes favoured by customers	Management: optimised planning of food quantities and portion sizes	Management: Order of the correct type and amount of food supplies	Kitchen Staff: Optimisation of food management	Kitchen Staff: Adapted quantities of food/meal	Kitchen Staff: Offering adjusted portion sizes	Management/Kitchen Staff: provision of educational material for customers Customers: higher sensibility towards food waste; higher appreciation of food	Kitchen staff: Higher sensibility towards food waste (amount and components)

food wasted and measures implemented amid the COVID-19 pandemic. Furthermore, this work provides an overview of the ongoing digital transformation of the sector and provides a classification scheme for digital food waste reduction technologies.

The pandemic, specifically the uncertainty about the number of customers, led to an adaptation to the new situation of the food service business operations. Overall, measures are taken more consciously and precisely than before the pandemic, to economise as well as possible. As a consequence, food wasted relative to food produced seems to decrease in food service companies. Along with the lower sales volumes in total this leads to less food wasted in the FSS. In terms of food waste reduction measures, results show a development towards a smaller range of menu options offered, more conscious purchasing and precise planning of meals. Companies state to benefit from on-demand cooking, which is easier to implement with a reduced number of costumers.

The less predictable nature of the pandemic also causes an increased amount of food waste for those companies that do not adapt offer and quantities produced. Due to the pandemic, it became more difficult to reliably forecast the number of guests to plan production volumes. In some instances, the pandemic changed procedures in case of over-production: for food safety and hygienic reasons, surplus food is rather discarded than re-used.

According to the findings of this study, food waste decreased in the FSS due to fewer operating restaurants and customers overall as well as due to more cautious planning. The demand of food from food service companies fell, causing food waste in primary production in form of a ripple effect [9]. The ripple effect demonstrates the strong interdependencies within the food supply chain and its just-in-time deliveries. Those effects could have been mitigated by a stronger cooperation between restaurants or increased donations to charities who specialise in redistribution of surplus food [9]. Although the reduction of food waste shown in the study indicate that SDG 12.3 may be more reachable now than before the pandemic, keeping an eye on the whole food supply chain is necessary. This holistic view from primary production to consumption is needed to avoid the shift of food waste from one step to another and to ensure food security in vulnerable environments.

The importance of accurate planning increased in businesses due to COVID-19. Whereas the companies offer standardised dishes or a limited menu selection due to the pandemic, digital technologies can provide information about menus and dishes with high sales volumes and thus support: the selection of favoured food, the optimisation of food quantities produced, and the offer of adequate portion sizes. For instance, measuring plate waste with waste analysis tools could help understand which portion sizes are suitable for each group of customers. Established food waste measures can be facilitated by digitalising this process.

Most food service processes are touched by digital technologies. Those technologies can be seen as solutions as they guide food service businesses through the uncertain state of the market, adapting to the changing socio-technological landscape. Based on the results of this study, digital tools can be considered as a window of opportunity, reducing or preventing food waste along the value chain. Thus, they contribute to maintain the economic viability of the food service business.

A categorisation scheme for digital food waste technologies was derived in this study. This scheme uses four systematization categories for food waste prevention technologies (forecasting, waste analysis, redistribution, and measures catalogue). Furthermore, it presents direct and indirect effects of the technologies along the process steps of the technologies' application.

Conclusively summarised, digital technologies can serve as a useful assistance, supplement or even substitution to taken measures in the FSS to reduce food waste and to reach SDG 12.3. It needs to be mentioned that food service companies face a new set of tension regarding SDG 12.3

due to COVID-19. Recurring closures, staff shortages or layoffs and economic difficulties could lead to less attention being paid to food waste. However, the mentioned events could give opportunities to a shift towards more sustainable business practices. Since this sector has always been under enormous cost pressure, the reduction of food waste can offer an economic incentive.

Conducting a digital transformation under fragile business conditions requires monetary and personnel resources. Both resource types are even more limited due to COVID-19. Almost half of the reviewed digital tools are free of charge or offer a freemium version, so the barrier to implementation would be lower compared to others. However, political assistance such as funding is needed to realize a digital transformation and pursue the German national strategy towards an implementation of digital food waste reduction measures.

7. Limitations and future recommendations

Due to the specialization on food waste in the FSS, the scope of this study did not allow to highlight all challenges and opportunities of the digital transformation in this economic sector. Rather, the focus was set on the implementation of digital technologies targeted at food waste reduction. Further studies should analyse the digital maturity level of the FSS and specifically address the barriers to the use of digital food waste reduction technologies. In particular, the different needs of companies should be identified in order to develop specific codes of practice to support the adaptation of appropriate technologies. To develop more tailored digital solutions for the prevention of food waste, the interdependency between all actors of the food supply chain also needs to be investigated to expose the diverse needs.

The results obtained through the empirical research of this study provide an initial qualitative overview on food wasted in the German FSS. A larger scale study could provide more distinguished information on the different groups of companies that make up the sector. Further studies should also collect quantitative data, which allows assessing the socio-economical or ecological effects in order to determine how sustainability is affected by the pandemic.

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CRediT authorship contribution statement

Christina Strotmann: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization, Supervision. **Vanessa Baur:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Investigation, Visualization. **Nora Börner:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Investigation. **Paula Gerwin:** Conceptualization, Methodology, Writing – original draft, Investigation.

Declaration of competing interest

The authors declare no conflict of interest.

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Annex A 1. Exemplary food waste reduction tools applied in the FSS (Source: Authors' own elaboration based on [46–62])

Examples of digital tools; type of technology	Menu planning	Production Planning	Food procurement	Storage and provision of raw material**	Processing and preparation	Distribution and serving	Consumption	Disposal	Utility
Delicious Data		Management						Kitchen Staff	Demand forecast; Based on algorithmic analysis of internal historical distribution data (e.g. from ERP systems) and current data (e.g. from waste tracking) in combination with external factors (such as weather, season etc.)
Food Save App*	Management	Management	Management	Kitchen Staff	Kitchen Staff	Management	Management	Kitchen Staff	Provision of measures assisting staff and management dealing with food in the respective process of the value chain.
Foodsharing*						Management Customer NPO			Donation of food surplus from company to customers (B2C) or exchange of private food surplus between citizens (C2C).
Kitchenmonitor*								Kitchen Staff	Food waste monitoring; Analysis of food waste data tracked by kitchen staff. Food waste can be categorised by its origin (e.g. kitchen, customer etc.)
Kitro		Management						Kitchen Staff	Automated food waste monitoring and performance tracking. Food waste can be categorised by its origin (e.g. kitchen, customer etc.). Share of knowledge and best practices on additional platform.
Leanpath								Kitchen Staff	Food waste monitoring by evaluating food waste data tracked by kitchen staff using different scenario specific devices. Food waste can be categorised by its origin (e.g. kitchen, customer etc.)
LAV Platform*	Management	Management			Management	Management	Management	Management	Register of instruments (measures, educational material and tools) for the hospitality sector in order to reduce food waste.
Matomatic							Customer	Kitchen Staff	Food waste monitoring by kitchen staff and customers with the use of scales transmitting the collected data into the software.
Mitakus		Management							Demand forecast; Based on algorithmic analysis of internal historical distribution data (e.g. from ERP systems) and current data (e.g. from waste tracking) in combination with external factors (such as weather, season etc.)
Prognolite		Management							Demand forecast; Based on algorithmic analysis of internal historical distribution data (e.g. from ERP systems) and current data (e.g. sale volumes) in combination with external factors (such as weather, season etc.)
Regusto App*						Management Customer			Distribution of surplus meals from business to customers for a lower price (B2C).
Regusto Platform						Management Hospitality businesses NPO			Distribution or donation of food surplus from the storage or overproduction to other businesses, institutions, non-profit organisations via platform.
ResQ*						Management Customer			Distribution of surplus meals from business to customers for a lower price (B2C).
TooGoodToGo*						Management Customer			Distribution of surplus meals from business to customers for a lower price (B2C).
Waste Analysis Tool								Kitchen Staff	Food waste monitoring; Analysis of food waste data tracked by kitchen staff. Food waste can be categorised by its origin (e.g. kitchen, customer etc.)
Waste Tracker App*								Kitchen Staff	Food waste monitoring; Analysis of food waste data tracked by kitchen staff. Food waste can be categorised by its origin (e.g. kitchen, customer etc.)
Winnow Vision AI								Management	Automated food waste monitoring. Food waste can be categorised by its origin (e.g. kitchen, customer etc.)
Winnow Waste Monitor								Kitchen Staff	Food waste monitoring; Analysis of food waste data tracked by kitchen staff. Food waste can be categorised by its origin (e.g. kitchen, customer etc.)

* free of charge for user or at least a freemium version for basic operation

** raw material includes unprocessed and processed food



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