

## Article

# Learnings from Food Waste Dynamics During the COVID-19 Pandemic: An Evaluation of Representative Diary Studies in German Households

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## Abstract

The COVID-19 pandemic had a major impact on the reliability of global supply chains, the availability of selected products including food, food prices, food purchase and consumption behaviour. The aim of this study is to identify potential differences in food waste levels and behaviours in Germany during the pandemic compared to pre-pandemic periods. The data are based on two highly representative household diary studies on food waste with sample sizes of over 6500 participants each. This study uses descriptive statistics as well as a mixed model approach to examine food waste amounts per product group, disposal reason and life cycle category and compare the survey year 2020 with the years 2016/17. A linear mixed model is applied to examine the effects of the pandemic and lockdown phases on the development of food waste amounts in 2020. The results show that total and unavoidable food waste increased significantly in the 2020 pandemic period compared to the same period in the 2016/17 survey, while avoidable food waste decreased. This suggests an improvement of food management skills while, at the same time, food consumption, and therefore also food waste, shifted from outside to inside the home. Also, the composition of product groups was affected by altered consumption patterns during the pandemic. The results are relevant to the post-pandemic period, as they raise the question of whether a deceleration in everyday life is a prerequisite for adopting more sustainable food behaviours and developing appropriate planning, storage and handling. Policies should therefore focus on encouraging citizens to engage with the issue, prioritise it and develop an interest in food management. Future research should focus on the ways in which behaviours that reduce food waste can be encouraged, as well as on the long-term effects of food supply chain disruptions and events altering everyday life in households in relation to food waste.

**Keywords:** food waste behaviour; food loss and waste; coronavirus; food management; food consumption; food practices



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## 1. Introduction

Food lost and wasted along the supply chain consumes resources and emits climate-relevant gases without ultimately benefiting human nutrition. The food system was

estimated to be responsible for 34% (18 Gt CO<sub>2</sub> equivalents per year) of global greenhouse gas emissions in 2015 [1], while 8 to 10% originate from food which is never eaten [2]. Reducing food waste can make a decisive contribution to reducing greenhouse gases [1,3–5]. The United Nations has also recognised this, and in 2015 set Sustainable Development Goal (SDG) 12.3 to halve global per capita food waste at the retail and consumer levels until 2030. According to the UNEP Food Waste Index Report, 19% of all food available at supply chain stages of retail and consumption is ultimately wasted [6].

In high-income countries, the share of food waste at the household level is particularly high; in Germany, 52% of all food waste from primary production to consumer level occurs here [7]. Household food waste, therefore, has a relevant environmental impact, as resource use and emissions accumulate along the food supply chain [8]. In order to achieve SDG 12.3 and to be able to verify this achievement, a better understanding of food waste behaviour and better data are needed. As part of the development of appropriate reporting to implement the SDG and to improve the data situation, the German Federal Ministry of Food and Agriculture, has commissioned the Gesellschaft für Konsumforschung (GfK) to conduct representative diary studies every four years to determine the amount of food waste in private households. The first monitoring period was in 2016/17 and the second period happened to fall in 2020, the year of the COVID-19 pandemic.

COVID-19 resulted in a global health crisis that inevitably had a major impact on almost all sectors of the economy [9]. The far-reaching changes in the everyday lives of the population were accompanied by changes in diet and consumption patterns. The number of COVID-19 cases increased in several countries, leading the World Health Organisation to declare the outbreak a pandemic [10]. During the period of the presented food waste measurement from January to December 2020, the first measures to contain the coronavirus COVID-19 were taken by governments in Europe. From March 2020, measures were taken in Germany to reduce social contacts. Gastronomy and service providers were closed nationwide and adherence to hygiene rules were prescribed in offices and public spaces [11]. Some of the rules were relaxed in May and then tightened again from November [12]. This led to an on-again, off-again pattern of lockdowns, which is reflected in this study for the whole of 2020.

A number of studies report an impact of COVID-19 on the perception and awareness of food waste in households. Specifically, there was more time to think about food waste [9,13–15]. Most studies have shown that food waste in households in different countries was comparatively low during pandemic or lockdown periods [13,14,16–18]. This appears to be due to better household diet planning and management (e.g., by shopping less often in view of the risk of infection and generally spending more time at home) as a result of COVID-19 [13,14,16,19,20]. For example, WRAP [21] found that in the UK shopping frequency decreased, there was more pre-shopping planning, food storage improved, and an increasing proportion of the population reported throwing away less food at the beginning of the pandemic. Vidal-Mones et al. [22] found that participants in Spain improved their shopping planning and became more creative in cooking with leftovers during the pandemic. However, there is also an opposite effect: Aldaco et al. [23] and the Standing Committee on Nutrition of the United Nations System [24] note a redistribution of food waste from consumption outside the home to consumption within the household. This redistribution is certainly also due to the closure of gastronomy, schools and offices and the time available at home, as a consequence of which citizens have increasingly prepared food at home.

Besides empirical studies on food waste behaviour, hypotheses on changes in food waste behaviour in households as a reaction to certain stimuli can be based on theoretical concepts. Many studies relate the Theory of Planned Behaviour (TPB) [25] to household

food waste [26]. Such studies analysed relationships between perceived behavioural control, attitudes, subjective norms and food waste [26]. The aspect of perceived behavioural control as well as the general intention to reduce food waste is related to food planning and shopping routines [27,28]. Moreover, intention to reduce food waste is correlated with the three dimensions of the TPB, while again, intention to reduce food waste affects actual behaviour in terms of food waste [26,29]. It is conceivable that a strong stimulus such as the massive cut in daily routines during the COVID-19 pandemic influenced not only planning and shopping routines but also attitudes, norms, perceived behavioural control and thereby, indirectly, intention and behaviour in manifold ways. Demographic factors may again moderate altered behavioural pathways [29]. This paper takes an outcome-based approach by mainly analysing food waste amounts and wasted product categories in relation to demographic factors and household characteristics to capture and interpret the effects of such potential behavioural changes.

Based on the above-described empirical and conceptual background, it can be hypothesised that people in Germany also became more aware of food waste, improved their meal planning and food management, and therefore experienced less food waste during the pandemic and lockdown periods. On the other hand, this potential effect may have been offset by a shift in food waste from the gastronomy sector to private households, as well as short-term effects from stockpiling specific food products [30].

The aim of this study is to analyse food waste behaviour in Germany in 2020, focusing on the influence of the COVID-19 pandemic. Further, it aims to identify potential differences in food waste levels, types and behaviours in Germany during the pandemic compared to pre-pandemic periods. It also aims to investigate food waste levels and behaviours in relation to the stringency of contra-COVID-19 measures and lockdowns. This investigation and comparison of food waste before, during and between pandemic and lockdown periods is not only informative to better understand household food waste behaviour in times of pandemic or crisis in general, but also to draw lessons for the post-COVID-19 era. The present study fills a research gap by providing an analysis for the whole year 2020, based on a household food waste diary study and a comparative study for the years 2016/17. Previous studies are mainly based on questionnaires and only cover short periods of time during the COVID-19 pandemic. These studies are often not able to compare pandemic and non-pandemic periods, but only severely affected and less affected regions during the pandemic, such as Qian et al. [15]. Furthermore, the questionnaire methodology used in most studies [18,21,22] may reflect perceptions, but the tendency to underestimate leads to unreliable figures [22,31,32]. Only one study applies the food waste diary method with an unrepresentative sample in Italy, conducted by Amicarelli and Bux [33]. The present study was already planned and started before the pandemic began in Germany and by chance includes the whole dynamics of the pandemic peak in 2020 in Germany.

## 2. Materials and Methods

Between July 2016 and June 2017, the German market research institute GfK SE carried out a representative self-reporting diary survey on behalf of the German Ministry of Food and Agriculture (BMEL) [34], which was repeated between January and December 2020 [35]. The data from 2016/17 was analysed by Herzberg et al. [36], while the corresponding data from 2020 initially provides the basis for a master's thesis [37], and now the resulting paper. The aim of these surveys is to assess the amount of food waste that accrues in households in Germany, as well as corresponding characteristics such as disposal paths, waste composition, disposal reasons, etc. The aim of the replication survey is to identify long-term trends in the amount and characteristics of German household food waste.

### 2.1. Dataset

The samples were drawn from the ConsumerScope Panel of the GfK SE, whose participants were already familiar with the diary reporting procedure. For each month, a representative sample was selected for the Federal Republic of Germany (min. 500 households) according to the criteria of the Federal Bureau of Statistics applied in the frame of the micro-census, namely:

- Size of place of residence and residence within the state;
- Age, employment and highest level of education of the head of household;
- Net income of household;
- Household size and number of children in the household;
- Living conditions.

The market research institute provided the selected households with necessary materials to undertake a diary survey (such as paper and pencil diary, operation instructions and Supplementary Materials). The 2016/17 diary study was repeated unchanged in 2020 to ensure maximum comparability of results [34]. The response rate of the respective households was 85% in both survey years. The pool of responsive households was again adjusted with regard to the criteria region, age of head of household, and household size when extrapolating to Germany to prevent an inequality of the sample. The sample values of the 14-day-period (not extrapolated) are utilised for the inductive statistics. The adjustment for inequality due to non-returned questionnaires was not applied to these sample values.

Each household participating in the survey recorded all food and drink waste (hereinafter “food waste”) generated within the household over a period of 14 days, including the disposal paths animal feed, residual waste, organic waste, home composting, sewer/sink and other options. Each month, a different set of households reported for such a 14-day-period. Overall, 6507 households in 2016/17 and 7372 households in 2020 reported their food waste. A total of 4030 of those households participated in both studies. Some households did not report food waste within the 14-day-period. These households are excluded from the analysis because it is unreasonable to expect no food waste within a 14-day period, given that inedible food waste is taken into account, and because households on holiday were not allowed to participate in the survey. In addition to the mass of food waste per disposal act, a set of further characteristics of the wasted food, as well as of the household itself, was selected and surveyed for each disposal act (Table 1). For further details on the surveyed socio-demographic characteristics, see also Tables S1 and S2 in the Supplementary Materials.

**Table 1.** Socio-demographic characteristics of the households and characteristics of wasted food sampled within the survey.

Characteristics of Wasted Food	Socio-Demographic Characteristics of Sample Household
Mass per disposal act in g	Household size
Food type (code)	Age group of the household head
Reason for disposal (first and second)	Education level of the head of household
Condition at disposal	Size of the place of residence
Disposal channel	BIK region <sup>1</sup>
Date of disposal	Life cycle stage
	Number of children under 18 in household

<sup>1</sup> Nationwide spatial classification system that depicts urban–rural relationships at municipal level for conurbations, urban regions, medium-sized and sub-centres.

To determine the mass of food waste per disposal act, the participants could choose either to measure or to estimate the mass/volume or to indicate the number of pieces

discarded. The corresponding mass of a piece of food could be estimated in retrospect by use of a provided conversion table. In addition, all food waste was classified by the respondents as edible (avoidable) or inedible (unavoidable) in the sense that, for example, the peel of certain fruits and vegetables is generally considered to be inedible. However, the classification of food waste as avoidable or unavoidable is not clearly defined. To support the classification, examples of unavoidable food fractions, such as bones, tea bags and coffee grounds, peels and cores of fruit, have been listed in the diary material.

## 2.2. Statistical Analysis

The statistical analysis is carried out in four consecutive steps. The year 2016/17 serves as a baseline in order to identify changes in 2020. The first section provides an overview of avoidable food waste in particular. This is followed by a comparative analysis of the extrapolated food waste volumes for the survey years. Subsequently, the development in 2020 is considered in order to then examine the effects of the pandemic and lockdown phases. Therefore, a linear mixed model [38] was initially determined. Separately considered are the following:

- Total food waste;
- Avoidable food waste;
- Unavoidable food waste;
- Product groups (separated according to avoidable and unavoidable);
- Reasons for disposal of avoidable food waste.

The last analyses only consider specific periods. The pandemic period considered in this study spans from March to December. Within this timeframe, the months of March, April, May, November and December are identified as distinct phases corresponding to the nationwide lockdowns implemented in Germany. The mixed model on which the analysis is based can be described as follows:

$$y_{ijklmn} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \zeta_m + \kappa_n + \epsilon_{ijklmn}$$

with

$y_{ijklmn}$ : food waste (in kg)

$\mu$ : overall mean,

$\alpha_i$ : data set ( $i = 1$  [2016/17],  $2$  [2020])

$\beta_j$ : age group ( $j = 1$  [-39 years],  $2$  [40–59 years],  $3$  [60+ years])

$\gamma_k$ : household size ( $k = 1, \dots, 8$ )

$\delta_l$ : education ( $l = 1$  [Secondary school/main school],  $2$  [High school diploma or similar],  $3$  [academics])

$\zeta_m$ : town size ( $m = 1$  [rural],  $2$  [urban])

$\kappa_n$ : participant effect ( $n = 1$  [36],  $\dots$ , 9849 [989074]),  $\kappa_n \sim N(0, \sigma_\kappa^2)$

$\epsilon_{ijklmn}$ : residual error,  $\epsilon_{ijklmn} \sim N(0, \sigma_\epsilon^2)$

The participant number is considered as a random effect, in order to account for the dependency of the measured values on households, which occur in both survey years. This explains the variation between households. The remaining variance of the model reflects the within-household variation that cannot be explained by the included effects. The verification of the stochastic requirements of the data (normal distribution and homogeneity of variance) was carried out using a graphical residual analysis.

The analysis focuses on household-level characteristics; therefore, food waste data were aggregated per household. To avoid potential information loss, individual food items were grouped into product categories, and total reported quantities of avoidable and unavoidable waste were recorded in separate variables. Depending on the research

question, different sub-datasets were generated. Only households that reported waste for a specific category (e.g., avoidable fruit waste) were included in the analysis to maintain data consistency and reliability. In order for the dependent variable “food waste (mass per disposal act)” to be approximately normally distributed, we apply a Box–Cox power transformation to the respective waste quantity. It is a common approach for data transformation, as the Box–Cox power transformation has been shown to outperform standard logarithmic or square-root transformations [39] (Figure S1 in the Supplementary Materials). The transformed amount of food waste is varied in the model, depending on the question. The dataset adapted for the respective question is the basis for the various linear mixed models. The transformed food waste quantities are considered accordingly in total or divided into avoidable/unavoidable and also limited to, e.g., certain time periods and product groups in the models. To reflect the extent of the explained variance, a (pseudo) coefficient of determination [40] is calculated for the linear mixed models [38]. A distinction is made here between marginal and conditional. The marginal coefficient of determination reflects the explained proportion for the fixed effects only, while the conditional coefficient of determination accounts for the fixed effects and random effects (in this case the participant number). Multiple contrast tests [41] are used to compare the different characteristics of the influencing factors. In this way, it is determined whether the mean differences in the transformed data are significant and, above all, when comparing for which levels this is the case.

### 3. Results

#### 3.1. Descriptive Statistics on German Food Waste

For a detailed comparison of the surveys in terms of household and socioeconomic characteristics, please refer to Table S1 in the Supplementary Materials. The sample size in 2020 is 865 participants larger than in the 2016/17 survey period. The relative sample composition is close to identical for the survey periods 2016/17 and 2020. The samples differ in variable manifestations by one to two percent. A more detailed overview of the 2016/17 sample can also be found in Herzberg et al. [36]. GfK SE uses an estimated value of 40.77 million households in Germany for the year 2020, and the data provided has been extrapolated accordingly. The extrapolated quantities of the sample result in a food waste volume of 3.9 million tons in German households for 2020. This translates into 95.75 kg of food waste per household. Based on a population of 83.16 million inhabitants in Germany, households generate 46.94 kg of food waste per capita and year.

The distribution of total food waste in kg per 14-day period is characterised as right-skewed and shows little difference from the 2016/17 diary study [36]. This indicates that a large number of households report relatively low amounts of food waste in the diary surveys and only a small proportion of households tend to produce rather large quantities of food waste. On average, households from the 2020 survey period report a food waste quantity of 3.44 kg per 14 days, which implies only marginal differences compared to the 2016/17 survey period.

Figure 1 shows the shares of product groups in total and avoidable food waste. In 2020, 75% of food waste consists of beverages, fresh fruit and vegetables. Regarding avoidable food waste, fresh vegetables and fruit, as well as cooked/prepared dishes, are at the top of the distribution with 18%, 17% and 15%, respectively. The share of bakery products wasted follows with a share of 13%.

In general, disposal reasons of avoidable food waste can be classified into four categories (Figure 2). In total, 57% of reported food waste is attributed to durability (best before date), which represents the main reason for disposal. A total of 22% is due to quantity problems at home and 12% due to quantity problems at purchase. The remaining 8% report

other reasons, such as failed dish preparation. Quantity problems at home are particularly relevant for prepared dishes and drinks and larger households. Households dispose of prepared foods such as pasta, rice, potatoes or surplus preparations of drinks such as coffee and tea. About 80% of avoidable food waste is declared as loose, open, prepared or cooked.

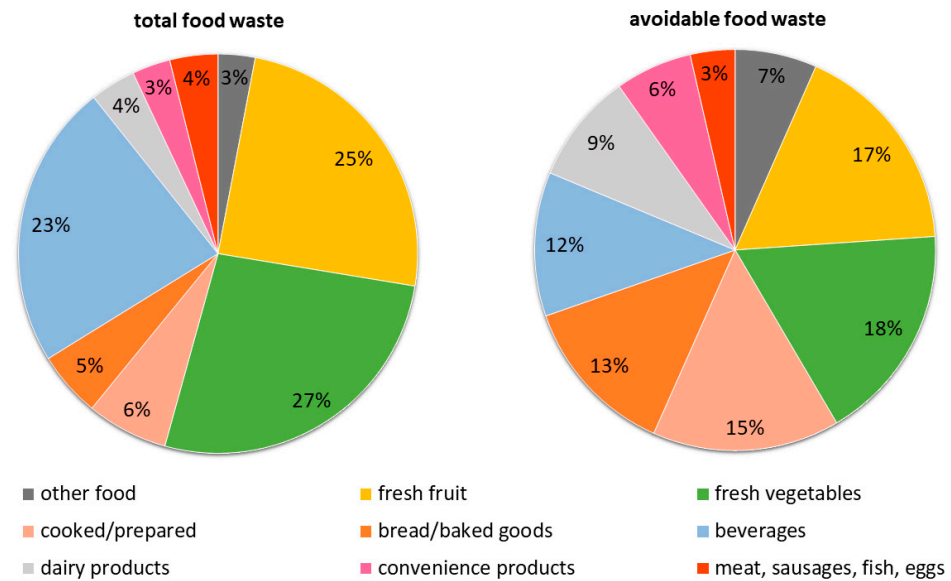


Figure 1. Total and avoidable food waste by product group in 2020.

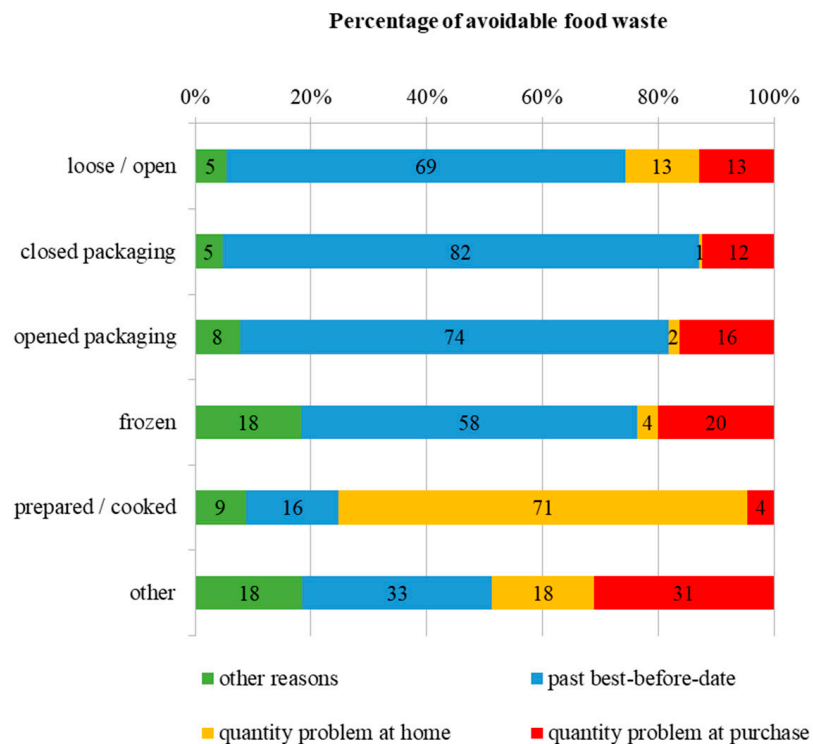
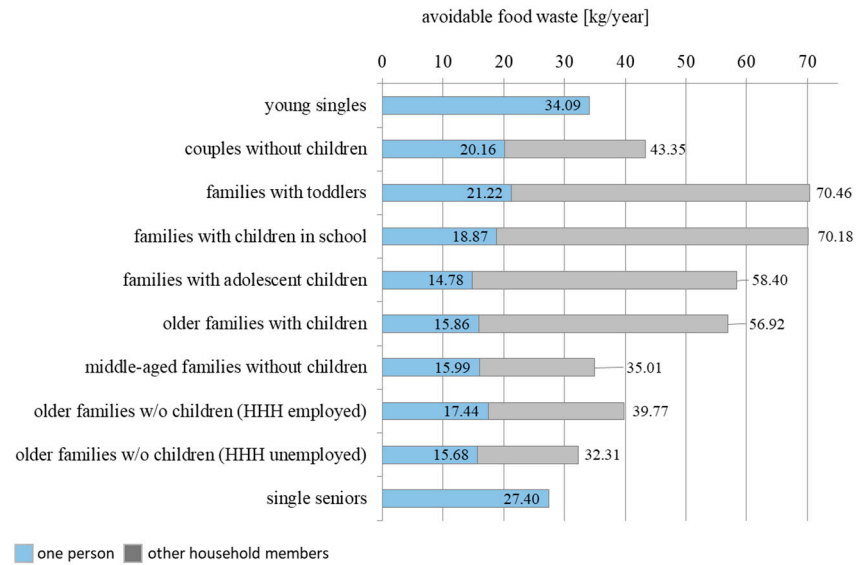


Figure 2. Reasons for disposal of avoidable food waste by condition at disposal in 2020.

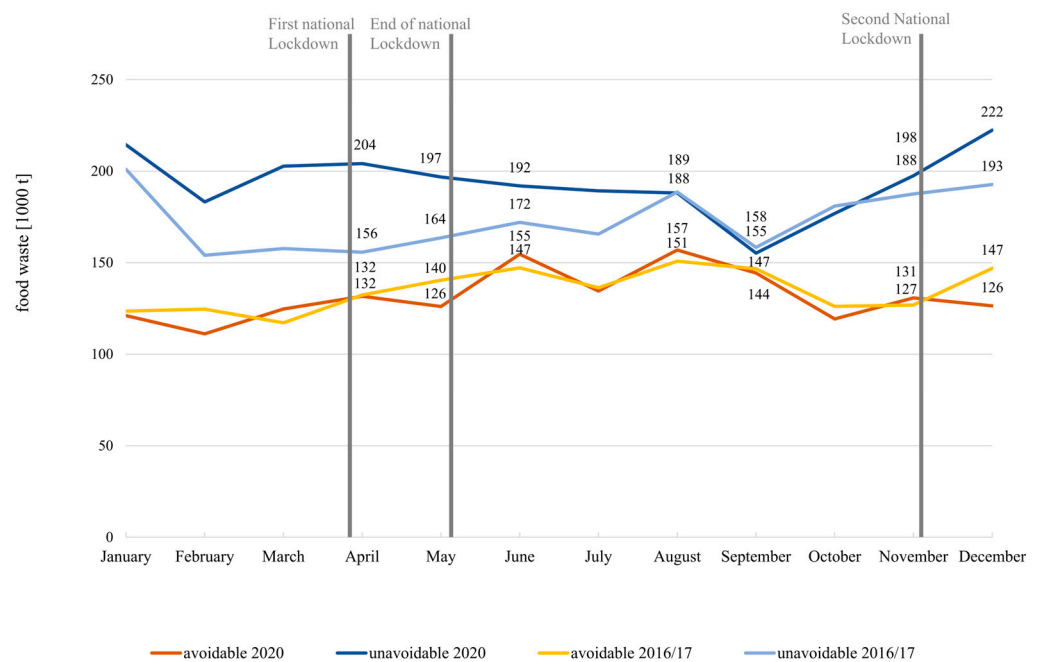
The amount of avoidable food waste per household varies depending on the life cycle and the associated household size (Figure 3). It ranges from 27.4 kg per year for single seniors to 70.46 kg per year for young families with small children. One-person households, however, have a notably higher per capita waste quantity. The amount of avoidable food waste is, on average, lower for older households.



**Figure 3.** Amount of avoidable food waste per household and person by life cycle category in 2020 (HHH = head of household, w/o...without).

3.2. Comparison of Food Waste Amount Generated in 2016/17 and 2020

Based on the extrapolated GfK SE data, total food waste from 40.2 million households was at 3.7 million tons in 2016/17. In 2020, with around half a million more households, the figure rises to 3.9 million tons. Relative to a population of 82.79 million, household food waste per capita in 2016/17 was at 44.7 kg compared to 46.9 kg in 2020. The proportion of potentially avoidable food waste has decreased from 2016/17 to 2020 by three percentage points. The annual course of food waste shown in Figure 4 shows a similar pattern for both survey periods, especially with respect to avoidable food waste. It is noteworthy that a high level of unavoidable waste can be observed from March to July in 2020. Furthermore, it becomes evident that in December 2020 avoidable waste decreases, while in 2016 it increased. In parallel, unavoidable waste increases in 2020 to a larger extent than in 2016.



**Figure 4.** Annual pattern of unavoidable and avoidable food waste in 2016/17 and 2020 and COVID-19 national lockdown periods.

In 2020, the share of avoidable food waste associated with prepared dishes decreases by 1.1%. An increase of about one percentage point is observed for beverages and other foods, such as cooking ingredients, spreads and sweets. The proportion of loose or open food waste has increased by 3.8%, while the proportion of avoidable food waste from prepared or cooked food has decreased by 2.4% in 2020. The proportions of disposal channels have also shifted. An increase in usage of 3.6% is recorded for the organic bin, while the share of residual waste and sewer has decreased by over one percentage point.

The best before date was already of minor importance for disposal motives in the first survey. This level of importance has further decreased in 2020 to only 4.6%. The share of the disposal reason 'unsavory' decreased by 1.1%, while the proportion of 'spoilage' as a reason for disposal has increased by 1.7% in 2020. More frequently, in 2020, large packaging units at purchase and bad taste are cited as reasons for disposal (increase of 0.7 and 0.6%).

Differences in the overall annual comparison between 2016/17 and 2020 are relatively moderate. However, notable changes are observable, and the comparative results for the selected periods are presented in Chapter 3.4.

### 3.3. Development of Waste Disposal Behaviour from 2016/2017 to 2020

In the following section, the situation in 2020 will be examined. The preceding survey period of 2016/2017 is used as a reference. To exclude seasonal effects, the specific time periods from 2016/2017 and 2020 will be used for comparison. This study is thus able to differentiate between pandemic and non-pandemic situations, lockdown and non-lockdown periods, and thus determine corresponding effects. As shown in Supplementary Materials Figure S1, the residuals of the transformed data are normally distributed and do not show heteroscedasticity. Furthermore, we control for multicollinearity in the analysis.

The results reveal a pseudo- $R^2$  of the model for the whole year of 0.088 for the fixed effects ("Marginal") and of 0.575 when including a participant-specific effect ("Conditional"). Therefore, 8.8% of variance of food waste quantities is caused by the fixed factors. When considering participant-specific effects (variance between households), 57.5% of variance in the model can be explained. The variance of the transformed waste quantities between households is 0.78 and the remaining variance (variance within households) is 0.73. A total of 13,879 households reported food waste and are considered in the model. The results reveal that period-specific effects, age group, household size and size of place of residency significantly influence food waste amounts.

To assess changes and effects beyond the pandemic and lockdown situations, the study also uses the months of January and February as a study period. With regard to the total food waste quantity, the model for the months of January and February 2020 reveals that 9.3% of the variance in food waste quantities is caused by the fixed influencing factors. In total, 61.2% of the variance can be explained by including the random component. With regard to avoidable food waste, a lower proportion of the variance is explained. The pseudo- $R^2$  measure is 0.039 (3.9%) for the fixed effects and 0.447 (44.7%) when controlling for the participants. The within-household variance is increased, reaching 0.93 (between-household 0.80). Additionally, the data reveals that within the non-pandemic period, no significant difference in food waste quantities are identified between years in any of the categories.

### 3.4. Impact of COVID-19 Pandemic and Lockdown-Periods on Household Food Waste

The year 2020 is characterised by the COVID-19 pandemic that emerged in March and continues beyond the end of the year. The objective is to disentangle the effects of the overall pandemic situation from those of the lockdowns.

Table 2 shows the total food waste as well as various sub-quantities in relation to the pandemic period, i.e., the months from March to December. As for many product groups, such as bakery and dairy products, almost the entire share is potentially avoidable; no unavoidable quantities are examined for these product groups. The same applies to the disposal reasons. If a product group is listed, food waste was classified as avoidable. The table shows that there are significant differences in food waste quantities for the pandemic period. The total and unavoidable food waste is significantly increased for the pandemic period in 2020 compared to the same period of the 2016/17 survey round and the avoidable food waste is significantly reduced. The breakdown by product group illustrates where the largest effects occurred over the pandemic period. The highest statistically significant increase during the pandemic was recorded with 70 g in unavoidable beverage waste (coffee and tea), followed by unavoidable vegetable waste. At the same time, the results indicate that the avoidable waste is significantly reduced. The largest reductions are found in the categories of convenience foods, fruit and prepared foods, with 40 g, 30 g and 30 g, respectively. The effects on food waste amounts seem to have been reduced more or less equally for all disposal reasons. Due to the smaller size of “quantity problem at home”, there were probably logical overlaps between the influencing variables, so that size of place of residency could not be taken into account in the model at this point.

**Table 2.** Food waste per household over 14 days in kg during the pandemic period in March to December 2020 compared to March to December 2016/2017.

Variable	<i>n</i>	2016/17	2020	Difference
Total food waste	11412	3.93	4.04	+0.11 ***
Avoidable	9807	1.41	1.31	−0.10 ***
Unavoidable	10477	2.54	2.68	+0.14 ***
<b>unavoidable</b>				
Fruits	8368	0.83	0.81	−0.02
Vegetables	8912	0.78	0.82	+0.04 **
Meat, fish, eggs	6717	0.10	0.10	0
Beverages	8975	0.75	0.82	+0.07 ***
<b>avoidable</b>				
Fruits	5042	0.39	0.36	−0.03 **
Vegetables	5537	0.36	0.34	−0.02
Meat, fish, eggs	2596	0.12	0.11	−0.01 **
Dairy products	3657	0.24	0.23	−0.01
Baked goods	5269	0.31	0.29	−0.02 ***
Other products	2829	0.20	0.20	0
Canned food	2371	0.14	0.12	−0.02 ***
Convenience products	1345	0.25	0.21	−0.04 ***
Prepared dishes	4166	0.39	0.36	−0.03 ***
Beverages	2328	0.33	0.32	−0.01
Past best before date	8573	0.91	0.86	−0.05 ***
Quantity problem at purchase	3559	0.25	0.22	−0.03 ***
Quantity problem at home	4608	Without variable town size: (−) **		
Other reasons	2795	0.25	0.22	−0.03 *

Note: \*\*\*, \*\* and \* indicate 1%, 5% and 10% levels of significance, respectively.

When considering the lockdown periods due to COVID-19 in Germany separately, the previously evolved impression of the disposal behaviour is reinforced. In the months of March, April, May, November and December, public life in Germany was increasingly restricted [11,12].

Table 3 shows that the total and unavoidable food waste amounts have increased significantly during the lockdown periods. At the same time, the estimates show that the reduction in avoidable waste is smaller than in relation to the entire pandemic period, and

statistically significant at the 10% level. With the exception of fruit, a significant increase in unavoidable food waste can be reported for all categories. Furthermore, the comparisons reveal that statistically significant reductions in waste volumes are observed in four out of ten avoidable food waste categories.

**Table 3.** Food waste per household over 14 days in kg during lockdown periods (March, April, May, November, December).

Variable	<i>n</i>	2016/17	2020	Difference
Total food waste	5785	3.87	4.21	+0.34 ***
Avoidable	4939	1.34	1.27	−0.07 *
Unavoidable	5341	2.52	2.84	+0.32 ***
<b>unavoidable</b>				
Fruits	4324	0.79	0.81	+0.02
Vegetables	4593	Without variable town size: (+) ***		
Meat, fish, eggs	3580	0.11	0.12	+0.01 **
Beverages	4620	0.71	0.82	+0.11 ***
<b>avoidable</b>				
Fruits	2461	0.38	0.35	−0.03 *
Vegetables	2747	0.37	0.35	−0.02
Meat, fish, eggs	1324	0.11	0.10	−0.01
Dairy products	1775	0.24	0.22	−0.02 *
Baked goods	2602	0.30	0.29	−0.01
Other products	1443	0.19	0.19	0
Canned food	1166	0.13	0.12	−0.01
Convenience products	632	0.24	0.19	−0.05 **
Prepared dishes	2112	0.38	0.33	−0.05 ***
Beverages	753	0.35	0.33	−0.02
Past best before date	4285	0.87	0.83	−0.04
Quantity problem at purchase	1755	0.24	0.22	−0.02 *
Quantity problem at home	2386	0.32	0.29	−0.03 **
Other reasons	1402	0.24	0.23	−0.01

Note: \*\*\*, \*\* and \* indicate 1%, 5% and 10% levels of significance, respectively.

Variances and coefficients of determination of the models during the lockdown periods indicate that, compared to the entire pandemic period, unavoidable food waste is driven by the influencing factors of the model by a few additional percentage points (Marginal: 1.5 and Conditional: 4.8). The variance between households is strongly reduced for avoidable beverage waste (difference: 0.17) and disposal reasons, such as cooking accident, bad taste or incorrect storage (difference: 0.12). Consequently, the “conditional” coefficient of determination decreases as well, as the variable “number of the household” accounts for a large part of the variance.

An overall tendency can thus be identified, according to which an increase in total food waste for all separately considered periods is mainly due to the increase in unavoidable food waste. This overall societal development is clearly reinforced both by the pandemic situation and, above all, by the lockdown periods. At the same time, for almost all product categories, decreasing avoidable food waste is observed.

#### 4. Discussion

The study highlights aspects of food waste relating to changes in quantities, products and reasons, which can be discussed in light of the findings of other studies. Policy recommendations and intervention recommendations can also be derived from these findings.

#### 4.1. Changes in Avoidable and Unavoidable Food Waste Quantities

For the entire pandemic period in 2020, significant differences can be observed compared to the years 2016/17. While avoidable waste is reduced, unavoidable waste increases, which also significantly increases the total food waste in 2020 compared to 2016/17. An increase in the total amount of food waste is observed for both the lockdown months and the entire pandemic period. At first sight, these findings differ from those of other studies, in which respondents reported that they disposed of less food during the pandemic [30,42]. However, the present study is based on two separate and independent rounds of data collection, while most of the other COVID-19-related studies are based on self-reported changes in food waste behaviour. This means that the latter results rely on perceived amounts reported by participants and there might be an additional bias due to difficulties in recalling the situation before the pandemic. The present study indicates that as soon as the pandemic started, there was a response by households, although the final impact of food chain interruptions and supply shortages was not perceived in the first weeks, and one cannot assume a rapid improvement of individual food management skills. This could lead to the conclusion that the problem is not only a lack of skills but also a lack of time or willingness to implement perceived time-consuming behaviours.

In fact, the increase in the present study is not surprising, as in-house consumption has increased and out-of-home consumption has decreased. Looking more closely, the significant increase in household food waste is mainly due to unavoidable food waste. In particular, there was unavoidable vegetable and beverage waste, which can be translated as peels, leaves and stalks of vegetables, as well as tea bags and coffee grounds. Since the study participants in Germany spent more time at home, they cooked, drank and ate at home. The hypothesis of a relocation of food waste from outside to inside the households can therefore be confirmed [23]. Unfortunately, there is no data basis available related to food waste from German out-of-home consumption during the assessed time period, in order to verify the assumed shift in numbers.

Although total and unavoidable food waste increased due to the pandemic, the proportion of avoidable waste decreased slightly. This decrease was smaller and less significant when comparing lockdown periods in 2020 with the respective periods in 2016/17. In contrast, the decrease was more noticeable when comparing the pandemic period. This decrease in avoidable food waste occurred despite the fact that more food was prepared and consumed at home. Therefore, the amount of food waste per unit of consumption was even lower in relative terms. This finding is consistent with the assessment of participants in other studies, which show that people become more aware of their food consumption and more aware of food waste, and actually reduce food waste during the pandemic. In this regard, a study by Jribi et al. [13] in Tunisia found that 93% of participants agreed that the COVID-19-related lockdown had a positive effect on food waste behaviour and 80% agreed that it had a positive effect on food purchasing behaviour. A study comparing high and low COVID-19-affected prefectures in Japan [15] found that people in areas more affected by the pandemic paid more attention to the amount, type and cost of daily household food waste. They were more meticulous about purchasing and managing food and felt they had more control over food choices than people in areas less affected by the pandemic. In Malaysia, Ismail et al. [43] found that the order to stay at home during the lockdown significantly reduced household food waste by 15%. More than 60% of the US respondents surveyed by Babbit et al. [30] reported to now conduct better meal planning before shopping, watch out for food preservation methods, save leftovers, eat more food likely past its best before date and replace perishables with shelf-stable food.

In parallel, there are also studies suggesting negative effects of the COVID-19 pandemic on household food management and food waste behaviour. Aldaco et al. [23]

conducted a case study in Spain comparing a pandemic month with a non-pandemic month. They examined the inputs and outputs of a representative basket of products along the entire supply chain using material flow analysis. The authors found that total food waste along the supply chain remained more or less the same, while household food waste increased by 12%. If it is assumed that out of household consumption is absorbed by households during the pandemic, which also coincides with an increase in food waste at this stage, then food waste in households and out of household consumption are similar in 2019 and 2020.

Even though the differences in food waste amounts are statistically significant, their absolute values in the gram range per 14 days and household appear to be small. However, when extrapolated to the entire year and 40.77 million German households, 70 g of unavoidable beverage waste translates into a significant waste of valuable resources, particularly if disposed of through non-recycling disposal paths. The significant reductions recorded for convenience foods, fruit and prepared foods, with 40 g, 30 g and 30 g, respectively, result in an overall reduction of approximately 86,000 tonnes of avoidable food waste per year. Since two of the food categories are highly processed, the impact on resource efficiency should be further analysed in detail.

#### *4.2. The Pandemics Effect on Product Groups and Disposal Reasons*

The pandemic also had an impact on the type of product groups that were wasted. On the one hand, unavoidable beverage waste (e.g., tea bags and coffee grounds) increased, which could be explained by the increase in home-based work and, more generally, more time spent at home. Common beverages such as coffee and tea are more often consumed and prepared at home. The increase in unavoidable vegetable waste might be related to a similar pattern—increased food preparation at home and therefore an increase in peels, seeds, etc.

On the other hand, there has been a reduction in the wasted amounts of prepared foods, fruits and convenience products in the present study. The Romanian respondents of Muresan et al. [42] reported a decreased food waste amount related to all four given food categories fruit and vegetables, bread and bakery products, meat and meat products, as well as milk and dairy products during the pandemic. In contrast, Aldaco et al. [23] show that processed food and pastry waste increased, at least during the first week of the lockdown.

A decrease in perishable food waste is consistent with some previous studies. For example, households became better at planning shopping and meals, organising food during the lockdown period, preventing overbuying and overcooking, as well as reusing leftovers for new dishes [13,14]. In particular, strategies for saving, storing and eating leftovers were improved in the Jribi et al. [13] study. Muresan et al. [42] report that their respondents started to freeze leftovers less often during the pandemic and concluded that there is more time available to reuse leftovers within the next few days, additionally supported by increased eating frequency at home. Nevertheless, overcooking remains the main reason for food waste in Romanian households during the pandemic [42]. In the present study, a significant decrease in the reason for disposal related to quantity problems at home during the lockdown period underlines the newly gained control of households over food storage and planning.

#### *4.3. Long-Term Behavioural Changes*

The question remains open to what extent the COVID-19 pandemic has led to a short-term or more long-term change in behaviour. In terms of avoidable waste, there seems to be a modest trend towards waste prevention, which may also be a small indication of a societal

development in this direction. According to Vidal-Mones et al. [22], consumers in Spain started to reflect more on broader issues concerning the food system during the pandemic, such as on overall consumption patterns, their dependence on the globalised food trade, disruptive factors within the food system and imbalances between actors in the supply chain. Results from WRAP [44] show that the positive trends could be continued at least until the second pandemic year in the UK. The comparison of surveys in mid of 2020 and mid of 2021 found that the improved food management practices of freezing, batch cooking and using up leftovers introduced during the pandemic were already declining after the UK returned to normality in mid of 2021. Roe et al. [19] states that improved food management practices and skills may be outweighed by returning to the pre-pandemic behaviour if the pandemic duration is too short for a behaviour change and crucial framework conditions (e.g., working from home) return to pre-pandemic conditions again. Thus, the new approaches may not become part of the set of behaviour implemented unconsciously. For positive behavioural adaptations to be maintained, educational campaigns focusing on handling of leftovers, storage and cooking habits could be an option [45] and are accepted and perceived as fair by consumers as opposed to other policies [46].

#### *4.4. Limitations and Future Research*

Limitations of the present study relate to data collection and analysis. Studies have shown that household food waste is often underestimated in food waste diaries [31,32]. This is because underestimation of food waste correlates with less reporting effort on the part of study participants, as well as with the social stigma of food waste. As compared to another German survey based on waste sorting analysis and waste statistics [7], the presented diary study underestimates the most accurate food waste figures at household level approximately by 1.7 times. If we assume the same underestimation magnitude for the 2020 study, the outcome would be a total food waste amount of 78.8 kg per capita and year for German households. Eurostat's official data for Germany for 2020 [47] is 78 kg per capita per year at household level, indicating at least a constant bias. Nevertheless, the aim of the present study is to compare the two periods from 2016/17 and 2020 which are based on identical methodology. It can be assumed that the same bias can be found in both studies.

Other limitations arise from slight differences between the sample and the population, which could not be compensated by weighting due to methodological reasons related to the model. For example, there is a 13% difference in age structure between the sample and the population. However, this study was able to reflect the population relatively well, for example, compared to Jribi et al. [13], who had a large proportion of women and highly educated participants due to the voluntary self-recruitment sampling strategy. Nevertheless, it is essential to acknowledge the strengths of the present study, which include a comprehensive coverage of 365 days and a representative sample size of 6507 households in 2016/17 and 7372 households in 2020, compared to the relatively small sample sizes of a few hundred households in other studies.

Further limitations include not sufficiently taking into account stockpiling. The study ended on 31 December 2020, which means that most of the staple food stockpiled during the first phases of the pandemic were still within its best before date. Literature indicates that non-perishable food was preferred for stockpiling during the pandemic [20,30,48]. The huge increase in demand for food items such as flour, rice or dry pasta could be an indicator for these items having been wasted after 2020 [19].

Future research should track those food items in order to capture the long-term effects of different food purchase, storing and consumption practices during challenging times. Some literature indicates that despite panic buying and stockpiling, the overall food waste

could be decreased [33,49], while others report an increase [50,51]. There is also evidence that there are different perceptions and behaviours concerning the need to stockpile food in challenging times, which are linked to the type of society, culture, individual economic situation, communicated political strategies as well as economic factors [9,51–53].

## 5. Conclusions

The results presented here are based on a study that was serendipitously able to build on two large and representative sample periods that fully cover household food waste during one year outside and one year inside the COVID-19 pandemic in Germany. Although the diary method has drawbacks, it can be considered more accurate than the questionnaire method used in many other studies of household food waste during the pandemic.

The present paper proves a positive effect of the COVID-19 pandemic on household food waste behaviour in Germany, which is reflected in lower amounts of avoidable food waste. The higher level of overall food waste as well as unavoidable food waste is likely based on a shift in consumption away from gastronomy as well as school and work canteens into homes during the pandemic. The pandemic has also led to a different composition of product groups wasted.

Even years after the pandemic, the highlighted results are of significant importance that goes beyond the COVID-19 impact. One learning outcome is that countries need to be well prepared for supply chain disruptions. A second lesson is the behavioural change in households during a slowdown in everyday activities. In times of potential supply chain disruptions due to crises and wars, protectionism, blackouts and climate change, the monitoring of household consumption and food waste behaviour as a reaction to these events is crucial. National contingency planning should be reviewed for potential improvements in infrastructure, organisation and public communication. It should also consider individual behaviour of citizens within the country when it comes to panic buying and overstocking in order to be prepared from the very beginning. The impact of food stockpiling could not be assessed in the present study. Therefore, it is recommended that in the event of another emergency situation, more official guidance should be provided to assist people with information on which products to buy, how to store them and how and when to use them, in order to prevent shortages for others and to avoid wastage of food after the expiry date.

Concerning the second lesson on behavioural changes, some of these changes induced by the pandemic may be permanent, such as more remote work, less work travel, and even the adoption of certain food management skills and practices. The assumption suggested by the paper that increased engagement with food, its preparation, storage and meal planning can lead to a lower level of avoidable food waste in households is of great importance. Policies should therefore focus on how to promote not only the skills but also the time and capacity of citizens to engage with the issue and to prioritise and develop an interest in food management among the many things that need to be managed in everyday life. These aspects should be clearly included in educational campaigns. A main goal of future policies should be to support those behaviours leading to less food waste, despite returning to more flexibility at work, school and leisure time, which touches not only food policies but also many other political frameworks. Ensuring policy coherence between food, labour and family policies might create fair food environments for consumers that support the development of favourable behaviours.

Future research could gain deeper insight into the question if a significant deceleration in everyday life is an imperative precondition to develop more sustainable behaviour,

attitudes and skills towards food value on a large scale or if available technologies or changeable framework conditions could enable those despite a busy lifestyle.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/resources14110173/s1>, Table S1. Distribution of attribute levels in the sample and extrapolation with difference in percentage points in 2020; Table S2. Definitions of the life cycle phases; Figure S1. Residuals of the transformed variable ‘amount of food waste’ of the linear model with mixed effects, summed up to households (plot and histogram).

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## References

1. Crippa, M.; Solazzo, E.; Guizzardi, D.; Monforti-Ferrario, F.; Tubiello, F.N.; Leip, A. Food systems are responsible for a third of global anthropogenic GHG emissions. *Nat. Food* **2021**, *2*, 198–209. [CrossRef]
2. Mbow, C.; Rosenzweig, C.; Barioni, L.G.; Benton, T.G.; Herrero, M.; Krishnapillai, M.; Liwenga, E.; Pradhan, P.; Rivera-Ferre, M.G.; Sapkota, T.; et al. Food Security. In *Climate Change and Land: An IPCC Special Report*; Shukla, P.R., Skea, J., Buendia, E.C., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., et al., Eds.; IPCC: Geneva, Switzerland, 2019; Chapter 5; pp. 437–550. [CrossRef]
3. Davis, K.F.; Gephart, J.A.; Emery, K.A.; Leach, A.M.; Galloway, J.N.; D’Odorico, P. Meeting future food demand with current agricultural resources. *Glob. Environ. Change* **2019**, *39*, 125–132. [CrossRef]
4. Tubiello, F.N.; Rosenzweig, C.; Conchedda, G.; Karl, K.; Gütschow, J.; Xueyao, P.; Obli-Laryea, G.; Wanner, N.; Yue Qiu, S.; De Barros, J.; et al. Greenhouse gas emissions from food systems: Building the evidence base. *Environ. Res. Lett.* **2021**, *16*, 65007. [CrossRef]
5. Osei-Owusu, A.K.; Towa, E.; Thomsen, M. Exploring the pathways towards the mitigation of the environmental impacts of food consumption. *Sci. Total Environ.* **2022**, *806*, 150528. [CrossRef] [PubMed]
6. UNEP. Food Waste Index Report 2024—Think Eat Save—Tracking Progress to Halve Global Food Waste, 2024. United Nations Environment Programme. Available online: <https://www.unep.org/resources/publication/food-waste-index-report-2024> (accessed on 24 June 2025).
7. Schmidt, T.; Schneider, F.; Leverenz, D.; Hafner, G. Lebensmittelabfälle in Deutschland—Baseline. *Thünen Rep.* **2019**, *71*, 103. [CrossRef]
8. Schanes, K.; Dobernig, K.; Gözet, B. Food waste matters—A systematic review of household food waste practices and their policy implications. *J. Clean. Prod.* **2018**, *182*, 978–991. [CrossRef]
9. Ben Hassen, T.; El Bilali, H.; Allahyari, M.S. Impact of COVID-19 on Food Behavior and Consumption in Qatar. *Sustainability* **2020**, *12*, 6973. [CrossRef]
10. World Health Organization. WHO Director-General’s Opening Remarks at the Media Briefing on COVID-19—11 March 2020. Available online: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020> (accessed on 20 June 2025).

11. German Federal Government. Besprechung der Bundeskanzlerin mit den Regierungschefinnen und Regierungschefs der Länder vom 22.03.2020. 2020. Available online: <https://www.bundesregierung.de/breg-de/themen/coronavirus/besprechung-der-bundeskanzlerin-mit-den-regierungschefinnen-und-regierungschefs-der-laender-vom-22-03-2020-1733248> (accessed on 13 May 2024).
12. Federal German Ministry of Health. Corona-Virus-Pandemie: Was Geschah Wann? Available online: <https://www.bundesgesundheitsministerium.de/coronavirus/chronik-coronavirus.html> (accessed on 13 May 2025).
13. Jribi, S.; Ben Ismail, H.; Doggui, D.; Debbabi, H. COVID-19 virus outbreak lockdown: What impacts on household food wastage? *Environ. Dev. Sustain.* **2020**, *22*, 3939–3955. [CrossRef]
14. Principato, L.; Secondi, L.; Cicatiello, C.; Mattia, G. Caring more about food: The unexpected positive effect of the Covid-19 lockdown on household food management and waste. *Socio-Econ. Plan. Sci.* **2022**, *82*, 100953. [CrossRef]
15. Qian, K.; Javadi, F.; Hiramatsu, M. Influence of the COVID-19 Pandemic on Household Food Waste Behavior in Japan. *Sustainability* **2020**, *12*, 9942. [CrossRef]
16. Dou, Z.; Stefanovski, D.; Galligan, D.; Lindem, M.; Rozin, P.; Chen, T.; Chao, A.M. Household Food Dynamics and Food System Resilience Amid the COVID-19 Pandemic: A Cross-National Comparison of China and the United States. *Front. Sustain. Food Syst.* **2021**, *4*, 577153. [CrossRef]
17. Kubičková, L.; Veselá, L.; Kormaňáková, M. Food Waste Behaviour at the Consumer Level: Pilot Study on Czech Private Households. *Sustainability* **2021**, *13*, 11311. [CrossRef]
18. Songür Bozdağ, A.N.; Çakıroğlu, F.P. COVID-19 outbreak and household food waste: Evidence from Turkey. *Int. J. Agric. Environ. Food Sci.* **2021**, *5*, 413–424. [CrossRef]
19. Roe, B.E.; Bender, K.; Qi, D. The Impact of COVID-19 on Consumer Food Waste. *Appl. Econ. Perspect. Policy* **2021**, *43*, 401–411. [CrossRef]
20. Vittuari, M.; Masotti, M.; Iori, E.; Falasconi, L.; Gallina Toschi, T.; Segrè, A. Does the COVID-19 external shock matter on household food waste? The impact of social distancing measures during the lockdown. *Resour. Conserv. Recycl.* **2021**, *174*, 105815. [CrossRef]
21. WRAP. Citizen Responses to the COVID-19 Lockdown—Food Purchasing, Management and Waste. Available online: [https://www.wrap.ngo/sites/default/files/2020-10/WRAP-Citizen\\_responses\\_to\\_the\\_Covid-19\\_lockdown\\_0.pdf](https://www.wrap.ngo/sites/default/files/2020-10/WRAP-Citizen_responses_to_the_Covid-19_lockdown_0.pdf) (accessed on 25 July 2025).
22. Vidal-Mones, B.; Barco, H.; Diaz-Ruiz, R.; Fernandez-Zamudio, M.-A. Citizens' Food Habit Behavior and Food Waste Consequences during the First COVID-19 Lockdown in Spain. *Sustainability* **2021**, *13*, 3381. [CrossRef]
23. Aldaco, R.; Hoehn, D.; Laso, J.; Margallo, M.; Ruiz-Salmón, J.; Cristobal, J.; Kahhat, R.; Villanueva-Rey, P.; Bala, A.; Batlle-Bayer, L.; et al. Food waste management during the COVID-19 outbreak: A holistic climate, economic and nutritional approach. *Sci. Total Environ.* **2020**, *742*, 140524. [CrossRef] [PubMed]
24. UNSCN. COVID-19 Pandemic: The Evolving Impact on How People Meet the Food System. *United Nations System Standing Committee on Nutrition*. 2020. Available online: <https://www.unscn.org/en/news-events/recent-news?idnews=2065> (accessed on 20 May 2024).
25. Ajzen, I. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]
26. Srivastava, S.K.; Mishra, A.; Singh, S.; Jaiswal, D. Household food waste and theory of planned behavior: A systematic review and meta-analysis. *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 97645–97659. [CrossRef]
27. Chen, M.-F. Integrating the extended theory of planned behavior model and the food-related routines to explain food waste behavior. *Br. Food J.* **2023**, *125*, 645–661. [CrossRef]
28. Mucha, L.; Oravec, T. Assumptions and perceptions of food wasting behavior and intention to reduce food waste in the case of Generation Y and Generation X. *Sci. Rep.* **2025**, *15*, 2991. [CrossRef]
29. Nguyen, G.T.T.; Nguyen, H.G. Extended theory of planned behavior and demographics in household food waste reduction: Evidence from Vietnam. *Clean. Waste Syst.* **2025**, *12*, 100349. [CrossRef]
30. Babbitt, C.W.; Babbitt, G.A.; Oehman, J.M. Behavioral impacts on residential food provisioning, use, and waste during the COVID-19 pandemic. *Sustain. Prod. Consum.* **2021**, *28*, 315–325. [CrossRef] [PubMed]
31. Giordano, C.; Alboni, F.; Falasconi, L. Quantities, Determinants, and Awareness of Households' Food Waste in Italy: A Comparison between Diary and Questionnaires Quantities'. *Sustainability* **2019**, *11*, 3381. [CrossRef]
32. Queded, T.E.; Palmer, G.; Moreno, L.C.; McDermott, C.; Schumacher, K. Comparing diaries and waste compositional analysis for measuring food waste in the home. *J. Clean. Prod.* **2020**, *262*, 121263. [CrossRef]
33. Amicarelli, V.; Bux, C. Food waste in Italian households during the COVID-19 pandemic: A self-reporting approach. *Food Secur.* **2021**, *13*, 25–37. [CrossRef] [PubMed]
34. Hübsch, H.; Adlwarth, W.; Systematische Erfassung von Lebensmittelabfällen der Privaten Haushalte in Deutschland. Schlussbericht. 2017. Available online: <https://www.zugufuerdientonne.de/fileadmin/zgfdt/inhalt/daten/GfK-Studie.pdf> (accessed on 14 July 2025).

35. Hübsch, H.; Systematische Erfassung des Lebensmittelabfalls der Privaten Haushalte in Deutschland. Schlussbericht 2020. 2021. Available online: [https://www.bmel.de/SharedDocs/Downloads/DE/\\_Ernaehrung/Lebensmittelverschwendung/GfK-Analyse-2020.pdf](https://www.bmel.de/SharedDocs/Downloads/DE/_Ernaehrung/Lebensmittelverschwendung/GfK-Analyse-2020.pdf) (accessed on 14 July 2025).
36. Herzberg, R.; Schmidt, T.G.; Schneider, F. Characteristics and Determinants of Domestic Food Waste: A Representative Diary Study across Germany. *Sustainability* **2020**, *12*, 4702. [[CrossRef](#)]
37. Witte, L. *Lebensmittelabfallaufkommen in Deutschen Haushalten: Eine Empirische Untersuchung*; Christian-Albrechts-Universität zu Kiel: Kiel, Germany, 2022. [[CrossRef](#)]
38. Pinheiro, J.C.; Bates, D.M. *Mixed-Effects Models in S and S-PLUS*; Springer: Berlin/Heidelberg, Germany, 2020.
39. Osborne, J. Improving your data transformations: Applying the Box-Cox transformation. *Pract. Assess. Res. Eval.* **2010**, *15*, 12. [[CrossRef](#)]
40. Nakagawa, S.; Schielzeth, H. A general and simple method for obtaining R<sup>2</sup> from generalized linear mixed-effects models. *Methods Ecol. Evol.* **2013**, *4*, 133–142. [[CrossRef](#)]
41. Hothorn, T.; Bretz, F.; Westfall, P. Simultaneous inference in general parametric models. *Biom. J.* **2008**, *50*, 346–363. [[CrossRef](#)]
42. Muresan, I.C.; Harun, R.; Andreica, I.; Chiciudean, G.O.; Kovacs, E.; Oroian, C.F.; Brata, A.M.; Dumitras, D.E. Household Attitudes and Behavior towards the Food Waste Generation before and during the COVID-19 Pandemic in Romania. *Agronomy* **2022**, *12*, 746. [[CrossRef](#)]
43. Heikal Ismail, M.; Ghazi, T.I.M.; Hamzah, M.H.; Manaf, L.A.; Tahir, R.M.; Mohd Nasir, A.; Ehsan Omar, A. Impact of Movement Control Order (MCO) due to Coronavirus Disease (COVID-19) on Food Waste Generation: A Case Study in Klang Valley, Malaysia. *Sustainability* **2020**, *12*, 8848. [[CrossRef](#)]
44. WRAP. Returning to Normality After COVID-19: Food Waste Attitudes and Behaviours in 2021. 2021. Available online: <https://wrap.org.uk/sites/default/files/2021-08/food-trends-report-august-2021.pdf> (accessed on 14 July 2025).
45. Szakos, D.; Szabó-Bódi, B.; Kasza, G. Consumer awareness campaign to reduce household food waste based on structural equation behavior modeling in Hungary. *Environ. Sci. Pollut. Res. Int.* **2021**, *28*, 24580–24589. [[CrossRef](#)]
46. Wheeler, B.S.A.; Xu, Y.; Gregg, D. Exploring South Australian households' perceptions towards various food waste policies. *Ecol. Econ.* **2025**, *227*, 108431. [[CrossRef](#)]
47. Eurostat. Food Waste and Food Waste Prevention by NACE Rev. 2 Activity—Tonnes of Fresh Mass. 2024. Available online: [https://ec.europa.eu/eurostat/databrowser/view/ENV\\_WASFW\\_\\_custom\\_5227594/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/ENV_WASFW__custom_5227594/default/table?lang=en) (accessed on 18 October 2025).
48. Lehberger, M.; Kleih, A.-K.; Sparke, K. Panic buying in times of coronavirus (COVID-19): Extending the theory of planned behavior to understand the stockpiling of nonperishable food in Germany. *Appetite* **2021**, *161*, 105118. [[CrossRef](#)]
49. Wang, L.; Yang, Y.; Wang, G. The Clean Your Plate Campaign: Resisting Table Food Waste in an Unstable World. *Sustainability* **2022**, *14*, 4699. [[CrossRef](#)]
50. Pappalardo, G.; Cerroni, S.; Nayga, R.M.; Yang, W. Impact of COVID-19 on Household Food Waste: The Case of Italy. *Front. Nutr.* **2020**, *7*, 585090. [[CrossRef](#)] [[PubMed](#)]
51. Cosgrove, K.; Vizcaino, M.; Wharton, C. COVID-19-Related Changes in Perceived Household Food Waste in the United States: A Cross-Sectional Descriptive Study. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1104. [[CrossRef](#)]
52. Bian, B.; Li, J.; Xu, T.; Foutz, N.Z. Individualism during Crises. *Rev. Econ. Stat.* **2022**, *104*, 368–385. [[CrossRef](#)]
53. Ellison, B.; McFadden, B.; Rickard, B.J.; Wilson, N.L.W. Examining Food Purchase Behavior and Food Values During the COVID-19 Pandemic. *Appl. Econ. Perspect. Policy* **2021**, *43*, 58–72. [[CrossRef](#)]

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## Supplementary Material

**Table S1:** Distribution of attribute levels in the sample and extrapolation with difference in percentage points in 2020

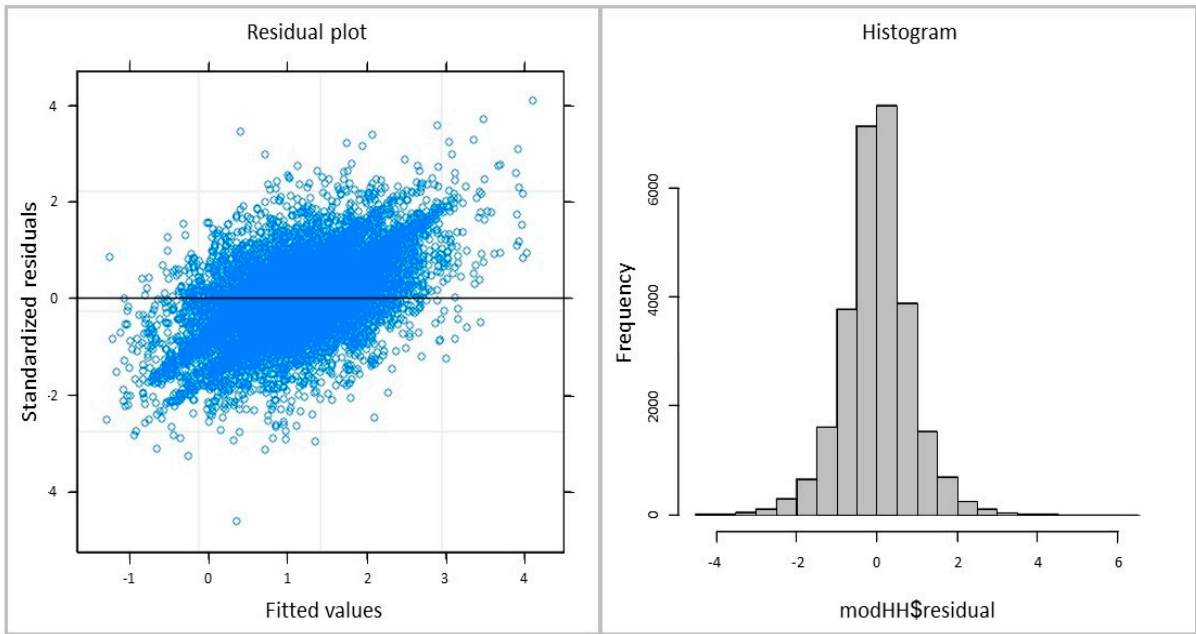
Variables and manifestations	<i>Sample</i>	<i>Extrapolatio n</i>	<i>Difference</i>
Household size			
1	38.9 %	41.0 %	+ 2.1
2	41.9 %	34.1 %	- 7.8
3+	19.2 %	24.9 %	+ 5.7
Town size			
rural < 500 000 inhabitants	84.3 %	81.6 %	- 2.7
urban > 500 000 inhabitants	15.7 %	18.4 %	+ 2.7
Age categories			
- 39 years	13.7 %	27.4 %	+ 13.7
40 - 59 years	36.9 %	36.5 %	- 0.4
60+ years	49.4 %	36.2 %	- 13.2
Educational level			
General Certificate of Secondary Education	48.1 %	46.5 %	- 1.6
General qualification for university entrance	21.7 %	21.9 %	+ 0.2
Academic Education	30.2 %	31.6 %	+ 1.4
Lifecycle phase			
Young singles	11.4 %	17.3 %	+ 5.9
Young families/ couples w/o children	2.4 %	4.3 %	+ 1.9
	2.6 %	4.7 %	+ 2.1

Young families with toddlers	4.5 %	6.7 %	+ 2.2
Families with school children	1.2 %	1.5 %	+ 0.3
Families with adolescent children	6.8 %	7.3 %	+ 0.5
Older families with children	3.6 %	3.8 %	+ 0.2
Middle-aged families w/o children	14.2 %	12.6 %	- 1.6
Older fam. w/o childr. (HHH employed)	25.7 %	18.3 %	- 7.4
Older fam. w/o childr. (HHH unemployed)	27.5 %	23.5 %	- 4.0
Single seniors			

Table S2: Definitions of the lifecycle phases

Lifecycle phase		Definition		
Code	Title	Age of head of household	Household size	Number / age of children

1	Young singles	< 50	1	-
2	Young families/ couples without children	< 35	> 1	-
3	Young families with toddlers	< 45	> 1	oldest child <6
4	Families with school children	< 45	> 1	oldest child >6 <14
5	families with adolescent children	< 45	> 1	oldest child >15 <19
6	older families with children	> 44	> 1	Children >0 <19
7	middle-aged families without children	> 34 < 50	> 1	No children (under the age of 20)
8	older families w/o children (HHH employed)	> 49	> 1	No children (under the age of 20)
9	older families w/o children (HHH unemployed)	> 49	> 1	No children (under the age of 20)
10	single seniors	> 49	1	-



**Figure S1:** Residuals of the transformed food waste of the linear model with mixed effects, summed up to households, plot and histogram