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Caring more about food: The unexpected positive effect of the Covid-19 lockdown on household food management and waste☆

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ABSTRACT

Over half of the total amount of food wasted in Europe concerns household food waste which is mainly due to incorrect food management habits and behaviour. During the Covid-19 outbreak, food management and consumption habits changed dramatically due to the tough lockdown restrictions imposed by governments to reduce infection. This study investigated how these dramatic changes in the daily lives of consumers influenced the generation of food waste at household level. A CAWI questionnaire was administered to a sample of 1078 Italian consumers during the lockdown (March–April 2020). The respondents were asked to self-estimate the percentage of food their households wasted before and during the lockdown and to explain their food management habits. We focused the analysis on the differences between the food the respondents declared to have wasted before and during lockdown, which revealed that most households threw away less food during the Covid-19 lockdown compared to the pre-Covid situation. We referred to Seemingly Unrelated Regression models to evaluate the association between the food waste behaviour in the two periods considered in the study and the other factors observed. The results disclosed that young consumers and people who started implementing good food management practices (shopping list, meal planning etc.) more frequently considerably reduced the food they wasted during lockdown. Also, the logistical difficulties of grocery shopping experienced by consumers during lockdown made them manage their household food consumption more carefully, which led to a reduction in the amount of food wasted.

1. Introduction

Over the last few years, the Food Waste (FW) phenomenon and its negative economic, environmental and social effects has been considered as one of the most important sustainability issues to be addressed at global level ([8,31]. In fact, FW reduction has been included among the 17 Sustainable Development Goals of the UN's 2030 Agenda and specifically in target 12.3 that aims to: "*halve* per capita *global food waste at the retail and consumer levels and reduce food losses along production and supply chains*" [72] by 2030.

The economic, environmental and social costs associated to FW amount to approximately USD 2.6 trillion per year [32]. FW is also responsible for 8% of global greenhouse gas emissions and occupies approximately 30% of the world's agricultural land used to produce food that is later wasted, which has a significant impact on the environment and climate change [31].

In the Global North, large amounts of food are wasted at the end of the food supply chain [54] which is mainly due to incorrect consumer behaviour, habits and attitudes [10,14,56,59,60]. Indeed, the annual rate of FW generation rate per capita is approximately 39% in North America and 31% in Europe [31].

In the EU-28 it is estimated that 88 million tonnes of food are wasted annually, thus amounting to 173 kg per capita which is mostly composed of Household FW [86]. The measurement of the exact quantities of FW at the household level deliver different results due to the array of the existing quantification methods [19]. Studies using direct quantification methods estimate that FW in Europe ranges between 23 kg per capita per year [50] and 48 kg per capita per year [22]. According to [37]; Italian consumers waste 530 g of food per week at home, which is approximately 27.5 kg per capita per year. The European project

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REFRESH estimates that each household wastes 94.64 kg of food each year [52], amounting to approximately 4.9 Euros per week and corresponding to 6.5 billion of Euros per year at national level [80].

Reducing FW is financially, environmentally and socially essential and it is important to gain a better understanding of how the Covid-19 pandemic has affected household consumption and FW habits and behaviour [83].

It is evident that epidemics and pandemics pose a serious threat to public health and social stability. Following the 2002 SARS epidemic in China, the Ebola epidemic in West Africa and the 2015 Middle East respiratory syndrome (MERS) outbreak, at the end of 2019 a new type of coronavirus was discovered in China which rapidly caused a pandemic within three months (March 10, 2020) which affected 216 countries causing several millions cases and almost 600,000 deaths [81].[1] The SARSCoV-2 virus that causes Covid-19 is predominantly spread from person to person and it is extremely contagious with a very high mortality rate especially for the elderly [17]. In Italy the Covid-19 pandemic spread rapidly; Italy was the first Western Country to implement self-isolation and social-distancing policies and total lockdown from March 9th until May 4th, during which most people were forced to stay home, avoid any social contact and go out only for essential reasons and basic needs such as grocery shopping, work or health issues. Non-essential economic activities and services were stopped, and all of the schools were closed. According to the Italian Statistical Institute [42], at least 7.1 million workers and 10.8 million students of all ages were forced to stay at home during the lockdown, while 55.7% of private sector workers continued to go to work during lockdown.

Consequently, individuals and households dramatically changed their food consumption habits and behaviour. Grocery retail grew by 18% in March–April 2020 compared to the same period in 2019, local shops and supermarkets saw a strong increase in volume of sales and grocery and food delivery services experienced demand (+160%) at record levels [41]. ISTAT [43] reported that food was the only sector that grew by 3.5% in value and 2.1% in volume on a trend basis in March 2020. ISMEA [41] reports a rise in the demand of several food categories in March–April 2020: flour purchases increased by 145%, pasta and rice by 14% and 25% respectively, +78% oranges, +60% apples, +57% mozzarella, +57% eggs, +32% cheeses, +31% cured meats, long-life milk made a +22%, while fresh milk dropped by −5%. These data suggest that during the lockdown Italians cooked their meals at home and enjoyed spending meal times with their families. Households spent more on groceries during lockdown [5] since they were forced to stay at home. However, many families experienced severe financial hardship, due to reduction in disposable household income and risk of bankruptcy/unemployment. Together with mobility restrictions, these issues made it harder for consumers to gain access to food [16]. New food provision solutions have emerged as a reaction to food insecurity and difficulties in food shopping [15,16]. It is likely that these changes in consumption patterns have affected quantities and types of food available/disposed at home. Therefore, it is essential to gain a better understanding of how lockdown have affected household FW behaviour.

To date studies on this topic have focused on Great Britain and Tunisia [35,48,83], highlighting the fact that further research is required in order to gain valuable insights on how a crisis of this kind can influence food consumption and waste consumer habits, attitudes and behaviors at household level. A first exploratory study conducted in Italy highlighted that FW at household level has dropped to 430 g per week per household [80] however the reasons and the factors underlying this reduction have not yet been explored.

The aim of this paper is to determine how these changes have affected the amount of FW generated at home by focusing on the underpinning factors of these dynamics. The main research questions that triggered our analysis are: (i) How were FW quantities affected by Covid-19 lockdown? (ii) Did the eating and food management habits acquired during lockdown help to revolutionize/rationalize household food consumption and management; (iii) Did eating at home more often than usual help to reduce FW? (iv) Is the context in which individuals live related to these changes?

The remainder of the paper is structured as follows. Section 2 describes the methodological approaches adopted for the data collection process, the theoretical framework underlying the construction of the questionnaire as well as the statistical techniques and methods used for analysing the data. Section 3 reports the results of the data analysis, focusing on the respondents' profiles and using Seemingly Unrelated Regression (SUR) models to determine if and to what extent the factors associated with FW at household level changed before and during lockdown. Lastly, Section 4 discussed the results obtained and draws some concluding remarks.

2. Methodology

2.1. Study design

This study is based on a sample survey carried out through a Computer Assisted Web Interview (CAWI) based questionnaire aimed at investigating if and to what extent changes in food-related habitudes due to the Covid-19 restrictions have impacted on the quantity of FW produced at home. Questionnaires are one of the tools available to conduct a direct measurement of FW at households [82] with the aim of collecting primary data [20] and are based on respondents' self-assessment of the quantity of food wasted. In the context of household FW studies, questionnaires are largely used to investigate consumers' perception of the quantity of food discarded at home [29], to explore the underlying causes for this waste [50], or to provide an estimate of the extent of the food wasted [1,47,77,78]. However, studies comparing the results of different assessment methods show that, when respondents are called to self-assess the amount of food discarded, they systematically underestimate the quantity of FW produced at their household [37]. For this reason, some studies have considered appropriate using different quantification methods on the same sample [50,83] or using self-declared quantities of FW to compare the situation across times and regions [66] rather than to provide an absolute measure of household FW. Moreover, questionnaires are considered a reliable tool to investigate the linkage between the amount of food discarded and other variables related to food shopping behaviour or ethical/social norms [19].

In this study, a questionnaire was implemented to explore the impact of the Covid-19 restrictions in Italy on the quantity and type of household FW. In the questionnaire, respondents were asked to self-assess the percentage of food wasted, with respect to the food purchased, prior and during lockdown. The analysis focuses on the difference between these two two pieces of information, by studying the variables that exerted an influence on the quantity of self-declared FW by the surveyed households before and during the Covid-19 lockdown.

The conceptual design of the study is visually represented in Fig. 1.

2.2. Structure of the questionnaire

The survey was conducted through a self-administered questionnaire written in Italian and implemented in Google Forms. The questionnaire consisted of 35 single-option and multiple-choice items structured in five sections. These sections draw from the most recent and relevant literature on FW at household level, and are defined as follows: i) situational, psychological and social factors; ii) food provisioning habits and shopping behaviors before and during lockdown; iii) food management and waste habits before and during lockdown; iv) rediscovery of culinary traditions; v) household socio-demographic characteristics.

The literature arguments from which we have drawn the structure of the survey are reported in this section.

FW has become a major global concern because it derives from

[1] Data updated at 19 July 2020.

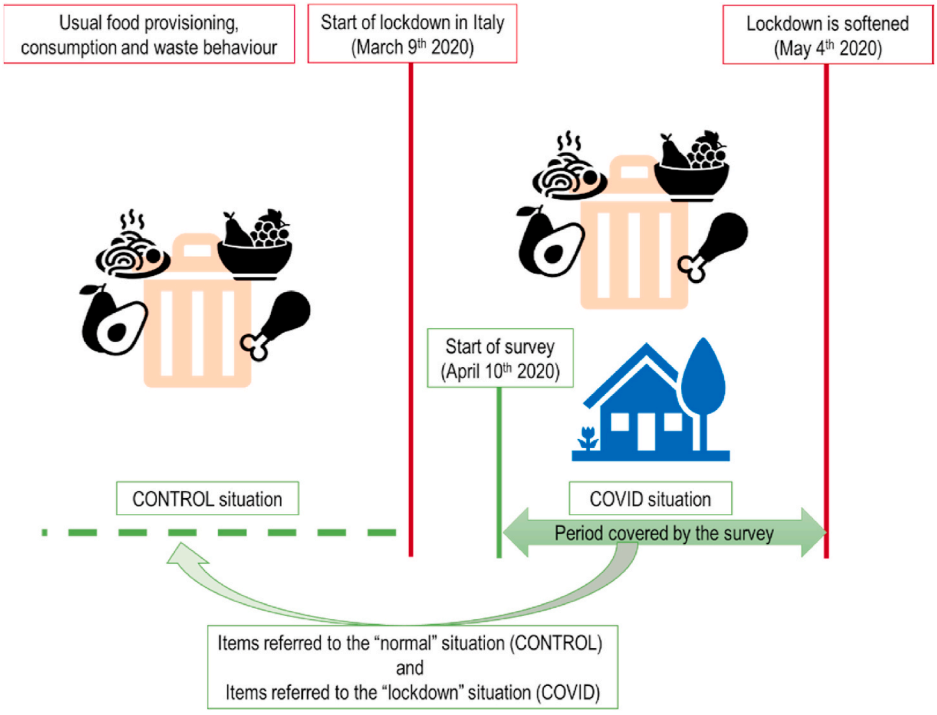

Fig. 1. Conceptual design of the study.

complex and multifaceted behaviors and for its implications on the different food supply chains [14,56,61]. Analyzing the past literature on consumer FW [60], sought to better explain wasteful behaviour drawing from consumer decision making theories and consumer food management process through the Household Wasteful Behaviour Framework (HWBF). According to this model, individual's wasteful behaviour is driven by different psychological, social, situational, and socio-demographic factors; and by incorrect habits and behaviors during the food management process, that is during the food planning, in-store, pre-consumption, consumption and disposition phases. For psychological factors we intend some non-cognitive elements of FW behaviour such as habits, FW knowledge and FW involvement, defined as one's level of awareness of the impacts of FW as well as perceived behavioural control (the degree to which individuals believe that they are capable of modifying a particular behaviour, like reducing the amount of food they waste). All these factors have been proven to influence individual's wasteful behaviors [7,53,58,69,77,78] and have been considered in section 1 of our questionnaire. Moreover, since it has been demonstrated that households waste larger amounts of food when they buy it from large supermarket chains rather than from small shops or local markets [47,87,88], we decided to include in section 1 an additional item about the main channels of food provisioning used by respondents before and during the lockdown, including: hypermarket and supermarket, small shops (butchers, food shops, bakeries etc.); local markets and street vendors; discounts; internet purchase (online shopping).

Section 2 of the questionnaire includes some quantitative items concerning food provisioning and shopping habits that were likely affected by the lockdown [41,42]. We added one item about food planning, to investigate whether individuals had improved their meal planning and/or were drawing a shopping list. Indeed, both these food management habits were found to be negatively correlated to FW [28,39,57,83] thus proving to effective in reducing the generation of household FW.

Considering the other phases of the food management process, we have included in section 3 of the questionnaire items about habits and incorrect behaviors that are likely linked with the HWBF: (i) purchases mistakes in-store (i.e. buying too much food, marketing "buy one get one free" offerings, too large packs) [26,36,89,90]; (ii) expiration dates [34,65,67,79]; (iii) incorrect storage [4,21,38,91]; (iv) cooking or serving too much food [21,58,74]; (v) food preferences [26,27]; (vi) poor cooking skills [74]; and (vii) food left by kids [26–28,37,92].

Following the evidence that the rate of waste is likely to change among food categories [30,68,71], we decided to collect data on the declared FW overall and by food category (pasta-rice; meat-fish-eggs; milk and dairy products; vegetables; fruits; bread), using specific items that were duplicated in order to assess the rate of waste for each category before and during the lockdown. These items were included in section 3.

Section 4 consists of two items about new habitudes of the household during lockdown. There is some evidence that – given the increased time spent at home and a reduction in the hectic activities of the life before the lockdown-families were spending more time cooking and were discovering nationals and traditional meals [80]. We therefore asked respondents about this "(re)turn to traditions" and about the time they used to spend in the kitchen during the lockdown.

Finally, section 5 focuses on the socio-demographic features of the respondents according to HWBF and the past literature. There is evidence that youths tend to waste more than elderly people [23,40,51,55]. Also, a relationship was found between the individuals' level of education and the amount of food he/she wastes: the higher the level of education, the larger the quantity of FW generated [66,77,78]. Furthermore, larger households tend to waste more than smaller ones [61], although it has been seen that the amount of per capita FW decreases as the number of family members rises [57]. Another study [61] established that families with children tend to waste more food than adult-only households of equal size, mainly due to children food preferences and for food safety reasons.

Moreover, literature offers contradictory findings about the relation between FW and income level: while some researchers found that higher-income households tend to waste more than lower-income ones [12,50,51,55,70,73], others suggest the opposite [21,69]. Lastly, according to [66] individuals living in urban areas tend to waste more than those living in rural areas, therefore we decided to add this situational (contextual) factor in the questionnaire, also considering that this

information can have noteworthy policy implications.

2.3. Sampling strategy

The period covered by the survey strictly followed the schedule of the Covid-19 restrictions applied in Italy. The questionnaire was launched on April 10th, 2020, one month after the start of the national lockdown (March 9th, 2020), and it remained open until May 3rd, 2020, just before the beginning of the so-called "phase 2", when the restriction measures were slightly softened. In total, it covered 24 out of 56 days of full Covid-19 restrictions.

The questionnaire was implemented online through Google Forms, with a short link enclosed in a message calling for volunteers willing to participate to "a research on food management habitudes during Covid-19 lockdown". The message was published on the personal social media of the promoters, including Facebook, LinkedIn and Instagram, and it was also shared via email and Google Groups in some (research) networks operating in the fields of food consumption and food policy studies across all the country. Readers were asked to share the message on own social networks, to increase the number of people potentially reached.

The sampling strategy was therefore non-probabilistic, and self-selection of respondents cannot be excluded. This limit is partially overcome by the large number of respondents, summing up to 1097 in total.

All respondents provided their informed consent before starting the survey.

The final database consisted in 1078 validated observations, after that 12 observations were excluded because they were not based in Italy and 7 because they missed the key items of the questionnaire or gave incoherent answers. 72.9% of the participants were recruited in the Lazio Region, with 534 observations in the province of Rome; the rest of the respondents was distributed across 73 (out of the total 110) provinces of the country. The mean age of the respondents was 40.7 years old, that is quite similar to the Italian average of 45.7 [44]. The large majority of the respondents were women (73.7%), as it was largely expected considering that only about 40% of Italian men are involved in households' food management, against the almost 90% of women [25]. The size of the surveyed households was 3.2 persons on average. In non-probabilistic samples it is very common to observe participants with a high level of education [29] and this study does not make an exception, with 55.7% of the participants owning a university degree, against the 19.6% national average [45]. The share of respondents declaring to be employed was 60.9%, which is very similar to the Italian occupancy rate of 59.2% [46]. Nearly half of the surveyed households (41.8%) declared a total net income lower than 2000 Euro, and 45.7% were based in cities with more than 100,000 residents.

2.4. Data elaboration

2.4.1. Statistical approach

Data related to food management behaviour and FW at home were first treated with statistical descriptive tools to show the changes occurred during the Covid-19 lockdown compared to the control situation before the restrictions. To this aim, comparisons between pairs of questions referring to the same behaviour (performed before and during lockdown) were carried out. Namely, food purchasing habitudes, expenditure and channels for the household food provision, patterns of food consumption at home and the quantity of FW produced were considered. It should be remarked that the latter (quantity of FW generated) was self-estimated by the respondents, by indicating a percentage of the food discarded out of the total food purchased. Respondents were invited to only consider the avoidable fraction of FW and to break down their estimation by food category before providing an overall estimation of the ratio of food wasted at home.

Cluster analysis was used as a second-step elaboration to further describe the FW-related behaviour of the respondents, while the factors associated with possible changes observed during the lockdown, with respect to the control situation, were studied through a Seemingly Unrelated Regression (SUR) approach.

2.4.2. Cluster analysis and description of the sample

The profile of respondents with respect to their FW-related behaviour was investigated by means of a cluster analysis (non-hierarchical k-means clustering, determinant W clustering criterion) conducted via the XLStat software on the database. The 14 variables concerning the self-estimated amount of FW in the control and lockdown situations were considered in the analysis. The number of clusters was gradually increased until the between-classes explained variance reached 50%. Despite some of the variables were not significantly contributing to the clustering of observations, none of them was removed, with the aim to retain all information related to FW behaviour in the results of the analysis. At the end of the process, 7 classes emerged, with a between-classes explained variance of 51.9%.

Other elaborations were conducted to describe in depth the changes occurred in the FW-related behaviour of the respondents during the Covid-19 lockdown, against the control situation. Such elaborations specifically focused on the difference between the two self-estimates rather than on their absolute values, in order to increase the reliability of the analysis. Indeed, literature reports that respondents systematically underestimate household FW data when they are asked to self-estimate the quantities of food discarded at home [19,37]. This is likely due to a positive illusion bias or, in general, to other forms of cognitive dissonance leading to a genuine conviction of the respondents to waste less than they actually do [37], thus avoiding the feeling of guilt associated to FW [29].

2.4.3. The Seemingly Unrelated Regression (SUR) approach

The core statistical elaborations were carried out by comparing Control and Covid-19 situations and referring to the SUR multiple-equation models firstly introduced by [85] and frequently applied in economics for modelling household and individuals' behaviour [6,9]. These models enabled us to test the existence of (and in case of presence, to correctly account for) contemporaneous correlations between FW behaviour assessed in two different moments (before and during lockdown) as well as among the amount of FW generated for the studied food categories.

The SUR method estimates the parameters of all equations simultaneously, so that each equation – which can include a set of explanatory variables different from the others – also considers the information provided by the other equations. Individual FW behaviour can properly fit with this type of model since it has been defined as a complex behaviour [61,66] related to different individual and contextual factors and even more multifaceted to be studied if two different temporal situations are considered as well as (partial) food categories are taken into account. Furthermore, the correlation among equations could be due to unobservable household specific attributes that influence the generation of FW for the food categories/groups [6].

Concerning the SUR model specifications, we distinguished between two different multiple-equation models:

i) initially we modelled the overall declared percentage of FW generated (before and during lockdown);
ii) then, we modelled the percentage of the food discarded out of the total food purchased for each of the six food categories considered in the study (pasta-rice; meat-fish-eggs; milk and dairy products; vegetables; fruits; bread).

Concerning the overall self-declared percentage of FW, we specified a two-equation SUR model. Without loss of generality and by considering the household i ($i = 1, \ldots n$) as unit of analysis, the specified model can be expressed as:

$$y_{it} = \sum_{j=1}^{J_t} x_{jit}\beta_{jt} + u_{it} \quad \text{for each equation } t = 1 \ldots T \qquad [1]$$

with t = 1,2 identifying the number of equations and therefore y_{i1} referring to the self-declared percentage of FW before lockdown (control situation) while y_{i2} to the self-declared percentage during lockdown (Covid period). In each equation t and for each household i, x_{ijt} is the i-th observation on j-th explanatory variable appearing in the t-th equation (with J_t as the number of explicative variables in each equation), β_{jt} refers to the j-th estimated coefficient in the t-th equation, while u_{it} is the error term. The model explicitly allows for contemporaneous correlation, i.e. $E(u_{it}, u_{it'}) = \sigma_{ij} with\ t \neq t'$.

On the other hand, for each food category *k* (k = 1, …K) with K = 6 (pasta-rice; meat-fish-eggs; milk and dairy products; vegetables; fruits; bread) we formerly calculated the difference between the FW self-declared percentage[2] as follows:

$$\Delta FW_k = FW_k^{Covid19} - FW_k^{Control} \qquad [2]$$

This difference ΔFW_k shows the increase, stability (no observed change), or decrease in FW for each category k during lockdown compared to the control (pre-Covid19) period, depending on whether its value is greater, equal or lower than zero. By computing this difference we also intended to reduce the error linked to the discrepancy between self-estimated and actual quantities of FW [20,37,66].

Starting from the quantity ΔFW_k defined above, the specification of the six-equation SUR models was carried out as follows:

$$STD(\Delta FW_{ik}) = \sum_{s=1}^{s_k} x_{sik}\beta_{sk} + u_{ik} \quad \text{for each equation } k = 1, 2, \ldots 6 \qquad [3]$$

with $STD(\Delta FW_{ik})$ representing the standardized FW difference observed for the i-th household and regarding the k-th food category (corresponding to the k-th equation), x_{isk} is the i-th observation on s-th explanatory variable appearing in the k-th equation, β_{sk} to the s-th estimated coefficient in the k-th equation, while u_{ik} is the error term. The model explicitly allows for contemporaneous correlation between error terms, with the SUR estimator that accounts for interrelations among the single equations obtained by means of a weighting matrix based on the covariance matrix of the error terms. In this perspective, the SUR model can be considered an application of the Generalized Least Squares (GLS) approach with the unknown residual covariance matrix estimated from the data [13].

The Breusch-Pagan test [11] was used to verify the assumption that the errors across equations were contemporaneously correlated. By rejecting the null hypothesis of independence among equations residuals, SUR models provides more efficient estimates than separate (classical) Ordinary Least Square (OLS) estimations with the gain in efficiency [13] increasing when the linear dependence among error terms of the different equations is high [49], for large sample size and high levels of multicollinearity among covariates [84].

3. Results

3.1. Effects of lockdown on food purchasing/consumption/management habitudes

Answers to section 2 of the questionnaire report several changes in the behaviour of the respondents concerning food purchasing, management and consumption. The average expenditure for food raised from 110 € to 132 € per week during the Covid-19 restrictions. Fig. 2 shows that, despite the important increase in the average expenditure during the lockdown, with respect to the previous habitudes, the observed median remained relatively stable. This is probably the consequence of different changes occurred in different households, with 57.3% of the observations reporting an increase in the food expenditure, while 28.5% did not report any changes and the rest reporting a decrease. This may partly reflect the higher number of meals consumed at home, considering that before the Covid-19 restrictions respondent households declared to consume on average 10 meals per week at home out of the 14 weekly meals.

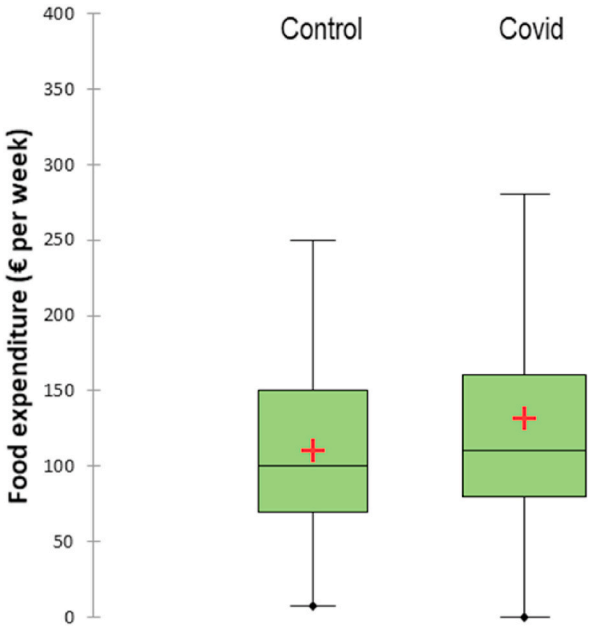

Fig. 2. Food expenditure before and during the Covid-19 lockdown.

Results highlight a sudden and deep change of the food purchasing habitudes among the respondents. Before the Covid-19 outbreak, 56.5% of the sample declared to shop for food 2–3 times per week (56.5% of the respondents), while during the restrictions a frequency of once a week was much more common (63% of the respondents). The channels used for food provisions also showed a change (Fig. 3): while supermarkets remained a source of food for over 80% of the respondents, online shopping was mentioned three times more often during the lockdown (10.7% of the respondents) than before (3.2%). Home delivery of the groceries was not very common in the control situation (83.4% never used this option) while it was a solution to avoid social contacts during the Covid-19 lockdown (39.1% used this option at least "sometimes").

The habitude to compile a shopping list was rather common among

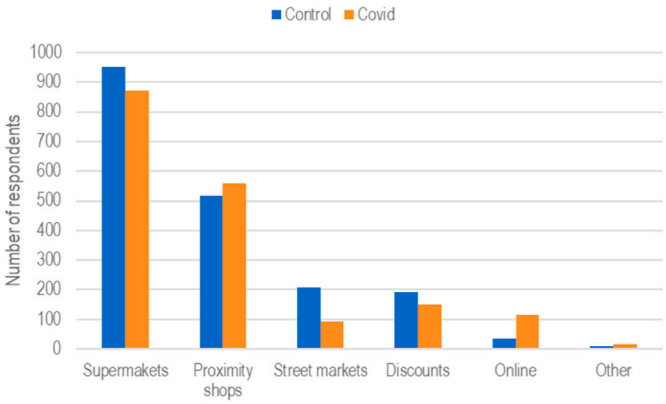

Fig. 3. Food provision channels before and during the lockdown.

[2] It is worth noting that respondents were asked to declare the percentage of FW generated for each food category. Therefore, possible values of the FW variable range between 0 and 100.

the respondents in the control situation (59% of the respondents used to make it "always" or "very often"), but its frequency increased very much during the lockdown (86.5% made it "always" or "very often").

The management of food leftovers showed some improvements. All the three leftover management strategies proposed in the questionnaire (freezing, keeping for the next meal, use as ingredient in another preparation) were largely used in the sampled households in the control situation, but they all showed an increase in frequency during the Covid-19 lockdown. Especially the habitude to use leftover to cook other preparations was mentioned by 65 more households with reference to the Covid-19 period.

Answers provided in section 4 of the questionnaire showed that many households took advantage of the increased time spent at home to rediscover traditional recipes, especially making bread (45.5% of the sample), pizza (65.2%) and cakes (67.5%).

3.2. An overview of self-declared FW before and during lockdown

The results of the survey enabled us to assess if and how households' FW behaviour changed during the lockdown, with respect to the control situation. To this purpose the self-estimated percentages of edible food that was wasted were studied. Table 1 shows descriptive (sample) statistics concerning the distribution of FW before (control) and during lockdown (COVID-19) by distinguishing the self-declared percentages among food categories (pasta/rice; meat-fish-eggs; milk-dairy products; vegetables; fruits) and the household overall FW generated.

The first descriptive result emerging from our study is that the overall average FW decreased from almost 10% before the COVID-19 outbreak (control period) to 6.3% during the lockdown. The average difference registered is equal to −3.6%. The median reduction was equal to −7%, showing a quite strong shrinkage of household FW even if referring to a subjective individuals' perception. This difference is also shown in Fig. 4 which compares the empirical distribution of self-declared percentages of FW before (control) and during lockdown.

As a further step of the descriptive analysis, we analyzed the changes occurred for each of the six food categories considered in the questionnaire. By focusing on the period before lockdown (control), the highest (average) percentage of FW was found for bread, vegetables and fruits, whose values are slightly greater than 10%, with the same median

Table 1
Summary statistics: overall FW and FW per categories before and during lockdown.

	mean	sd	cv	IQR
CONTROL (before lockdown)				
Pasta/Rice	5.180	9.341	1.803	10
Meat-fish-eggs	4.639	8.560	1.845	5
Milk- dairy products	6.749	10.936	1.620	10
Vegetable	10.036	12.540	1.250	15
Fruits	10.188	12.753	1.252	15
Bread	10.526	15.492	1.472	15
Overall FW	*9.996*	*10.360*	*1.036*	*15*
COVID19 (during lockdown)				
Pasta/Rice	2.866	6.463	2.255	5
Meat-fish-eggs	2.300	5.457	2.373	1
Milk- dairy products	3.278	6.933	2.115	5
Vegetable	5.088	8.632	1.696	10
Fruits	5.112	8.300	1.624	10
Bread	4.219	8.962	2.124	5
Overall FW	*6.325*	*8.337*	*1.318*	*10*
Δ (Differences COVID19 - Control)				
Pasta/Rice	−2.382	6.682	−2.806	0.49
Meat-fish-eggs Meat-fish-eggs	−2.398	7.691	−3.207	1
Milk/dairy products	−3.554	9.180	−2.583	5
Vegetable	−4.985	9.604	−1.927	10
Fruit	−5.076	10.193	−2.008	10
Bread	−6.378	12.746	−1.999	10
Overall FW	−3.622	8.756	−2.417	5

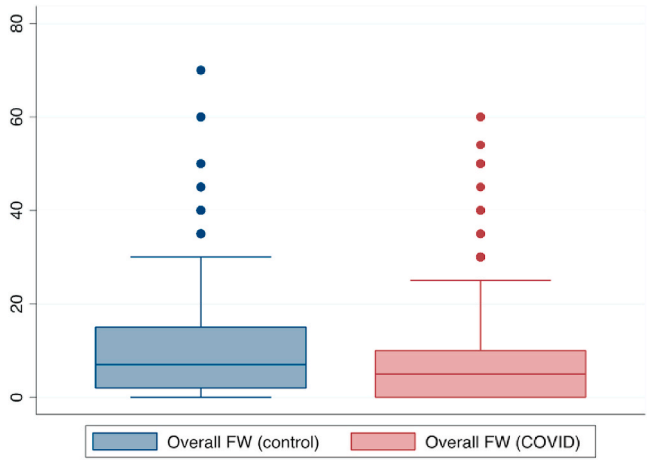

Fig. 4. Total self-declared FW at household level: before (control) vs. during (Covid) lockdown.

and Interquartile Range (IQR) values. The lowest average values equal to 4.6% was found for the meat-fish-egg category. With respect to this control situation, the participants declared that their households reduced FW for all food categories during the Covid-19 lockdown: the greatest (average) difference was still found for bread whose percentage of waste during the lockdown was approximately 4%, with an observed mean difference equal to about −6.4% compared to pre-Covid period. A remarkable reduction was also observed for fruits and vegetables. Fig. 5 shows the entire distributions of the empirical ΔFW for the k = 6 food categories which from the left (pasta-rice) to the right (bread) show an increasing variability in the mid-range (central) part of the distribution.

3.3. FW-related profiles of respondents

A cluster analysis was used to describe the profile of groups of participants with similar features with respect to FW generation. Clear differences can be observed among the 7 classes emerged from the analysis with respect to the FW-related variables considered. Fig. 6 reports the profile of the groups against the seven items considered (waste of pasta/rice, meat/fish, dairy products, vegetables, fruits, bread, total FW) before (CTRL) and during (COVID) the Covid-19 lockdown. Class 7, a small group composed of only 20 observations, stands out for the high wasteful behaviour, very different from the other respondents, for all food categories. In contrast, Class 1 is characterised by a very low amount of declared FW, for all food categories; this group is the largest,

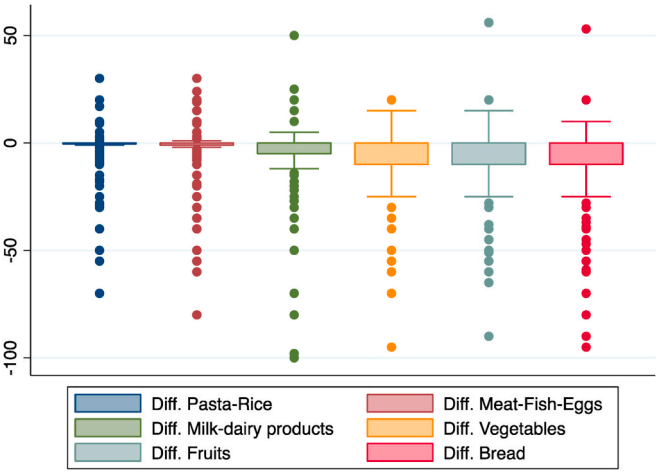

Fig. 5. Distribution of the empirical ΔFW for the k = 6 food categories.

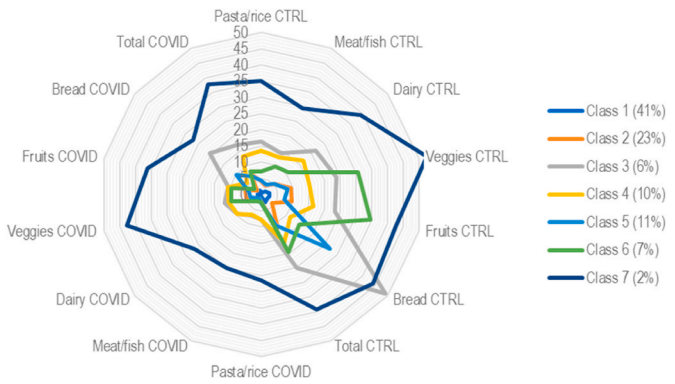

Fig. 6. Profile of clusters based on FW-related behaviour.

counting 41% of the observations (439 respondents). Class 3 and 6 show a different pattern of FW with respect to the other groups because they mostly waste, respectively, bread and fruits/vegetables; however, both groups show a remarkable reduction of waste for these categories during the lockdown compared to the control situation. Class 5 shows the same pattern of Class 3, but with a lower amount of waste declared. Class 2 and 4 show an intermediate wasteful behaviour with respect to the other classes.

Except for Class 7, all groups show percentages of FW remarkably lower in the left-side part of the graph (situation during the lockdown) than on the right-side (situation before the lockdown).

3.4. FW before and during lockdown: what has changed?

In this sub-section the estimates of the SUR models are reported both for the overall self-declared percentage of FW (Table 2) and for the k = 6 food categories (Table 3).

The estimates of the two-equation SUR model reported in Table 2 compares the self-declared percentages of FW generated by the households before (Control) and during (COVID) lockdown. It is worth noting that the two models show the same groups of covariates: i) socio-economic characteristics of the household and the "householder" (h-head) identified as the person responsible for food purchase and management; ii) contextual variables (and opinions) related to the (administrative/municipal) area in which individuals live; iii) shopping habits and behaviour regarding food purchase; iv) habits and practices towards meals and leftover management; v) attitudes towards FW issues.

The aim of this model was to identify the changes occurred within these sets of explicative variables under the two food management situations (Control and COVID), thus identifying groups of variables related with FW individual behaviour. Before analyzing the estimated coefficients and their statistical significance, it is important to focus on the Breusch-Pagan test, whose results (correlation between residuals equal to 0.6345; Chi2 (1) = 422.047, P-value<0.001) lead us to reject the null hypothesis of independence among residuals and therefore to prefer SUR model estimates towards classical separate OLS estimations.

Concerning socio-economic characteristics, age and its squared term were found to be significantly related with the amount of FW generated. Specifically, the introduction of the age^2 term gave us the opportunity to analyze in-depth the existence of a significant non-linear relationship. According to [2] the sign of the squared term determines whether the relationship is bowl shaped (opens up or convex functions if the squared term if greater than zero) relative to the x-axis or mound shaped (opens down or concave functions if the squared term is lower than zero). Both before and during lockdown we found a bowl-shaped (convex) functions since the parameter age^2 was statistically significant and greater than 0 (while the estimated coefficient for age was negative and statistically significant). This type of non-linear relationship proves that the amount of FW decreases when the age increase, but also that there is a minimum

Table 2
Two-equation SUR model for overall FW: estimates referring to before (control) and during (Covid) lockdown.

	I EQUATION: before lockdown (CONTROL)			II EQUATION: during lockdown (COVID)		
	Coeff	SE	Sign	Coeff	SE	Sign
Household and "H-head" socio-economic characteristics						
Age	−0.699	0.215	***	−0.596	0.172	***
Age^2	0.006	0.002	***	0.006	0.002	***
Gender (ref. Female)	−4.421	2.059	**	−0.299	1.646	
Gender_age	0.068	0.050		0.000	0.040	
Education (year)	−0.681	0.677		−0.434	0.540	
Marital status (ref. Married or cohabiting)						
Unmarried	−1.074	0.947		−0.192	0.757	
Separated/Divorced	−0.094	1.454		0.505	1.165	
Widower	5.439	2.915	*	5.622	2.324	**
Job status (ref. Employed)						
Temporary employed	−1.654	1.123		−0.723	0.898	
Looking for employment	0.817	1.441		1.260	1.149	
Retired	−4.681	1.896	**	−2.172	1.515	
Student	−2.511	1.501	*	−0.914	1.194	
Housewife	−0.112	1.439		1.221	1.142	
Self-employed	−0.264	1.314		0.208	1.053	
Other condition	−1.317	2.500		−0.131	1.998	
Household size	0.427	0.328		0.361	0.262	
Number of children (0–14)	0.351	0.223		0.134	0.178	
Income (ref. Up to 1000 Euros)						
1001–2000 Euros	0.709	1.319		−0.143	1.053	
2000–4000 Euros	−0.926	1.383		−0.835	1.102	
More than 4000 Euros	−0.620	1.599		−1.341	1.272	
Number of income earners	0.898	0.542	*	1.082	0.434	**
Contextual variable – milieu of residence						
Municipality size (ref. up to 50,000)						
More than 50,000 inhabitants	−1.786	0.730	**	−1.099	0.584	*
Area (ref. rural zone)						
Urban zone	1.502	0.901	*	1.185	0.718	*
The place where I live seems a dirty place	0.529	0.271	**	0.044	0.217	
Shopping habits and behaviour for food purchase						
Weekly food expenditure	0.003	0.004		0.0002	0.0029	
Shopping list (ref. Always)						
Often	1.161	0.624	*	0.258	0.491	
Sometimes	0.674	0.659		2.004	0.659	***
Never	0.781	0.846		1.835	1.142	
Shopping places for food						
Hypermarket and supermarket	0.881	0.900		0.232	0.616	
Proximity shops	0.007	0.616		−0.197	0.489	
Street markets	0.065	0.756		−0.148	0.768	
Discounts	0.037	0.601		0.114	0.651	
Online	−0.735	1.404		−0.113	0.708	
Other	−4.711	2.658	*	−0.152	1.758	
Habits and practices towards meals and leftover management						
Food leftovers management						
Food freezing	−1.043	0.589	*	0.350	0.482	
Storage for the next meal	−0.220	1.151		0.297	1.032	
Reuse leftovers for new recipe	−2.098	0.620	***	−1.774	0.533	***
Sharing food with neighbours	−1.192	0.787		−0.383	0.577	
	−0.322	0.095	***	−0.108	0.076	

(*continued on next page*)

Table 2 (*continued*)

	I EQUATION: before lockdown (CONTROL)			II EQUATION: during lockdown (COVID)		
	Coeff	SE	Sign	Coeff	SE	Sign
Number of meals eaten at home (during Control period)						
No tradition rediscovered (during COVID period)				−0.276	0.533	
Attitude towards FW issues						
The phenomenon of FW is widespread	0.983	0.363	***	0.580	0.290	**
It is important for ME to reduce FW	−0.750	0.519		−0.481	0.412	
It is important for my FAMILY to reduce FW	−1.272	0.428	***	−1.029	0.341	***
Constant	33.178	5.837	***	22.947	4.631	***

Notes: ***p-value<0.01; **p-value<0.05; *p-value<0.10.

(age) after which the relationship between age and FW grows again. This happens at the value of age $= -\beta_{age}/2\beta_{age\hat{}2}$. The estimated age corresponding to the minimum FW was approximately 68 years in the control situation, while it decreased to about 63 years during the lockdown, ceteris paribus. Focusing on marital status, we also found a stability in the relationship across the two studied periods, with widowers showing a significant and positive relation with the amount of FW generated. A similar relationship was found for the number of income earners, whose increase within a household leads to an increase of FW generated.

Focusing on contextual variables, we found a stability of the positive relationship between urban areas and quantity of FW generated at household level with individuals living in urban areas more likely to generate greater amounts of FW. However, the size of the city (and, specifically, regarding municipalities with more than 50,000 residents) was negatively associated with the quantity of declared FW. It follows that, apparently, individuals living in larger cities tend to waste less, holding constant the other variables in the model. We included in this set of variables an individual subjective perception of the cleanliness of the milieu of residence (neighborhood) in which respondents live. In this case, we found a positive and significant relationship with the quantity of FW declared in the control situation, whilst no relation was found with reference to the period of the Covid-19 lockdown.

The importance of best practices to avoid food discard is confirmed in our analysis. Both before and during lockdown, reusing leftovers for new recipes was strongly associated with a reduction of the quantity of FW declared (p-value<0.01 in both equations), while freezing food was negatively associated with the dependent variable only in the equation focusing on the control period, before the Covid-19 outbreak.

Variables related to shopping habits and expenditure were not (or only weakly) significantly associated with the overall FW generated at household level. The only exception concerns the habitude to compile a shopping list, that was found to have a strong (p-value<0.01) and positive association with the quantity of FW declared during lockdown. This means that individuals who plan their food purchase using only "sometimes" the shopping list rather than "always" tend to generate a higher amount of FW.

Lastly, focusing on attitudinal variables, the importance of the personal awareness to the problem of FW was confirmed in our analysis. In fact, both in the control period and during the Covid-19 lockdown, the participants' own perceived importance of reducing waste translates into realizing the connected (conservative) behaviour of producing low level of FW.

A more detailed and in-depth analysis was carried out for the $k = 6$ food categories considered in the survey. As specified in section 2.4 above, we studied changes in FW behaviour for each food category (pasta/rice; meat-fish-eggs; milk and dairy products; vegetables; fruits; bread). This analysis was intended to support a supply-chain perspective in tackling household FW. Table 3 shows the parameter estimates while Table 4 shows the correlation matrix of residuals as well as the results of the Breusch-Pagan test which confirmed the existence of dependence among residuals, thus confirming SUR models as a suitable choice for modelling FW behaviour per category.

In the interpretation of the estimated coefficients, it should be remarked that the dependent variable is standardized, and it refers to the difference between the amount of FW generated (declared) during the Covid-19 lockdown compared to the control period. This difference is negative or equal to zero for at least 90% of the sample, thus signifying an observed reduction of FW also within the various categories of food involved in the survey. Bearing this evidence in mind, it is therefore interesting to study which factors have influenced the reduction of FW.

On one hand, for a specific covariate an estimated positive coefficient is related with a limited change on the household FW behaviour across the two periods considered. On the other hand, a negative value of the estimated coefficient shows a greater divergence between the FW generated during the Covid compared to the control period. In these cases, those characteristics that exerted the greatest effect on FW during and pre lockdown are highlighted.[3]

With the aim of facilitating an overall reading of the results obtained, Table 5 below summarizes signs and significance levels of statistically relevant relationships only.

Focusing on socio-economic variables, we found a significant and non-linear relationship for age with regard to pasta, meat-fish-eggs, dairy products and vegetables. The increase in age generally decreases the Δ differences. This means that as the age increases, changes in FW-related behaviour are less likely to occur; therefore, youth – i.e. the type of consumers that is commonly believed to have a less attentive behaviour towards FW - have experienced a greater reduction/contraction of the amount of waste, due to the lockdown.

Even more specifically about this non-linear relationship, the combination of the ± signs in the estimated coefficients for the categories of pasta, meat-fish-eggs, milk and dairy products and vegetables, indicate the existence of a quadratic relationship with a concave function (since the estimated coefficient of age^2 is lower than zero) and therefore the existence of an increasing effect which reaches a maximum and then starts to decrease. The estimate of the maximum point identified with the method already described for the general model (Table 2) highlights an age for which there is the highest positive marginal positive contribution of age to the dependent variable (and therefore the minimum observed Δ): this age is identified in 52 years for pasta and meat-fish-eggs, and about 48 years for milk and dairy products and vegetables.

Concerning fruits, there is a positive linear relationship as age increases, therefore the differences in wasted quantities (during the lockdown and compared to the control period) tend to vary linearly with age, observing little differences for older people. Lastly, a quadratic positive relationship was found for bread.

Relationships with a positive and statistically significant signs are associated to the coefficients linked to the "unmarried" status: in fact, there is a positive relationship for all foods except vegetables, for which there is not statistical validity of the relationship. Single (unmarried) people have observed a lesser difference in the quantity of FW produced across the two periods, compared to families with married or cohabiting status.

When households were already familiar with food management practices such as "Food freezing" or "Reuse leftovers for new recipes", a lower contraction of FW across the two periods was observed. Instead, when these practices have been used during the lockdown for the first

[3] For a complete reading of the results it should be remarked that models in which the dependent variable is not standardized have also been estimated, with results available on request. However these models, even if suitable for reading results by food category, do not consider the different magnitude (in terms of position and variability) of the observed differences.

Table 3
Food category (six-equation) SUR model estimates.

	Δ (Pasta)			Δ (Meat–Fish–Eggs)			Δ (Dairy products)			Δ (Vegetables)			Δ (Fruits)			Δ (Bread)		
	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z
Age	0.068	0.021	***	0.078	0.021	***	0.055	0.021	***	0.052	0.021	**	0.036	0.021	*	0.047	0.021	**
Age^2	−0.001	0.000	***	−0.001	0.000	***	−0.001	0.000	**	−0.001	0.000	**	0.000	0.000		0.000	0.000	**
Gender (ref. Female)	0.037	0.071		−0.059	0.070		−0.042	0.070		0.015	0.070		0.062	0.070		0.071	0.071	
Education (ref. Up to secondary school)																		
Degree or post degree	−0.064	0.067		−0.064	0.067		0.027	0.066		−0.043	0.067		0.042	0.067		0.024	0.067	
Marital status (ref. Married or cohabiting)																		
Unmarried	0.211	0.094	***	0.370	0.093	***	0.183	0.093	**	0.095	0.094		0.380	0.093	***	0.173	0.094	*
Separated/Divorced	0.045	0.144		0.068	0.143		0.127	0.142		0.056	0.144		0.090	0.143		0.111	0.145	
Widower	0.222	0.289		0.351	0.287		0.270	0.285		0.103	0.288		0.179	0.287		0.055	0.290	
Municipality size (ref. Up to 1000 inabithants)																		
1001-5000	0.027	0.229		0.108	0.227		0.160	0.226		0.394	0.228	*	0.082	0.227		−0.135	0.229	
5000–10,000	0.082	0.227		0.133	0.225		0.438	0.224	**	0.253	0.226		−0.201	0.225		−0.262	0.227	
10,001–50,000	0.061	0.222		0.085	0.221		0.362	0.219	*	0.218	0.222		−0.081	0.221		−0.111	0.223	
50,001–100,000	0.225	0.222		0.151	0.220		0.394	0.219	*	0.229	0.221		−0.065	0.220		−0.137	0.223	
More than 100,000 inabhitants	0.271	0.218		0.253	0.217		0.333	0.215		0.262	0.218		−0.036	0.217		0.006	0.219	
Job (ref. Employed)																		
Temporary employed	0.073	0.111		0.058	0.111		0.070	0.110		−0.015	0.111		−0.015	0.111		0.028	0.112	
Looking for employment	0.115	0.142		−0.189	0.141		−0.351	0.140	**	−0.202	0.141		−0.009	0.141		−0.089	0.142	
Retired	0.165	0.187		0.147	0.186		0.237	0.185		0.454	0.187	**	0.245	0.186		0.182	0.188	
Student	0.225	0.148		0.288	0.147	**	0.174	0.146		0.307	0.147	**	0.069	0.147		0.068	0.148	
Housewife	−0.012	0.140		−0.021	0.139		0.053	0.138		0.231	0.139	*	0.014	0.139		−0.138	0.140	
Self-employed	−0.021	0.131		0.050	0.131		0.151	0.130		0.163	0.131		0.159	0.131		0.001	0.132	
Other condition	0.163	0.242		0.340	0.240		0.378	0.239		0.385	0.241		0.332	0.240		−0.032	0.243	
Area (ref. Rural zone)																		
Urban zone	−0.366	0.091	***	−0.092	0.090		0.031	0.090		0.045	0.091		−0.077	0.090		−0.111	0.091	
Household size	−0.034	0.032		−0.011	0.032		0.019	0.032		−0.032	0.032		−0.018	0.032		0.047	0.032	
Number of children (0–14)	−0.003	0.022		0.021	0.022		−0.064	0.022	***	0.012	0.022		0.050	0.022	**	−0.082	0.022	***
Net available income (ref. Up to 500 Euros)																		
501–1,000 Euros	0.085	0.262		−0.112	0.260		0.015	0.258		0.069	0.261		−0.285	0.260		0.082	0.263	
1000-1,500	0.025	0.237		−0.248	0.236		0.050	0.234		0.005	0.237		−0.377	0.236		−0.099	0.238	
1,501-2,000	−0.035	0.234		−0.029	0.232		0.051	0.231		−0.020	0.233		−0.455	0.232	**	−0.078	0.235	
2,001-3,000	0.184	0.235		0.116	0.234		0.207	0.232		0.101	0.235		−0.206	0.234		−0.038	0.236	
3,001-4,000	0.234	0.240		0.144	0.239		0.245	0.237		0.069	0.240		−0.127	0.239		−0.030	0.241	
More than 4000 Euros	0.269	0.245		0.065	0.243		0.189	0.242		0.134	0.244		−0.202	0.243		−0.117	0.246	
Weekly food expenditure CONTROL	0.000	0.001		0.002	0.001	**	0.001	0.001	*	0.000	0.001		−0.001	0.001		0.000	0.001	
Weekly food expenditure COVID	−0.001	0.001		−0.001	0.001	**	−0.001	0.001		0.000	0.001		0.001	0.001		0.000	0.001	
Shopping list habit CONTROL (ref. Always)																		
Often	−0.113	0.081		−0.058	0.081		−0.172	0.080	**	−0.149	0.081	*	−0.126	0.081		−0.071	0.082	
Sometimes	−0.134	0.089		−0.215	0.088	**	−0.219	0.087	**	−0.249	0.088	***	−0.271	0.088	***	−0.200	0.089	**
Never	0.008	0.117		0.081	0.116		0.001	0.115		−0.138	0.116		−0.129	0.116		−0.081	0.117	
Shopping list habit COVID (ref. Always)																		
Often	−0.014	0.082		−0.072	0.081		0.157	0.081	*	0.186	0.082	**	0.110	0.081		−0.042	0.082	
Sometimes	−0.047	0.111		0.043	0.110		0.125	0.109		0.226	0.110	**	0.215	0.110	*	0.119	0.111	
Never	−0.023	0.192		−0.392	0.190	**	−0.127	0.189		0.298	0.191		0.422	0.190	**	0.122	0.192	
Food leftovers management CONTROL																		
Food freezing	0.225	0.115	**	0.100	0.114		0.185	0.113	*	0.195	0.114	*	0.002	0.114		0.187	0.115	
Storage for the next meal	0.196	0.168		0.264	0.167		0.150	0.166		−0.138	0.168		0.040	0.167		−0.105	0.169	
Reuse leftovers for new recipe	0.301	0.112	***	0.188	0.111	*	0.461	0.111	***	0.235	0.112	**	0.428	0.111	***	0.436	0.113	***
Sharing food with neighbours	0.149	0.113		0.188	0.112	*	0.168	0.112		0.080	0.113		0.040	0.112		0.124	0.114	
Food leftovers management COVID																		
Food freezing	−0.130	0.117		−0.050	0.116		−0.162	0.116		−0.219	0.117	*	0.087	0.116		−0.076	0.118	
Storage for the next meal	−0.502	0.189	***	−0.444	0.188	**	−0.161	0.187		−0.018	0.189		−0.046	0.188		0.034	0.190	
Reuse leftovers for new recipe	−0.145	0.121		−0.019	0.120		−0.378	0.119	***	−0.291	0.120	**	−0.367	0.120	***	−0.314	0.121	***
Sharing food with neighbours	−0.122	0.104		−0.134	0.103		−0.031	0.103		0.002	0.104		−0.056	0.103		−0.116	0.104	
Having rediscovered food preparation at home (ref. At least one tradition)																		
No tradition rediscovered	0.067	0.086		0.070	0.085		0.035	0.084		0.109	0.085		0.107	0.085		0.170	0.086	**
Number of meals eaten at home (during Control period)	0.020	0.009	**	0.032	0.009	***	0.031	0.009	***	0.047	0.009	***	0.036	0.009	***	0.020	0.010	**
The phenomenon of FW is widespread	−0.038	0.036		−0.013	0.036		−0.067	0.036	*	−0.106	0.036	***	−0.099	0.036	***	−0.058	0.036	
it is important for ME to reduce FW	0.035	0.051		0.033	0.051		0.067	0.051		0.110	0.051	**	0.089	0.051	*	0.089	0.051	*
	0.019	0.042		−0.022	0.042		−0.038	0.042		−0.037	0.042		−0.003	0.042		−0.046	0.043	

(*continued on next page*)

Table 3 (*continued*)

	Δ (Pasta)			Δ (Meat–Fish–Eggs)			Δ (Dairy products)			Δ (Vegetables)			Δ (Fruits)			Δ (Bread)		
	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z	Coef.	SE	P > z
It is important for my FAMILY to reduce FW																		
The place where I live seems a dirty place	−0.003	0.027		−0.018	0.027		−0.003	0.027		−0.016	0.027		−0.021	0.027		−0.008	0.027	
Constant	−1.611	0.616	***	−2.192	0.612	***	−2.037	0.608	***	−1.558	0.615	**	−1.074	0.612	*	−1.181	0.619	*

Notes: SE: standard error; ***p-value<0.01; **p-value<0.05; *p-value<0.10.

time, a greater difference (i.e. reduction) in the amount of FW produced at the household was observed.

Planning food purchases by compiling a shopping list has helped reducing FW. In fact, by observing the estimated relationship for this variable before the lockdown (Control), it can be observed that planning of food provisions (even occasionally) was associated with a greater reduction of FW, especially with regard to milk/dairy products and vegetables.

The number of meals consumed at home before the Covid-19 outbreak was found to be a good predictor of a conservative behaviour before and during the lockdown. As the number of meals consumed at home increased, there was a lesser contraction in the difference in FW for all categories of food analyzed during the lockdown compared to the control period. Similarly, the importance of the attitude towards FW played a role in shaping the change of behaviour: a greater awareness of the FW issues resulted in smaller differences observed between the quantity of FW generated during the lockdown compared to the previous period.

4. Discussion and conclusions

The Covid-19 outbreak is challenging many aspects of human society, however it has offered unexpected opportunities towards sustainable food production and consumption [62] in line with the UN Sustainable Development Goals. In accordance with other early studies [48,80,83], our research found that the Italian families who participated in the survey reduced their household FW considerably during the Covid-19 lockdown. Contrastingly, another study conducted in Spain estimated an increase in household FW during the lockdown [3] even if these estimations are based on secondary data and not on direct measurement.

In our study, most of the participants (41%) were regarded as "mindful wasters", meaning that they wasted little or no food both before and during the lockdown. It is important to note that the incidence of this type of consumers might be overestimated in our analysis due to a possible self-selection bias during sampling. However, these consumers who are extremely aware of FW issues are gradually increasing in number [29]. Only a small percentage of "super wasteful" individuals (2%) declared that they throw away one-third of the food they purchase, irrespective of lockdown or not. The rest of the sample tend to waste only fruit and vegetables, or bread; they might be considered "occasional wasters" unaware of the importance of reducing the quantity of food they throw away at home. It was interesting to observe that this group reported a greter reduction of the amount of household FW produced during the Covid-19 lockdown than the other groups.

As it might be expected, most of the participating households (57%) declared that they spent more on groceries during the lockdown, which is consistent with early findings that emerged in other countries, although this increase in food expenditure may not be linearly shaped. Baker et al. [5] found that in the UK food expenditure rose considerably at the beginning of the Covid-19 outbreak probably due to panic buying and returned to "normal" levels after a while. In our sample, 28% of the households did not change the amount of money they spent on food, while 15% spent less for food during the lockdown, probably due to economic constraints.

The pandemic drastically changed shopping routines for all households, since the frequency of food shopping, which usually was 2–3 times a week before the outbreak, suddenly dropped to once a week during the lockdown. Consumers probably found it difficult to go to supermarkets [16] and may have preferred local shops and online shopping as alternative food provision channels [15]. Indeed, these channels experienced a surge during the lockdown, which is in line with another study conducted in the UK during the Covid-19 outbreak [35]. Only shopping for groceries once a week may have triggered changes in household food management. It was observed that consumers checked their food stocks more carefully, planned their meals in advance and reported to compile a shopping list more frequently (86.5% made it "always" or "very often") during the lockdown. All of these practices proved to effectively reduce the quantity of FW generated at home [28,36,39,57,66,83].

This study also provides evidence of the variables that are related with changes in FW-related habits and behaviour observed during the Covid-19 lockdown. The role of socio-economic and behavioural variables in shaping the quantity of household FW is well-established in the literature [29,50,66], however one of the aim of this study was to determine how these variables affect the changes observed in FW behaviour. Given that most households reported a reduction in the quantity of food they wasted during the Covid-19 lockdown compared to the control situation, the findings of our study reveal the factors that brought about this positive change. In particular, young people greatly reduced their FW, suggesting that the wasteful behaviour that is commonly reported for youths [66] can be effectively corrected when individuals have more time to cook and manage their meals. It is interesting to note that the spread of planning-related food management practices (compiling a shopping list, planning food purchases and meals

Table 4
Food category (six-equation) SUR model estimates.

	Δ (Pasta)	Δ (Meat–Fish–Eggs)	Δ (Dairy products)	Δ (Vegetables)	Δ (Friuts)	Δ (Bread)
Δ (Pasta)	1					
Δ (Meat–Fish–Eggs)	0.4473	1				
Δ (Dairy products)	0.347	0.4519	1			
Δ (Vegetables)	0.2862	0.3931	0.3318	1		
Δ (Fruits)	0.2296	0.3591	0.2539	0.4801	1	
Δ (Bread)	0.3244	0.2603	0.3384	0.255	0.3488	1

Breusch-Pagan test of independence: chi2(15) = 1938.568, Pr = 0.0000.

in advance, reuse of leftovers for other recipes) played a key role in reducing the quantity of food discarded by the participating households during the lockdown. It seems that, after the panic buying during the first days of lockdown [5], people tended to plan their household food shopping and meals more carefully due to logistical shopping difficulties. Future research could focus on whether consumers had time to experience the food management advantages brought by the lockdown. It is possible that some of the good practices acquired during the lockdown may be continued, thus reducing household FW in the long term, especially for "occasional wasters" who improved their FW-related behaviour to a larger extent.

The results also confirm the importance of training courses and information campaigns on these good food management practices in order to educate individuals to minimize the quantity of waste generated at home [58,69,70].

Another interesting result of this study concerns the role of contextual variables that have proved to be significant in previous studies on consumer FW [29]. In our analysis, the urban/rural areas of residence and the size of the cities both played important and significant roles in reducing FW generated during lockdown. Moreover, the variable regarding the subjective perception of cleanliness of the area in which individuals live proved to be significantly related with the FW in the control situation: therefore, the dirtier the environment is perceived, the greater the amount of FW generated, which is in line with a previous study [66]. Instead, no statistical significance was observed for the same variable during the lockdown.

Although food losses at the early stages of the supply chain have increased during the Covid-19 lockdown [33,76] due to supply chains disruptions, limited access to markets and perishable food left unsold at the retail level, it was observed that this may not be the case at household level. Some FW hotspots have continued at household level during the Covid-19 lockdown: (i) panic buying, (ii) misinterpretation of expiration dates; (iii) incorrect food storage; (iv) negative attitudes towards donating excess food to needy people [33,35]. Moreover, while

Table 5
(Six-equation) SUR model estimates: summary of the statistically significant relationships.

Variable	Δ (Pasta)		Δ (Meat–Fish–Eggs)		Δ (Dairy products)		Δ (Vegetables)		Δ (Fruits)		Δ (Bread)	
Age	+	***	+	***	+	***	+	**	+	*	+	**
Age^2	-	***	-	***	-	**	-	**			+	**
Marital status (ref. Married or cohabiting)												
Unmarried	+	***	+	***	+	**			+	***	+	*
Municipality size (ref. Up to 1000 inabithants)												
1001-5000							+	*				
5000–10,000					+	**						
10,001–50,000					+	*						
50,001–100,000					+	*						
More than 100,000 inabhitants												
Job (ref. Employed)												
Temporary employed												
Looking for employment					-	**						
Retired							+	**				
Student			+	**			+	**				
Housewife							+	*				
Self-employed												
Other condition												
Area (ref. Rural zone)												
Urban zone	-	***										
Number of children (0–14)					-	***			+	**	-	***
Net available income – Ref. Up to 500 Euros												
1,501-2,000									-	**		
Weekly food expenditure CONTROL			+	**	+	*						
Q9- Weekly food expenditure COVID			-	**								
Shopping list habit CONTROL (ref. Always)												
Often					-	**	-	*				
Sometimes			-	**	-	**	-	***	-	***	-	**
Shopping list habit COVID (ref. Always)												
Often					+	*	+	**				
Sometimes							+	**	+	*		
Never			-	**					+	**		
Food leftovers management CONTROL												
Food freezing	+	**			+	*	+	*				
Reuse leftovers for new recipe	+	***	+	*	+	***	+	**	+	***		***
Sharing food with neighbours			+	*								
Food leftovers management COVID												
Food freezing							-	*				
Storage for the next meal	-	***	-	**								
Reuse leftovers for new recipe					-	***	-	**	-	***	-	***
Having rediscovered food preparation at home (ref. At least one tradition)												
No tradition rediscovered											+	**
Number of meals eaten at home (during Control period)	+	**	+	***	+	***	+	***	+	***	+	**
The phenomenon of FW is widespread					-	*	-	***	-	***		
It is important for ME to reduce FW							+	**	+	*	+	*

Notes: ***p-value<0.01; **p-value<0.05; *p-value<0.10.

greater attention to food management is observed during the lockdown [48], current worries regarding financial constraints and food affordability may have made consumers eat foods that have passed the "use by" date, posing them at serious food safety hazards [35]. Policy measures highlighting the differences between "use by" and "best before" dates [65] should be implemented in order to spread the appropriate use of this information. New strategies for tackling FW should focus on other levels of the supply chain where date-based pricing strategies may be used to offer alternative safe choices to consumers facing financial constraints [18].

Considering the food insecurity aspects also in the developed countries due to Covid-19 and the development of food sharing apps and food rescue and delivery operations [64,93,94], it is essential that individuals are able to donate their surplus food to people in need according to a circular economy approach [63].

As implications for policy makers and practitioners, the results of our study highlight the importance of awareness raising campaigns in order to maintain the good food management practices that individuals acquired during lockdown. Particular attention should be paid to meal planning and food shopping; citizens should be encouraged to compile a grocery list before going shopping and to freeze their excess food. Information campaigns to this regard shall be especially targeted on youths, who have considerably reduced the amount of food they waste during the lockdown; they also appear to be more inclined towards positive nudging actions against FW, as emerged in previous studies [75], which may support the long-term uptake and maintenance of the good habits acquired during the Covid-19 outbreak. Similarly, since this study found a significant role concerning contextual variables, it might be proved useful to implement these recommendations in large cities and places perceived as dirty.

In conclusion, this study provides valuable insights on how the Covid-19 pandemic has influenced consumer food habits, routines and wasteful behaviour at household level. Future research should analyze in depth whether and to what extent the virtuous anti-waste food management practices acquired during lockdown will be maintained by consumers.

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CRediT authorship contribution statement

Ludovica Principato: Conceptualization, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Luca Secondi:** Formal analysis, Investigation, Methodology, Software, Writing - original draft, Writing - review & editing. **Clara Cicatiello:** Data curation, Investigation, Writing - original draft, Writing - review & editing. **Giovanni Mattia:** Project administration, Supervision.

Declaration of competing interest

The authors declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.seps.2020.100953.

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