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Sufficiency in the kitchen: Intention to reuse food leftovers and associated design strategies

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ABSTRACT

Household food waste plays a crucial role in the overall global food waste problem. A significant portion of this waste consists of edible leftovers that could be repurposed instead of discarded. However, leftover reuse remains an underexplored strategy for reducing food waste, despite its potential to contribute to more sustainable food consumption. By framing leftover reuse as a sufficiency-driven behavior, this study positions it as a key strategy for reducing food waste and fostering responsible consumption. Following a mixed method approach consisting of qualitative interviews, a survey and creative sessions with designers, this research explores the psychological factors that influence individuals' intentions to reuse food leftovers and provides practical design strategies to encourage leftover reuse. Based on a dataset of 244 households in the Netherlands, we use Structural Equation Modeling (SEM) to test a conceptual model grounded in psychological constructs, assessing factors influencing intention to reuse leftover food. The findings reveal that attitudes, and personal norms are significant factors in encouraging reuse of leftover food, while perceived health risks negatively affect attitudes towards reuse. Based on qualitative and quantitative insights, six evidence-based design strategies were developed to address both psychological motivators and practical challenges. The results contribute to the literature and practice by highlighting the psychological determinants of food leftover reuse and proposing interventions to foster sustainable food consumption practices.

1. Introduction

The global food system is one of the main drivers of environmental degradation (Winowiecki, 2023). Globally, the production of food represents more than one quarter of all Global Greenhouse Gas (GHG) emissions and thereby strongly contributes to climate change (DeClerck et al., 2023). It also strongly contributes to the loss of biodiversity, as 50 % of all lands are used for agriculture (Poore & Nemecek, 2018). Furthermore, food system is responsible for 70 % of freshwater withdrawals and 78 % of global freshwater and ocean pollution.¹ Sadly, one third of all food produced is lost, making the reduction of food waste a critical component in building a more sustainable food system (Gatto & Chepeliev, 2024; Xue et al., 2017). Notably, a significant portion of this waste occurs at the household level, with an alarming 79 kg of food wasted per person annually (equivalent of 1 billion meals of edible food is being wasted every single day in households worldwide) (Dri et al., 2018; FAO, 2022; Sigala et al., 2024). This food waste is rich in various

nutrients. For example, in the Netherlands, food waste at household level consists in majority of bread (19 %), vegetables (13 %), fruit (13 %), potatoes (8 %) and dairy (8 % excluding cheese) (Netherlands Nutrition Centre, 2024). The high nutritional value of food waste makes it imperative to realize effective valorization.

Over the past decade, research on food waste has been prolific, identifying numerous determinants of food waste behaviors. These determinants exist at three levels: societal, individual, and behavioral (Stangherlin & De Barcellos, 2018). At the societal level, periods of scarcity and economic recessions have been naturally associated with reduced food waste (Abeliotis et al., 2014). Factors related to the supply chain also play a role, such as misleading expiration date labeling (Aschemann-Witzel et al., 2015) and packaging characteristics that make products difficult to empty or lead to overconsumption (Williams et al., 2012). Moreover, research on the impact of quantity promotions on food waste has yielded mixed results. While quantity promotions have long been assumed to increase food waste (Jörissen et al., 2015), a

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¹ <https://ourworldindata.org/environmental-impacts-of-food>

recent study suggests that it may actually promote waste prevention, as consumers who buy in larger quantities tend to be more aware of the risk of wastage (Van Lin et al., 2023). Additionally, the acceptance of sub-optimal food products, such as “ugly” fruits and vegetables, by both retailers and consumers is another critical factor influencing food waste (De Hooge et al., 2017).

At the individual level, demographic factors such as household size, education, and gender have been explored as antecedents of food waste, though findings remain inconsistent (see Stangherlin & De Barcellos, 2018, for a review). Psychological factors, however, have shown clearer patterns. Attitudes and concerns about food waste (Graham-Rowe et al., 2015), as well as negative emotions—particularly guilt—have been linked to lower food waste tendencies (Graham-Rowe et al., 2014). Perceived behavioral control, where individuals believe they can effectively reduce their food waste, also plays a significant role (Stancu et al., 2016). Similarly, personal norms such as the moral obligation to avoid waste have been found to directly influence waste reduction behaviors (Graham-Rowe et al., 2014; Stancu et al., 2016; Visschers et al., 2016). Notably, financial concerns about the cost of wasted food appear to be a stronger motivator for reducing waste than environmental concerns, which have been found to have a comparatively minor influence (Neff et al., 2015). At the behavioral level, household routines are key determinants of food waste. Effective meal planning, including inventory checks before shopping and shopping lists, has been linked to lower waste levels (Jörissen et al., 2015; Stefan et al., 2013). Purchasing habits and food storage practices also play a crucial role, with improper storage contributing significantly to spoilage (Aschemann-Witzel et al., 2015; Janssens et al., 2019; Lahath et al., 2021).

To address these challenges, literature has proposed strategies to reduce food waste such as improving the consumption of suboptimal food (Cao & Miao, 2021; De Hooge et al., 2017; Varese et al., 2022), reducing over-purchasing (Woolley et al., 2021), reusing food waste for animal feed, fertilizers and/or compost (Schanes et al., 2018). Among these, reusing food leftovers emerges as a direct and practical household-level intervention that can directly help to reduce food waste. Unlike other strategies that focus on reprocessing food waste, leftover reuse involves behavioral changes that can significantly extend the lifespan of edible food within households. For example, by promoting proper storage (freezing, vacuum sealing), meal reintegration into a new meal (repurposing cooked vegetable into soups), ensuring that food remains consumable for a longer period within households (Attiq et al., 2021; Panda et al., 2024; Teng et al., 2021).

In this paper, food leftovers are defined as edible food items that were either intended to be used as meal ingredients but remained unused or were prepared and served as part of a meal but were not consumed (Andrews et al., 2018). The reuse of food leftovers is conceptually rooted in the sufficiency paradigm (Nogueira et al., 2023; Spiller et al., 2024). Sufficiency revolves around reassessing personal needs to avoid excess consumption (Gossen et al., 2019), reducing overall resource usage, waste, and other negative impacts to contribute to staying within planetary limits (Garcia-Ortega Graham-Rowe et al., 2014; Princen, 2005). A necessity given the alarming rate at which humanity is consuming resources beyond these boundaries (Bengtsson et al., 2018). Reusing food leftovers helps reduce the total amount of food purchased by households through effective leftover management. This approach can significantly contribute to lowering the overall ecological footprint of food consumption and promoting sustainability (Berners-Lee et al., 2018; Jungell-Michelsson & Heikkurinen, 2022). Despite growing research on food waste behaviors, few studies have focused on the psychological determinants of leftover reuse within households. This research is particularly interested in addressing this gap by integrating insights from behavioral theories to explore the motivators and barriers influencing leftover reuse, thereby contributing to the literature on sustainable food consumption (Ananda et al., 2021; Ananda et al., 2023; Attiq et al., 2021; Kirmani et al., 2023).

The central research questions guiding this study are: “Which factors

influence the intention to reuse food leftovers?”, and “Which design strategies for behavior change can enable people to re-use food leftovers?”. These questions reflect the dual focus of this research on understanding the underlying psychological and behavioral factors towards intention to reuse leftover food as well as developing practical strategies to influence these behaviors positively.

To address these research questions, we employ a mixed methods approach that integrates qualitative and quantitative methods for a comprehensive exploration of the subject (Johnson et al., 2007). This research begins with the literature review to identify a theoretical grounding, and existing research and research gaps on food waste reduction in general and the reuse of food leftovers in particular, serving as the foundation for developing the initial conceptual model, and corresponding research hypotheses. In Section 3, a qualitative study involving interviews is presented to provide deeper insights into the factors shaping intentional behavior related to the reuse of food leftovers, and to subsequently support the validation of the proposed model. Building on these insights, the proposed model is subsequently tested using Partial Least Squares Structural Equation Modeling (PLS-SEM) (Hair et al., 2011) to validate the relationships among the identified factors. Then, the results of both qualitative and quantitative analyses are used in creative ideation session to develop design interventions promoting the reuse of food leftovers. Finally, Sections 4 and 5 present the discussions and conclusions.

This research contributes to the field of sustainable consumption in several ways. First, it provides a deeper theoretical understanding of individuals’ motivations and barriers to reuse food leftovers. Second, it presents a validated conceptual model that quantifies the psychological and behavioral factors influencing the intention to reuse of food leftover. Finally, the research presents practical design strategies applicable in real-world settings that can be used to create interventions promoting the reuse of food leftovers, thereby reducing food waste and advancing sustainable food consumption practices (Graham-Rowe et al., 2014; Stancu et al., 2016).

2. Literature review

2.1. Sufficiency in the food context

Sufficiency, often referred to as “enoughness” (Di Giulio & Fuchs, 2014; Kropfeld, 2023) or strong sustainable consumption, has gained attentions across multiple disciplines, including sustainable behavior, philosophy, energy economics, and ecological economics (Hartmann, 2024; Nguyen et al., 2023; Niessen et al., 2023; Sorrell et al., 2020). The concept is intrinsically linked to the planet’s environmental limits, highlighting the urgent need to address overconsumption and its environmental impacts (Alexander & Rutherford, 2019; Jungell-Michelsson & Heikkurinen, 2022). The current consumption levels in affluent societies exceed the planet’s ecological boundaries (Dubuisson-Quellier, 2022; WHO, 2023), necessitating a significant reduction in material consumption to ensure that the global population can live within the safe operating space, as outlined by the planetary boundary framework (Rockström et al., 2009).

In the context of food consumption, the relevance of sufficiency is particularly emphasized (Reisch et al., 2013; Ribbers et al., 2024; Shubbar et al., 2024). Feeding a growing global population while reducing the environmental impact of the food sector requires substantial shifts in consumption patterns and a significant reduction in food waste. This transition towards sufficiency in the food sector is vital for creating a sustainable and equitable food system (Berners-Lee et al., 2018; Brinken et al., 2022; Stein & Santini, 2022).

Sufficiency strategies are central to this transition and can be categorized in four types of consumption changes: (i) “absolute reductions”, (ii) “modal shifts”, (iii) “product longevity”, and (iv) “sharing practices” (Sandberg, 2021). Collectively, these strategies help to reduce the environmental impact of consumption (Gossen & Kropfeld, 2022).

Absolute reductions involve reducing overall consumption. In the food context, this could mean reducing calorie intake to a healthy level, avoiding impulsive purchases, and minimizing food waste (Bajželj et al., 2014; Franco et al., 2022; Whybrow et al., 2017). Modal Shifts involve changing the way food is consumed to reduce its environmental impact (e.g. shifting from a meat-based diet to a plant-based one; Lettenmeier et al., 2019). Longevity focuses on extending the usability of food products, delaying the need for new purchases. Improved storage practices, reducing spoilage, and reusing leftovers are essential for minimizing food waste and optimizing resource use in the food system (Koppel et al., 2016; Zainal & Hassan, 2019). Finally, sharing practices, such as communal meals or food-sharing initiatives, allow for more efficient use of resources. By maximizing the utilization of available food, these practices reduce the need for new food production and minimize waste (Frenken & Schor, 2017). This paper highlights absolute reductions in food purchases through leftover reuse and inherent considerations of product longevity as key sufficiency practices (Stancu & Lähteenmäki, 2022).

2.2. Reuse of food leftovers

Research on the reuse of food leftovers from a consumer perspective has primarily focused on restaurant settings, examining factors that predict taking away food leftovers (Hamerman et al., 2018; Talwar et al., 2021, 2023). In this context, key predictors include food-ordering behaviors, attitudes towards taking away leftovers, and the proactive role of restaurant staff in offering take-away options. Social factors also play a significant role, as individuals' comfort level with their dining companions can influence their likelihood to request to take leftovers home (Hamerman et al., 2018).

In the context of household consumption, much of the research has centered on food waste behavior but some studies have specifically addressed the reuse of food leftovers (Babbitt et al., 2021; Eriksson et al., 2023), and found that inefficient cooking practices, such as poor portioning, and improper storage behaviors are linked to the discarding of cooked meals (Ananda et al., 2023). Reusing food leftovers involves a series of practices, classifying, selecting, storing, and reusing, which transform leftovers from "polluted" to "clean" food that can be reintroduced at the table (Diekmann & Germelmann, 2021). A study conducted in India explored individuals' willingness to share leftover food, finding that subjective norms, attitudes, and perceived behavioral control influence their intentions. Additionally, factors such as religiosity, moral obligation, and environmental concern significantly predict attitudes towards food-leftover sharing (Kirmani et al., 2023).

While existing research highlights the importance of leftover reuse in mitigating food waste and reducing the environmental footprint of food in general, a theoretical gap remains in quantifying how various psychological and behavioral factors influence individuals' reuse of leftovers. Furthermore, tailored interventions that draw on these determinants and by doing so foster the adoption of sustainable consumption habits are needed (Diekmann & Germelmann, 2021; Kirmani et al., 2023).

2.3. Determinants of food leftovers reuse

This section begins by exploring various psychological theories that help explain how individuals shape their behaviors, particularly in the context of food waste and the reuse of food leftovers. The theories discussed are Theory of Planned Behavior (TPB: Ajzen, 1991), Motivation-Opportunity-Ability (MOA: Ölander & Thøgersen, 1995), and Norm Activation Model (NAM: Schwartz, 1977). These theories provide a foundation for developing a conceptual model that identifies the key drivers affecting the intention to reuse food leftovers.

In the context of this research, TPB suggests that individuals who have a positive attitude towards reusing food leftovers and feel confident in their ability to do so safely are more likely to develop the intention to

engage in this behavior. While subjective norms are usually included in TPB models, in the context of this research, we decided to include personal norms following the NAM because leftover reuse is a private behavior occurring within households, where social pressure is minimal. Research shows that in private, sustainability-related behaviors, personal norms are often stronger predictors than subjective norms (Thøgersen, 2006). This has also been suggested in the context of food waste reduction (Wang et al., 2022). According to the MOA model, individuals not only need the motivation to perform a behavior but also the ability to do so, which relates to the perceived behavioral control highlighted in the TPB. Motivation is driven by internal factors such as attitudes and personal norms, while ability involves the skills, and the contextual factors required for effective engagement (Soma et al., 2021).

The integration of TPB, NAM, and MOA not only provides a foundation for understanding leftover reuse behaviors but also reflects the interplay of psychological motivators, moral obligations, and practical capabilities. Table 1 shows how each determinant used in the proposed conceptual model relates to these three theories.

2.4. Conceptualization of leftover reuse intentions and associated hypotheses

2.4.1. Awareness of the consequences of food waste

Awareness of the environmental, social, and economic consequences of food waste is a key determinant of pro-environmental behaviors, as highlighted in the NAM. According to NAM, awareness of consequences is essential for activating personal norms that drive individuals to engage in behaviors aligned with environmental responsibility (Schwartz, 1977; Wang et al., 2022). Literature supports this assumption; for instance, Aschemann-Witzel et al. (2015) and Principato et al. (2015) demonstrate that greater awareness of food waste impacts significantly shapes attitudes and personal norms related to food management practices. As such, it can be argued that awareness of consequences not only reinforces the moral obligation to reduce food waste but also enhances the perceived value and acceptability of practices like reusing leftovers. Building on this, we hypothesize that:

H1a. Awareness of the consequences of food waste positively affects attitudes towards the reuse of food leftovers.

H1b. Awareness of the consequences of food waste positively affects personal norms regarding the reuse of food leftovers.

2.4.2. Perceived health risks

Perceived health risks, particularly concerns about food safety and the potential for foodborne illnesses, can be seen as a psychological barrier to the reuse of food leftovers. Therefore, it can be assumed that high perceptions of health risks negatively influence attitudes towards the behavior. Literature confirms the significant impact of health-related concerns on food management behaviors. Andrews et al. (2018) highlight that insufficient knowledge about food safety and storage can increase the perceived risks and subsequently the likelihood of individuals

Table 1
Determinants and theories.

Determinant	Theory	Explanation
Attitude towards the Reuse of Food Leftovers	TPB	Positive attitudes influence intentions
Skills in Processing Food Leftovers	MOA	Skills are part of the ability required to engage in leftover reuse behavior
Awareness of the Consequences of Food Waste	MOA / NAM	Drives motivation (MOA) and activates moral responsibility (NAM)
Perceived Health Risks	TPB	Influences attitude over safe reuse of leftovers
Personal Norms	NAM	Personal norms drive intentions by aligning actions with moral obligations

reusing leftovers. Additionally, [Hamerman et al. \(2018\)](#) show that concerns about contamination and spoilage influence the decision of individuals to engage in food reuse practices, even when motivated by pro-environmental values. Building on these insights, we posit that perceived health risks serve as a critical barrier, negatively shaping attitudes towards the reuse of food leftovers.

H2. *Perceived health risks negatively affect attitudes towards the reuse of food leftovers.*

2.4.3. Attitude towards the reuse of food leftovers

Attitudes are a central determinant of behavioral intentions ([Ajzen, 1991](#)). In the context of food leftovers, individuals who hold favorable views towards reusing leftovers are more likely to practice this behavior. Literature supports this; for example, [Hamerman et al. \(2018\)](#) suggests a link between individuals' positive attitudes towards leftover reuse and their intention to reuse them. The attitudes are shaped by factors such as sensory appeal, perceived quality of leftovers, and positive past experiences with leftover meals ([Graham-Rowe et al., 2014](#); [Stancu et al., 2016](#)). For instance, leftovers that are visually appealing and perceived as high-quality are more likely to promote favorable attitudes, reinforcing intentions to reuse them. Building on this foundation, we hypothesize that positive attitudes towards the reuse of food leftovers will have a direct and positive effect on the intention to engage in this behavior.

H3. *Positive attitudes positively affect the intention to reuse food leftovers.*

2.4.4. Personal norms

Personal norms, defined as internalized moral obligations to perform specific behaviors, are a critical determinant of pro-environmental intentions. [Schwartz \(1977\)](#), argues that personal norms are activated when individuals become aware of the negative consequences of their actions and feel a moral responsibility to mitigate them. Prior literature indeed indicates that personal norms are often considered a stronger predictor of pro-environmental behaviors than subjective norms, especially when perceived social pressures may not be as relevant for behaviors typically performed privately, like handling food waste at home ([Schwartz, 1977](#); [Thøgersen, 2006](#)). In the context of food waste, individuals who perceive reusing food leftovers as the "right thing to do" are more likely to develop intentions to engage in this behavior. [Savari et al. \(2023\)](#) found that individuals with awareness of the environmental and social consequences of food waste are more likely to internalize norms that oppose wasteful behaviors. This moral internalization directly influences their attitudes and intentions towards reusing food leftovers. We propose that personal norms not only positively influence intentions to reuse food leftovers but also influence attitudes towards this behavior by fostering a sense of moral alignment.

H4a. *Personal norms positively affect attitudes towards reusing food leftovers.*

H4b. *Personal norms positively affect the intention to reuse food leftovers.*

2.4.5. Skills in processing food leftovers

The lack of skills in cooking with leftovers, properly storing them, or assessing their edibility serve as barriers to reuse, reducing individuals' confidence and likelihood of engaging in this behavior. [Farr-Wharton et al. \(2014\)](#) argue that individuals with higher levels of food management skills are more likely to reuse leftovers, as these skills empower them to transform leftover food into appealing and safe meals. Similarly, [Stancu et al. \(2016\)](#) emphasize that improving storage practices can significantly mitigate food waste. Building on this evidence, we hypothesize that insufficient skills in processing food leftovers negatively affect the intention to reuse them.

H5. *Insufficient skills in processing food leftovers negatively affect the intention to reuse food leftovers.*

Drawing on the literature findings and the factors identified, we present a conceptual model that explains the intention to reuse food leftovers. The model's relationships are visualized, and seven hypotheses are formulated to test these relationships through empirical research, see [Fig. 1](#).

3. Qualitative interviews

3.1. Procedure

Following the literature review and the development of the proposed conceptual model a series of interviews were conducted to confirm the model and the factors influencing the reuse of food leftovers. These interviews were designed to capture real-life practices, attitudes, and perceptions, leveraging both contextual observations and structured discussions. By incorporating diverse participants and employing a thematic analysis approach, the case study practice aimed to gain additional insights related to food waste and leftover reuse.

The interviews were conducted over two weeks in March and April 2024, involving nine participants from different types of households who were all involved in the preparation of meals. These interviews were conducted mostly at participants' homes, with one interview conducted online. The selection of participants was based on purposive sampling to ensure a diverse representation in terms of age (between 23 and 63 years), gender (six females and three males), and household composition. This approach was intended to capture a wide range of insights, also involving households with children, as previous studies have shown that families with children tend to produce more food waste ([Porpino et al., 2015, 2016](#)). Consent from the participants was obtained prior to the interviews. The interviews were conducted in Dutch, the native language of the participants, to ensure that they could express themselves comfortably. The conversations were recorded, transcribed, and analyzed.

The interview process consisted of two parts: a "walk-through" segment and a semi-structured interview. The walk-through involved participants showing the contents of their refrigerators and kitchen cabinets, allowing the researcher to observe participants' practices regarding food leftovers in real-time. This method, known as contextual inquiry ([Duda et al., 2020](#)), is valuable for uncovering habitual behaviors that participants might not be consciously aware of or might not mention in a traditional interview setting.

The second part was a more structured interview with open-ended questions designed to gain deeper understanding of participants' attitudes, beliefs, and practices concerning food leftovers. The interview guide is available in Appendix A. The data analysis was carried out using thematic analysis, following the six-phase approach described by [Braun and Clarke \(2006\)](#). An inductive coding process was used to allow new themes to emerge naturally from the data. Thematic analysis enabled the identification of three main themes, consisting of ten sub-themes, which were then used to confirm the proposed conceptual model.

3.2. Results of interviews

The results of the interview analysis are presented through the lens of the themes and sub-themes that emerged from the data. The findings are categorized into three primary themes: (1) Difficulties of Organizing (2) Doing the Right Thing, and (3) Value Ascribed to Leftover Food. These themes encapsulate the key factors influencing the reuse of food leftovers.

3.2.1. Difficulties of organizing

This theme captures the challenges participants face in organizing their food storage and managing leftovers. From a theoretical standpoint, this theme relates to MOA, covering determinant "Skills in Processing Food Leftovers" as a part of the ability required to engage in reuse behavior. Many participants indicated that they were often

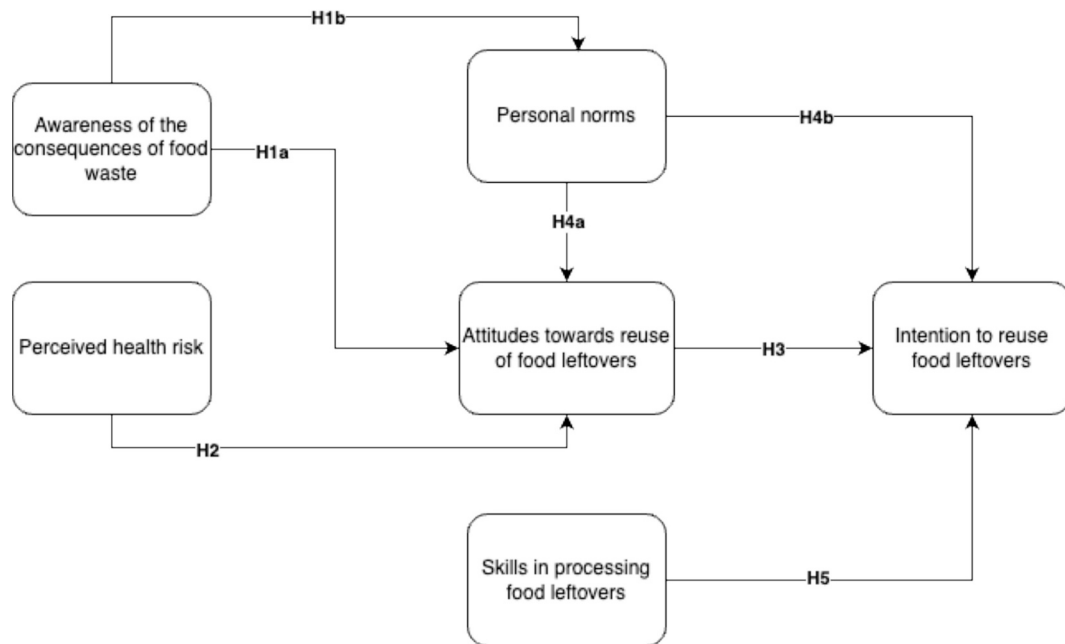


Fig. 1. Proposed conceptual model.

unaware of the contents of their refrigerators or cupboards, leading to food items being forgotten and eventually wasted. For example, Interviewee 1 mentioned “Because there is a lot on it, and I always just throw everything on it, and then I do not know what is behind it anymore”. The interviews revealed that participants frequently had to move items around to discover what was at the back of their shelves, with some participants finding food items that had become moldy or expired during the process. As Interviewee 2 mentioned “Hm, well often you just forget that you have something, and it just disappears somewhere behind another product or something”.

This disorganization was particularly evident in shared households, such as those of students, where communal shelves were often neglected, leading to a higher likelihood of food waste. One mentioned “I think I will first look at the bottom shelf, because I also know my housemates do not look here much. They put it down and grab it when it suits them. But it is really never that they think, oh, something is going to expire soon, let’s eat it now. We just do not think about it. At least, I do not think about it”, Interviewee 9. The findings highlight the importance of effective household organization in reducing food waste. Participants who have the required skill and ability are better at organizing their food storage tended to reuse leftovers, suggesting that interventions aimed at improving organizational skills could be beneficial.

3.2.2. Doing the right thing

This theme reflects participants’ moral and ethical considerations regarding food waste. It covers the determinants “Personal Norms”, and “Awareness of the Consequences of Food Waste”. Many participants expressed a strong desire to avoid wasting food, which they saw as “the right thing to do”. One mentioned “It just does not feel right. I just feel a bit guilty towards people who really need it. I could just throw it away myself, thinking, well, it would not make my day any better or worse. But you know there are people in the world who do not have any food at all”, Interviewee 3. The interviews revealed that participants’ personal norms played a significant role in their decisions to reuse food. However, this intention was sometimes influenced by practical barriers, such as lack of time or uncertainty about the safety of leftover food. The theme shows the potential of leveraging personal norms and awareness of food waste consequences in designing interventions that promote leftover reuse. By enhancing these values, it may be possible to encourage more consistent behavior aligned with participants’ ethical beliefs.

3.2.3. Value ascribed to leftover food

This theme captures participants’ perceptions of the value of leftover food and emerged as a critical factor in determining whether leftovers were reused or discarded. It covers the determinants “Attitude Towards the Reuse of Food Leftovers”, and “Perceived Health Risks”. Some participants saw leftovers as valuable resources that should not be wasted, while others viewed them as inferior to fresh food. The interviews revealed that participants who viewed leftovers as valuable resources tended to be creative and proactive in incorporating them into new, healthy meals. In contrast, those who associated them with health risks, taste concerns, or inconvenience tended to discard them. One interviewee mentioned “It is just too much hassle for me, it costs me too much time”, Interviewee 4. Another mentioned “I usually throw that away because I have so much extra of something else somewhere”, Interviewee 3. This theme highlights that participants’ perceptions of the value of leftover food play a critical role in determining whether leftovers are reused or discarded. These findings suggest that shifting perceptions of leftovers, from being seen as waste to valuable resources, through targeted interventions that address health and taste concerns could foster more positive attitudes and sustainable practices.

3.2.4. Summary of interview findings

The interview findings align with existing literature, offering valuable insights into confirming the proposed conceptual model based on empirical data. In addition, it provides insights regarding the importance of contextual aspects that extend the current understanding regarding the intention to reuse leftover food. For instance, students living in shared housing often neglect communal shelves, resulting in increased food waste, a behavior consistent with findings on the impact of shared environments on food management (Porpino et al., 2016).

Moreover, the observation that some participants deliberately keep leftovers as “back-up” meals highlights a pragmatic dimension of food management, reflecting a dual focus on convenience and resource efficiency (Graham-Rowe et al., 2014). This indicates that practical strategies for leftover reuse are influenced not only by skills, attitudes and norms but also by logistical considerations. The findings further emphasize the interplay between psychological motivators and practical/ contextual barriers in influencing leftover reuse. While personal norms and awareness of consequences, serve as strong motivators, barriers such as uncertainty about food safety and contextual factors can

influence individual engagement in such behavior. Contextual factors are crucial in the intention-behavior gap, where individuals' intentions to engage in a behavior do not always lead to corresponding actions (Sheeran, 2002). External constraints, such as environmental cues or unplanned events, can either support or obstruct intended behaviors. Although our model does not explicitly test these factors because the dependent variable is a behavioral intention, acknowledging their influence is essential for designing interventions that mitigate their impact and help bridge the gap between intention and action.

4. Survey research

The following sections present the research procedure, including data collection, sample, and the development of the survey questionnaire designed to test the proposed theoretical model.

4.1. Method

4.1.1. Data collection and sample

Data collection was conducted using an online questionnaire tool "Qualtrics" between April–May 2024. The sample of the study includes a combination of convenience sampling and snowball sampling strategies. The initial invitations were sent to individuals within the researchers' personal network, who were then encouraged to share the questionnaire with others. This approach, while useful for reaching a broad audience, resulted in a sample that was not entirely representative of the general population. Specifically, the sample was skewed towards older adults and those with higher educational backgrounds, with 69 % of respondents being female and 85 % holding a higher education degree (see Table 2). A total of 301 responses were collected, with 244 valid responses remaining after excluding incomplete responses and those who failed an attention check question. The minimum sample size required was determined to be 155, based on the significance level and path coefficients used in the PLS-SEM analysis (Hair et al., 2022). Thus, the final sample size of 244 was sufficient for the analysis.

4.1.2. Measurements

The questionnaire consisted of 29 items (see Appendix B) to measure the six constructs of the conceptual model (see Fig. 1). Each construct was measured using four to five items, adapted from existing literature on food waste and pro-environmental behaviors. The four items measuring the intention to reuse food leftovers were adapted from studies by Visschers et al. (2016) and Stancu et al. (2016). These studies provide a foundation for understanding the determinants of food waste behavior. Five items measuring personal norms were also adapted from Visschers et al. (2016) and Stancu et al. (2016). Five attitude factor items were adapted from the study of Ajzen (1991, 2006) and Han (2014). Skills in processing food leftovers five items were adapted from Visschers et al. (2016), Stancu et al. (2016), and Scavedi and Rossi (2021) studies. Five items were used to measure the perceived health risks factor from Visschers et al. (2016) and Principato et al. (2015). With the awareness of consequences of food, five items were taken from studies of Attiq et al. (2021), Panda et al., 2024, and Principato et al. (2015).

4.2. Survey results (measurement and structure results)

This section presents insights derived from the Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis using SmartPLS software. The analysis involved two main steps: testing the measurement model for validity and reliability and testing the structural model to test the hypotheses.

4.2.1. Measurement model results

The first step in PLS-SEM is evaluating the results from the measurement models. For a reflective model, the first step is to assess the

Table 2

Socio-demographic and background characteristics of respondents (N = 244).

Category	Sample
<i>Gender</i>	
Female	169 (69.3 %)
Male	73 (29.9 %)
Other	2 (<1 %)
<i>Age</i>	
Under 18	1 (<1 %)
18–24 years old	35 (14.3 %)
25–34 years old	36 (14.8 %)
35–44 years old	20 (8.2 %)
45–54 years old	35 (14.3 %)
55–64 years old	75 (30.7 %)
65+ years old	42 (17.2 %)
<i>Education level</i>	
Primary school diploma	1 (<1 %)
High school diploma	5 (2 %)
MBO but no diploma	2 (1 %)
MBO diploma	13 (5.3 %)
HBO but no diploma	13 (5.3 %)
HBO diploma	70 (28.7 %)
University but no diploma	12 (4.9 %)
University bachelor's degree	33 (13.5 %)
University Master's degree	87 (35.7 %)
PhD	7 (2.9 %)
<i>Occupation</i>	
Full-time work (30 h per week or more)	119 (48.8 %)
Part-time work (less than 30 h per week)	40 (18.4 %)
Retired	34 (13.9 %)
Student	41 (16.8 %)
Unemployed	3 (1.2 %)
Other	7 (2.9 %)
<i>Household composition</i>	
Single person household	35 (14.3 %)
Shared household (student housing, home sharing)	40 (18.4 %)
Married or partnered without children	100 (41 %)
Married or partnered with children	62 (25.4 %)
Single parent with children	2 (1 %)
<i>Household income</i>	
Less than 25,000 Euros	45 (18.4 %)
25,000–49,999 Euros per year	34 (13.9 %)
50,000–99,999 Euros per year	70 (28.7 %)
100,000–199,999 Euros per year	52 (21.3 %)
Prefer not to say	43 (17.6 %)

factor loadings (Hair et al., 2018, Hair et al., 2022). Factor loadings show how each item explains the variance of a construct with the value of between -1 and 1 . Loadings above the threshold of 0.70 are recommended, however, values above 0.6 are also acceptable if the composite reliability of the factor is at an acceptable value (Hair et al., 2011).

The results show that all items (except for three items) loaded into their respective factors. Three items (Awareness 1, 2, and Skills 3) with low factor loading were removed from further analysis. A second measure to assess the internal reliability of latent variables is the Cronbach's alpha and should exceed a value of 0.7 (Bernardi, 1994). As seen in

Table 3

Reliability test results.

	α	CR (rho_a)	CR (rho_c)	AVE
Attitude towards reuse of food leftovers (5 items)	0.840	0.849	0.887	0.611
Awareness of the consequences of food leftovers (3 items)	0.752	0.754	0.890	0.801
Intention to reuse food leftovers (4 items)	0.898	0.900	0.929	0.766
Perceived health risks (5 items)	0.829	0.840	0.879	0.592
Personal norms (5 items)	0.826	0.849	0.877	0.590
Skill in processing food leftovers (4 items)	0.764	0.824	0.847	0.583

α = Cronbach's alpha, CR = Composite reliability (rho_a), CR = Composite reliability (rho_c), AVE = Average variance extracted (AVE).

Table 3, the Cronbach's alpha is above 0.7 for all the constructs, indicating a good internal consistency reliability of the measurement model.

Next, convergent validity was assessed to examine whether the items that are supposed to measure the same construct, are indeed related to each other. This means that the items in the same construct should have high correlation with each other. Average Variance Extracted (AVE) was used to measure the convergent validity of the constructs. An acceptable value for the AVE is above 0.5, (Hair et al., 2018), and as seen in Table 4, all constructs exceed the recommended threshold of 0.5 for the AVE, which means a sufficient level of convergent validity (Thoma et al., 2018).

The discriminant validity assesses the extent to which a construct is distinct from the other constructs in the model. To measure the discriminant validity, two measures: the Fornell-Lackner criterion and the Heterotrait-Monotrait ratio (HTMT) were applied. The former criterion is a widely used in SEM studies, and a model passes the criterion if the square root of the AVE of a certain construct is higher than the correlation of that construct with the other constructs in the model (Hair et al., 2018). As it can be seen in Table 4, all correlations between the constructs have a lower value than the square root of the AVE for the constructs. This indicates that the model fulfils the criterion and thus sufficient discriminant validity.

However, literature debates if the Fornell-Larcker criterion and suggested using the HTMT (Henseler et al., 2015). Higher values indicate a problem with the discriminant validity. Henseler et al. (2015) suggest that the HTMT should be below 0.90 as a more liberal value. The results show that all values are well below the recommended conservative threshold of 0.85, which means that according to the HTMT test the model has sufficient discriminant validity, see Table 5. The standardized root mean square residual (SRMR) value for the model was 0.078, indicating a good fit.

4.2.2. Structural results

The results of the model testing provide valuable insights into the psychological factors that drive the reuse of food leftovers. The R^2 measures the variance that is explained in each of the endogenous constructs in the model, and ranges from 0 to 1. The higher the value, the more variance is explained and therefore the more explanatory power the construct has (Hair et al., 2018). The results are shown in Fig. 2. The dependent variable, intention to reuse food leftovers is explained by 53 % of the variance. In comparison to related studies (Kirmani et al., 2023; Stancu et al., 2016; Stefan et al., 2013; Visschers et al., 2016) and the fact that the research discipline is consumer behavior, this value is relatively high, and the model has quite good explanatory power. The other endogenous constructs, personal norm and attitude towards reuse, are explained by 17 % and 26 % of the variance respectively.

The confirmed hypotheses highlight the importance of positive attitudes, strong personal norms, and adequate skills in promoting leftover reuse. Additionally, the findings show the need to address perceived health risks to overcome a negative influence on the attitude towards reuse. The results of the analysis show that six out of the seven hypotheses were confirmed, indicating that the model effectively captures the key factors influencing the intention to reuse food leftovers.

The hypothesized relationship between awareness of the

consequences of leftover food and attitudes towards reuse (H1a) was not supported. However, while awareness does not directly influence attitudes, it has a positive and significant effect on personal norms ($\beta = 0.42$, $t = 6.991$, $p < .001$), providing statistical support for H1b (Savari et al., 2023; Schwartz, 1977). Perceived health risks were found to negatively impact attitudes towards reusing food leftovers ($\beta = -0.30$, $t = 4.781$, $p < .001$), supporting H2. The SEM analysis confirmed that attitudes have a strong positive effect on the intention to reuse food leftovers ($\beta = 0.45$, $t = 3.900$, $p < .001$), thus supporting H3. Personal norms were also found to have a significant positive effect on the intention to reuse food leftovers ($\beta = 0.35$, $t = 4.664$, $p < .001$), supporting H4b. Moreover, personal norms also had a positive effect on attitudes towards reuse of leftover food ($\beta = 0.31$, $t = 4.050$, $p < .001$), supporting H4a. Finally, the lack of skills in processing food leftovers had a negative effect on the intention to reuse them ($\beta = -0.14$, $t = 2.725$, $p < .005$), supporting H5. Regarding mediation effects, the SEM results indicate that all relationships, except for the link between awareness of the consequences of food leftovers and the intention to reuse them, are mediated through either attitude or personal norms (see Table 6).

5. Creative session

Based on the interview and survey findings and to enhance the practical relevance of the findings, a creative session was conducted. The following outline the creative session aiming to design targeted interventions to reduce food waste by promoting leftover reuse.

5.1. Procedure

Five designers with at least a BSc degree in Industrial Design Engineering were selected for their expertise in creative thinking to participate in the creative session. By anchoring the creative process in the conceptual model results, we aimed to ensure that the identified interventions were both evidence-based and contextually relevant and feasible. This approach allowed us to provide stakeholders with concrete, actionable solutions tailored to address the key factors influencing the reuse of food leftovers. This integration of data-driven analysis and participatory design exemplifies how scientific research can directly inform practical outcomes.

In doing so, the results from both the interviews and the structural findings were synthesized to form six distinct design opportunities. Five of these, were directly derived from the psychological constructs identified within the conceptual model, while the sixth (i.e., household organization) was based on contextual factors revealed during the interviews. The design opportunities serve as significant areas for developing interventions that either strengthen a particular psychological construct or reduce identified barriers. To provide more specific guidance for our participant designers, two examples of strategies were formulated for each design opportunity.

- (1) **Attitudes towards reuse of food leftovers:** Creating positive perceptions and enjoyable experiences related to leftover reuse. Example strategies include (i) enhancing the sensory appeal of leftovers and (ii) providing rewards for positive behavior.

Table 4
Discriminant validity (Fornell-Larcker criterion).

	Attitude	Awareness	Intention	Health risks	PN	Skills
Attitude towards reuse of food leftovers	0.782					
Awareness of the consequences of food leftovers	0.232	0.895				
Intention to reuse food leftovers	0.630	0.236	0.875			
Perceived health risks	-0.399	-0.240	-0.412	0.770		
Personal norms	0.410	0.417	0.564	-0.282	0.768	
Skill in processing food leftovers	-0.228	-0.096	-0.310	0.443	-0.181	0.764

Table 5
Discriminant validity (HTMT).

	Attitude	Awareness	Intention	Health risks	PN	Skill
Attitude towards reuse of food leftovers						
Awareness of the consequences of food leftovers	0.285					
Intention to reuse food leftovers	0.721	0.285				
Perceived health risks	0.456	0.293	0.468			
Personal norm	0.465	0.519	0.635	0.312		
Skill in processing food leftovers	0.264	0.136	0.353	0.582	0.234	

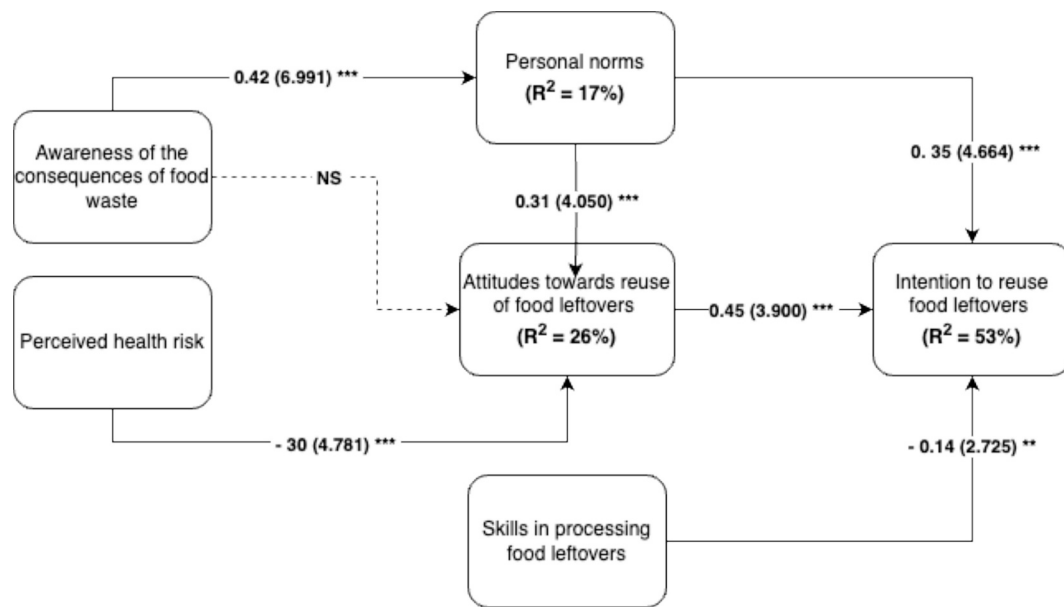


Fig. 2. Structural results.

Note: *** $p < .001$. ** $p < .005$. * $p < .01$.

Table 6
Mediation effect.

Path relationships	β	T statistics	p
Awareness → Attitude → Intention	0.013	0.374	0.709 (NS)
Awareness → Personal Norm → Intention	0.131	3.442	0.001 (S)
Awareness → Personal Norm → Attitude → Intention	0.059	3.004	0.003 (S)
Awareness → Personal Norm → Intention	0.147	4.016	0.001 (S)
Health risks → Attitude → Intention	-0.138	2.557	0.011 (S)
Personal Norm → Attitude → Intention	0.142	3.447	0.001 (S)

- (2) **Personal Norms:** Strengthening ethical beliefs against food waste and increasing the perceived value of food. Example strategies include (i) campaigns to raise awareness about the moral implications of food waste and (ii) to promote food as a valuable resource.
- (3) **Skills to process food leftovers:** Improving cooking and food storage skills. Example strategies include (i) providing practical tips and inspiration for creating meals with leftovers, and (ii) educating people on optimal storage techniques to extend the life of leftovers.
- (4) **Awareness of Consequences of food leftovers:** Increasing awareness about the environmental and social impacts of food waste. Example strategies include (i) educational campaigns that highlight the broader consequences of wasting food, such as the loss of resources and (ii) the impact on food security.

- (5) **Perceived Health Risks:** Enhancing confidence in food safety practices. Example strategies included providing (i) clear guidelines on how to safely store and reheat leftovers, and (i) tools to help users determine the edibility of food.
- (6) **Household Organization:** Improving household organization as a contextual factor that prevents the reuse of food leftover. Example strategies include (i) tools to help households better manage their food inventory and (ii) reminders to use leftovers.

The creative session was based on the Integrated Creative Problem-Solving framework (Buijs & Van der Meer, 2013), specifically the content finding sub-process, which is organized into three phases: defining the problem, generating and selecting options, and improving the options. The ideation session was conducted and took place in a closed meeting room and lasted approximately two hours. The participants were provided with a session brief beforehand to familiarize them with the subject and the activities planned for the session. During the session, the participants were guided through a series of exercises designed to stimulate creativity and generate a wide range of ideas for each design opportunity. Techniques such as brainwriting and creative confrontation were employed to encourage participants to think beyond the obvious solutions. After generating ideas, the group used clustering and selection techniques to identify the six most promising concepts, which were then further developed (one per design opportunity).

5.2. Outcomes of the creative sessions design interventions

Six design interventions were developed based on the design opportunities and accompanying strategies. These interventions are

intended to serve as examples and sources of inspiration for designers. Their visual representations are presented in Appendix C. [Table 7](#) offers an overview of these interventions linked to the related design opportunities, and together with their definitions and the actors that need to be involved next to consumers and environmental and food waste organizations who may be involved in each of them.

6. Discussion

6.1. Theoretical implications

This paper investigates the intention to reuse leftover food within households as a sufficiency strategy to extend the lifespan of foods, thereby preventing food waste and reducing overall household food purchases. By integrating elements from established behavioral theories - namely the TPB ([Ajzen, 1991](#)), the MOA model ([Ölander & Thøgersen, 1995](#)), and the NAM ([Schwartz, 1977](#)), as well as qualitative interviews, we propose a conceptual model outlining the antecedents of the intention to adopt leftover food reuse behaviors at home.

Our research extends the existing literature on consumer behavior related to food waste by shifting the focus from restaurant settings ([Hamerman et al., 2018](#); [Talwar et al., 2021, 2023](#)) to the household context, which represents a substantial portion of overall food waste ([Dri et al., 2018](#); [Sigala et al., 2024](#)). Furthermore, we highlight that understanding the determinants of behaviors such as leftover reuse can inform targeted interventions. By integrating elements from different theoretical models, we aim to provide a comprehensive understanding of the antecedents of leftover reuse behaviors. For instance, while the TPB includes subjective norms, we specifically examine the role of personal norms, drawing from the NAM to better capture internal moral motivations behind food-related decisions ([Schwartz, 1977](#); [Thøgersen, 2006](#)).

The SEM results reveal that attitudes towards reusing leftovers and personal norms are the strongest predictors of the intention to reuse leftover foods, emphasizing the importance of these determinants in designing effective behavioral interventions. This finding is consistent with previous studies that have identified personal norms as significant predictors of pro-environmental intentions and behaviors (e.g., [Wang et al., 2022](#)). More specifically, we examined the influence of two antecedents of attitude towards leftover reuse, awareness of the consequences of food waste ([Aschemann-Witzel et al., 2015](#); [Principato et al., 2015](#)) and the perceived health risks ([Andrews et al., 2018](#))—to quantify their role in shaping individuals' attitudes.

Interestingly, while perceived health risks play a negative role in shaping attitudes towards the reuse of food leftovers, our hypothesis that awareness of the consequences of food waste influences attitudes was not supported. This suggests that simply knowing about the environmental impact of food waste may not be sufficient to change individuals' attitudes, highlighting the complexity of behavioral change in this context.

However, our analysis confirmed that awareness influences perceived norms, which in turn shape both attitudes and the intention to reuse food leftovers. This suggests that leftover reuse is a morally grounded practice, aligning with the recent research on this topic ([Ribbers et al., 2024](#)). In addition to attitudes and personal norms, skills which relate to ability or perceived behavioral control also play a significant role in predicting the intention to reuse leftovers, further emphasizing the importance of practical skills and competences in adopting new sustainable practices. This is in line with studies that have highlighted the role of skills and competencies in facilitating pro-environmental behaviors (e.g. [Shove et al., 2012](#)).

Overall, the findings show how psychological factors shape consumer preferences and behaviors, particularly in the context of leftover reuse ([Graham-Rowe et al., 2015](#); [Stancu et al., 2016](#)). For example, positive attitudes towards reuse ([Zaidi et al., 2022](#)) reflect consumers' openness to sustainable practices, while strong personal norms

Table 7

Interventions, definitions and involved actors.

Intervention / Design Opportunity	Definition	Actors involved
(1) Leftover Challenges/ Attitude towards the reuse of food leftovers	The leftover challenges intervention encourages people to reuse leftovers through engaging challenges shared on social media. Each week, a new challenge invites followers to participate, share photos and stories of their leftover meals, and reflect on habit changes. The most inspiring story is featured and rewarded. Occasionally, influencers or chefs take on the challenge to boost engagement. By combining visual content, community interaction, and celebrity influence, this approach fosters a positive shift in attitudes towards leftovers.	Non-governmental organizations, Municipalities, Retailers
(2) The food journey shop sign/ Awareness of the consequences of food waste	The Food Journey Shop Sign is a large information board placed above fresh food sections in stores, designed to raise awareness about the journey food takes from farm to table. It visually illustrates key stages, planting, harvesting, processing, and transportation, while highlighting the significant resources involved, such as water, energy, and labor. By showcasing the effort behind food production, the sign encourages shoppers to appreciate their food and reduce waste.	Grocery stores, farmers and food producers
(3) Children's picture book/ Personal norms	Max the Leftover Hero is a fun and engaging children's picture book that teaches kids about reducing food waste through storytelling and vibrant illustrations. The story follows Max and his grandmother as she introduces him to the fascinating journey of food from farm to kitchen and the importance of not letting it go to waste. With the help of the Leftover Hero Jar, Max learns how to save and creatively reuse food to make delicious meals. By personifying leftovers as heroes, the book instills an early appreciation for food, highlights the effort behind its production, and encourages families to make eating leftovers a shared habit.	Families and children, Governments and public institutions, book publishers
(4) The leftover check app/ Perceived health risks	The Leftover Check App helps users determine if their leftovers are safe to eat by combining modern technology with the latest food safety guidelines.	Food safety & Health organizations, Governments and public institutions, Tech developers and Data scientists,

(continued on next page)

Table 7 (continued)

Intervention / Design Opportunity	Definition	Actors involved
	Health risks related to leftovers primarily arise from the growth of bacteria and the potential for foodborne infections, which can occur when food is improperly stored or kept for too long. Key factors influencing these risks include food type, cooking method, storage conditions, and duration, which are taken into consideration in the app to provide clear recommendations on edibility. It also offers tips on optimal storage and food safety practices. With a user-friendly design and reliable advice, the app builds confidence and encourages a positive approach to reusing leftovers	
(5) The Use-Up App / Skills to process food leftovers	The Use-Up App helps users create meals with ingredients they already have by matching them to recipes. Users input ingredients and portion sizes, and the app suggests recipes, showing how much can be made with available items and what needs to be bought. A filter allows customisation, and additional features include a shopping list and weekly meal planner. By simplifying meal planning and encouraging creative use of leftovers, the app helps reduce food waste and save money.	Tech developers, AI experts, recipe creators, retailers
(6) Automatic Leftover Tracker / Contextual factors – Household organization	The Automatic Leftover Tracker helps households manage leftovers efficiently using NFC-equipped containers and a companion app. An NFC reader in the fridge and freezer detects new leftovers, adding them to the app's list. Users receive a prompt to log the meal's contents and portion size. The app tracks storage time and sends reminders to prevent waste. By increasing awareness and sharing responsibility among household members, the system ensures leftovers are eaten.	Tech developers, Internet of Things experts, Smart kitchen appliance manufacturers

underscore the moral dimension of food-related decision-making. The observed influence of skills and perceived health risks further highlights the interaction between practical capabilities and psychological perceptions in shaping behavior.

These results not only validate the proposed theoretical model but also shed light on the nuanced interplay of motivators and barriers in consumer food behavior. By combining theoretical insights with empirical findings, this research highlights the multidimensional nature

of consumer decision-making in the context of leftover reuse. Positive attitudes and personal norms emerged as the strongest predictors, highlighting the central role of internal motivators in shaping pro-environmental behavior. Additionally, the influence of skills and perceived health risks further emphasizes the need for holistic interventions that address both psychological and practical dimensions.

Finally, our research uniquely contributes the field by not only identifying and quantifying the psychological factors influencing the reuse of food leftovers but also by bridging the gap between theory and practice. We translate our model's insights and qualitative findings into actionable design interventions, also tackling contextual aspects that often moderate the relationship between behavioral intention and actual behavior (Sheeran, 2002). This approach advances the field by demonstrating how psychological theories can inform practical strategies for promoting more sustainable food consumption.

6.2. Practical implications

The findings provide implication for the development of strategies to encourage sustainable food practices. For instance, strengthening personal norms and fostering positive attitudes can guide the design of interventions that promote moral responsibility and environmental consciousness. Also, addressing contextual barriers such as household disorganization and concerns about food safety can better support individuals in integrating sustainable practices into their daily routines. Moreover, the findings emphasize the importance of developing interventions that respond directly to individual motivations and challenges. Strategies such as skill-building workshops, organizational tools, and targeted education can help bridge the gap between intention and actual behavior, making leftover reuse more accessible and achievable. Building on these insights, the following practical recommendations are proposed:

Targeted Communication Campaigns: Governments and NGOs can develop communication campaigns that target individual's attitude as well as their personal norms by highlighting the environmental and ethical implications of food waste. These campaigns could include storytelling, testimonials, and visual content that make the consequences of food waste more tangible to the public.

Skills Development Programs: Municipalities, regional communities, and supermarkets can introduce programs that enhance people's skills in managing leftovers, such as cooking workshops, online tutorials, and mobile apps that provide recipes specifically for leftovers. These programs should focus on making leftover meals more appealing and accessible to a wider audience.

Household Organization Tool: manufacturers and App developers should design tools and systems that help households better organize their food storage, such as smart fridges that track expiration dates or kitchen management apps that remind users to consume leftovers. These tools could significantly reduce the likelihood of food being forgotten and wasted.

Health and Safety Education: Healthcare institutions and professionals should address individual's health risks perceptions by providing clear, reliable information on food safety practices, particularly storing and reheating leftovers. Also, municipalities via educational campaigns could encourage safe practices that increase confidence in consuming leftovers.

Policy Interventions: Governments and NGOs can encourage policy-makers to support initiatives that reduce food waste, such as subsidies for food-sharing programs or regulations that promote better food labeling. Policies that incentivize reduced consumption and promote sustainable food practices could also amplify the impact of individual behavior change.

6.3. Limitations and recommendations for future research

The research acknowledges several limitations that might have

impacted the outcomes. Firstly, the sample used for the survey was not entirely representative of the general population of the Netherlands. Most respondents in our survey were female and highly educated, which may have introduced bias into the findings, and the generalizability of the results to broader, more diverse populations. Secondly, the reliance on self-reported data in both the interviews and the survey could lead to social desirability bias, where participants might report behaviors they perceive as socially acceptable rather than their actual behaviors. This is a common issue in behavioral research, especially concerning environmentally friendly practices like food waste reduction. Another limitation was the focus on Dutch households, which may not capture cultural differences that could influence food waste behaviors in other countries. The specific cultural context in the Netherlands, where the study was conducted, might mean that the findings are not fully applicable to other cultural settings with different food consumption habits and norms. Finally, while the PLS-SEM analysis provided valuable insights into the relationships between the psychological factors and leftover reuse intentions, the research did not include longitudinal data on actual behavior. Therefore, it cannot establish causal relationships or account for changes in behavior over time.

Future studies should aim to include more diverse populations both in terms of demographics and cultural backgrounds to enhance the generalizability of the findings. Cross-cultural research could provide insights into how cultural differences influence food waste behaviors and the effectiveness of different interventions. Conducting longitudinal research to track changes in food waste would help establish causal relationships and understand how interventions might produce long-term behavior change. Future research could potentially explore the role of emerging technologies, such as Artificial Intelligence (AI) and the Internet of Things (IoT), in reducing the environmental impact of food waste – while also accounting for the environmental impact of these technologies. Research could investigate how these technologies can be more extensively integrated into everyday household practices to automate and optimize food management. We suggest future research to focus more on how perceived health risks are formed and how to design for an accurate perception of this health risk.

Finally, future research could explore the cost-effectiveness of different interventions and the potential for large-scale policy changes to influence consumer behavior. This could be done by investigating the economic and policy implications of reducing food waste at a systemic level. The finding that skills in processing food leftovers play a significant role suggests that practical interventions could effectively enhance leftover reuse behaviors.

7. Conclusion

This research contributes to both theoretical and methodological understanding of food waste reduction through the reuse of leftovers. By proposing a conceptual model, which includes constructs from the TPB, NAM, and MOA, the findings provide new knowledge about the psychological determinants of leftover reuse, such as attitudes, personal norms. Additionally, perceived health risks and organizational challenges have emerged as a contextual factor, highlighting the importance

of improving food storage and management practices. Notably, awareness of food waste consequences only influences personal norms rather than directly shaping attitudes, highlighting the moral dimensions of leftover reuse behaviors.

Methodologically, this research employs an innovative approach by combining qualitative interviews, structural equation modeling, and participatory design techniques, such as brainwriting and creative confrontation. This approach enables the design of interventions that are both evidence-based and practically feasible. By blending analytical rigor with creative exploration, we bridge the gap between understanding behavior and shaping a more sustainable future.

The results provided in this paper extend sufficiency research from durable goods to the food domain, emphasizing the role of leftover reuse in sustainable household practices and contributing to the growing body of literature on food waste behavior (Gossen & Kropfeld, 2022; Lahath et al., 2021; Niessen et al., 2023). These findings have significant implications for influencing consumer behavior towards sustainable food practices.

By aligning intervention strategies with the psychological drivers and contextual factors involved in reusing leftover food identified in this research, stakeholders can more effectively promote behavior change and encourage sustainable consumption patterns. Lastly, the research emphasizes the importance of context-specific solutions, offering insights for policymakers, educators, and environmental agencies. These findings suggest that interventions aimed at reducing food waste should focus on enhancing positive attitudes, reinforcing personal norms, enhancing leftover management skills, addressing health concerns, and promoting better household organization.

CRediT authorship contribution statement

Shahrokh Nikou: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Lise Magnier:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Heleen S. Sinnige:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Ethical statements

Ethical approval for the involvement of human subjects in this study was granted by the Delft University of Technology Research Ethics Committee, Reference ID: 146850, 22.02.2024.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Interview guide

General information questions

Could you shortly describe yourself?

- Can you state your age and gender?
- Can you state your highest achieved educational level?
- Can you state the composition of your household?

Walk through

Instructions: I would like to start this interview with a walk-through component. I would like you to take me through your fridge and kitchen cabinets. Please state every thought that you have out loud.

Fridge and freezer:

- Can you show me the leftovers that you have in your fridge now?
- Can you explain why you store them the way you store them?
- Can you show me how you would make a new meal out of these leftovers

Cabinets:

- Can you show me the leftovers that you have in your fridge now?
- Can you explain why you store them the way you store them?
- Can you show me how you would make a new meal out of these leftovers

Interview questions:

What is your opinion on food waste?

- Do you sometimes think about the amounts of food you waste?
- Do you take actions to reduce the amount of food you waste?

Do you sometimes have leftovers? Can you describe what these leftovers usually are?

- How do you decide what leftover foods to keep for later use and what not to keep?
- Is the production of leftovers on accident?

Do you ever consciously re-use your food leftovers? Why?

- Do you plan when to re-use your food leftovers? Are you able to stick to that plan?
- What motivates you to re-use leftovers when you choose to do so?
- Are you more motivated to re-use certain types of leftovers than others? Why?
- Do you feel like you should always re-use food leftovers? Why?
- In which context would you be likely to use leftovers? Which not?

Would you say you are able to make a good new meal out of food leftovers? (for example, with the ones you have in the fridge now)

- Do you sometimes experiment with new recipes with your leftovers? Why or why not?

Which associations do you have with leftover foods?

- Can you describe how you compare preparing and eating food leftovers compared to eating newly made foods?
- Are you used to eating food leftovers? Did you often eat leftovers when growing up?

Do you ever throw away food leftovers? What were the reasons that you threw away the leftovers?

- How did you feel (which concerns) when you had to throw out your leftovers?
- Can you describe the factors that kept you from re-using your food leftovers?
- What do you think that needs to change in order to re-use your food leftovers more often?
- What would make it more attractive for you to re-use your leftovers?

Do you believe that reusing leftovers contributes to sustainable food practices? Why or why not?

- Would you consider yourself aware of the amounts of food that you waste?
- Do you ever think about where your food comes from, and the energy resources needed to produce the food you eat?

Do you think there is something that I missed or that I should have asked in this interview?

Appendix B. List of the items

Item	Definition	Mean
Intention 1	I always try to waste no leftovers at all	5.95
Intention 2	I always intend to re-use food leftovers	6.09
Intention 3	My goal is to always re-use food leftovers	5.94
Intention 4	I intend to re-use food leftovers by eating them as such or reheating them	6.05
Attitude 1	In my opinion, re-using food leftovers is good	6.53
Attitude 2	In my opinion, re-using food leftovers is pleasant	5.83

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(continued)

Item	Definition	Mean
Attitude 3	In my opinion, re-using food leftovers is favorable	6.02
Attitude 4	In my opinion, re-using food leftovers is desirable	6.44
Attitude 5	I like re-using food leftovers	5.84
Personal norm 1	Wasting food leftovers would make me feel guilty towards people that do not have enough food	4.40
Personal norm 2	Wasting food leftovers would make me feel guilty towards the environment	5.19
Personal norm 3	It is contrary to my principles to waste food leftovers	5.71
Personal norm 4	I have been raised to believe that food leftovers should not be wasted, and I still live according to this principle	5.18
Personal norm 5	Wasting food leftovers does not bother me	5.03
Skills 1	I find it difficult to prepare a new meal with food leftovers	2.98
Skills 2	I find it difficult to cook anything other than the recipes I know with my food leftovers	2.57
Skill 3	I find it difficult to tell if food leftovers are still good to eat based on the appearance, smell, and/or the taste	Removed
Skills 4	I have the ability to store my food leftovers in appropriate conditions so they will last	3.05
Skills 5	I have the ability to plan ahead when I will use my food leftovers for a meal, and I keep to this plan.	2.72
Health risks 1	I believe that the risk of becoming ill as a result of eating food past its best before date is high	3.06
Health risks 2	I am not worried that eating leftovers results in health risk	2.50
Health risks 3	I think that consuming leftovers is harmless	2.22
Health risks 4	I think that one can perfectly eat food products whose best-before dates expired a few days ago without risking their health	2.54
Health risks 5	I think it is better to throw away leftovers than to risk eating unsafe food because it is no longer fresh	2.80
Awareness 1	Food thrown away is not an issue as it is natural and biodegradable	Removed
Awareness 2	The packaging of the food thrown in the trash is a bigger environmental problem than food waste.	Removed
Awareness 3	I think that the phenomenon of food waste is widespread	6.11
Awareness 4	I consider household food waste reduction to be a major way to reduce pollution	5.18
Awareness 5	I consider household food waste reduction to be a major way to conserve natural resources.	5.18

Appendix C. Visual representations of the interventions

LEFTOVER CHALLENGES



EXAMPLE CHALLENGES

'Zero Grocery Week': Don't buy any groceries for a whole week. Use only what you have at home.

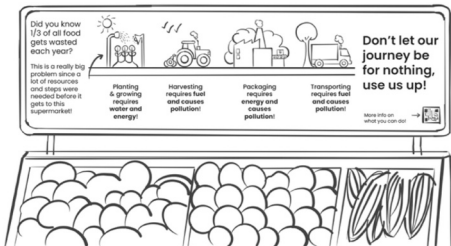
'Fridge Shuffle': Store all products usually at the back of your fridge in the front and vice versa.

'Surprise Ingredient': Add a 'surprise' leftover ingredient to your meal every day this week.

'Meal Prep Master': Plan all your meals for the week using leftovers as the main ingredients.

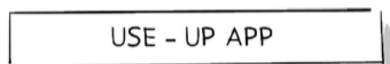


FOOD JOURNEY SHOP SIGN



CHILDREN'S PICTURE BOOK





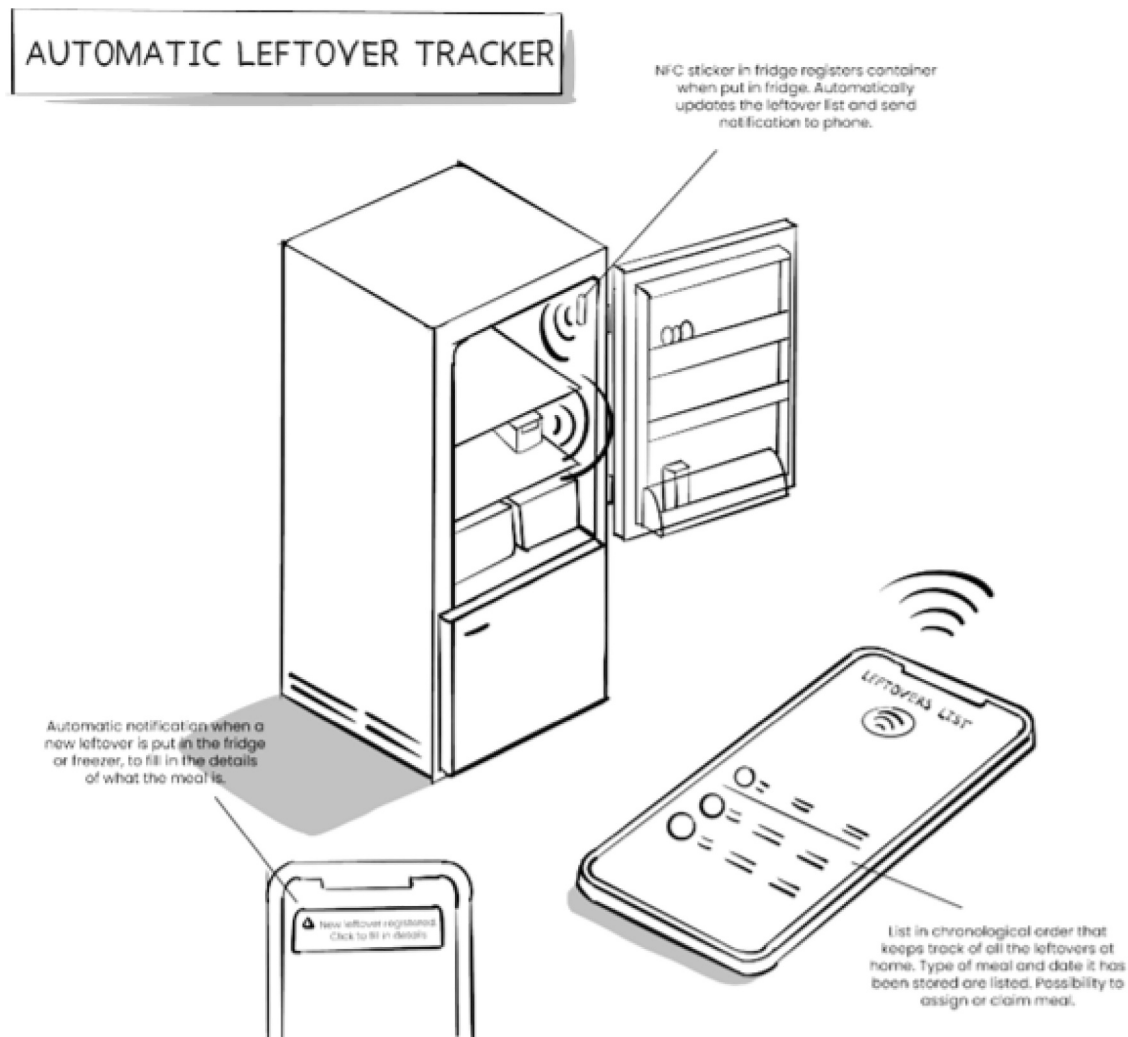
- Generate a recipe just for today, based on a selection of products that you have left at home.
- Generate recipes for the whole week, based on all the products you have left at home.
- Option to click on an ingredient in the recipe to get more info on its regular uses, possible substituting ingredients, often used prepping techniques, etc.



- Whenever you have chosen a recipe to make, you can add the recipe to your meal calendar for the week. You can click and drag to any day your prefer.
- When you have used the function to generate recipes for the whole week, you can automatically add all the recipes to your calendar for that week.



- When you have chosen one of the recipes to make, you can add the ingredients that you don't have yet to your shopping list in the app.
- The shopping list can be organised by ingredient or by recipe.



Data availability

Data will be made available on request.

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