

**Louvain School of Management
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Effects of Nudging on Consumer Food Waste

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Master's thesis with the view of getting the degrees:
Master in Business Administration: Supply Chain Management
Master in Business Engineering: Innovation Management

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Academic Year 2022-2023

Acknowledgements

First of all, I would like to express my gratitude to my first supervisor, Prof. Carlos Desmet, for his valuable support, genuine guidance, and firm confidence in the development of this work. I would also like to extend my appreciation to my second supervisor, Prof. Dr. Andreas Fügner, for granting me the possibility to write this thesis under his supervision. A very special thanks goes to Dr. Monika Westphal. Her continuous support, dedicated effort, and enriching ideas significantly contributed to the outcome of this work.

I am also deeply grateful to all the participants who took part in this study. Their reliable and persistent contributions were crucial in bringing this work to fruition.

Lastly, I want to express my gratitude to my family and close friends, whose support and encouragement have been a constant source of motivation throughout the course of this work.

Table of Contents

List of figures	VI
List of tables	VII
List of abbreviations	VII
1 Introduction	1
2 Literature review	4
2.1 Consumer food waste	4
2.1.1 Overview, definitions, and classification	4
2.1.2 Drivers and barriers to food waste reduction	6
2.2 Nudging	10
2.2.1 Overview, definitions, and classification	10
2.2.2 Nudging and consumer food waste	13
3 Methodology	16
3.1 Participants	17
3.2 Procedure	18
3.2.1 Nudge design	18
3.2.2 Data collection	20
3.3 Measures	24
4 Results and analysis	25
4.1 Descriptive statistics	25
4.2 Testing of the effect of nudge on food waste quantity	29
4.3 Testing of the effect of nudge on food waste awareness and perceived behavioral change	32
4.4 Testing of the effect of nudge on food waste-related household practices and evaluation of the nudge	33

4.5	Testing of the effect of socio-demographic characteristics on food waste quantity.....	34
5	Discussion	35
5.1	Implications for theory	35
5.2	Implications for practice	38
5.3	Limitations and future research directions	39
6	Conclusion	40
	Reference list.....	41
	Appendix A: Visualizations of food waste quantity by treatment group.....	50
	Appendix B: Visualizations of food waste quantity by different socio-demographic characteristics.....	51

List of figures

Figure 1: Food supply chain and activities that give rise to food losses and waste	5
Figure 2: Classification of food waste among avoidability, lifecycle stage, and packaging	6
Figure 3: Drivers and barriers to consumer food waste reduction at the household level	10
Figure 4: Overview of measurement instruments used in the study	25
Figure 5: Selected FW-related household practices of participants in the nudge and control group	26
Figure 6: Total food waste quantity of the nudge and control group by product group	27
Figure 7: Total food waste quantity of the nudge and control group by disposal reason	28
Figure 8: Total food waste quantity of the nudge and control group by packaging and lifecycle stage	28
Figure 9: Average daily food waste quantity of the nudge and control group throughout the study	29
Figure 10: Interaction effect of nudge and willingness on average daily food waste quantity	32
Figure 11: Effect of nudge on food waste awareness and perceived behavioral change resulting from the study	33
Figure 12: Evaluation of the reminder nudge	34
Figure 13: Moderation effect of willingness on nudge	37

List of tables

Table 1: Overview of intervention studies related to nudging and consumer food waste at the household level.....	14
Table 2: Socio-demographic background of the sample (n=28).....	17
Table 3: Characteristics of the initial survey.....	21
Table 4: Characteristics of the daily survey	22
Table 5: Characteristics of the final survey.....	23
Table 6: Results of two-way repeated measures ANOVA (I): Effect of nudge and time on food waste quantity	30
Table 7: Results of two-way repeated measures ANOVA (II): Effect of nudge and willingness on food waste quantity	31

List of abbreviations

CG	Control Group
FW	Food Waste
FWQ	Food Waste Quantity
NG	Nudge Group
TPB	Theory of Planned Behavior

1 Introduction

According to the FAO (2011), approximately one-third of food produced for human consumption is lost in production or wasted during consumption annually. In absolute terms, Stenmarck et al. (2016) estimate the total quantity of food waste (FW) along the food supply chain in Europe at 88 million tons. This striking number has not only severe implications for the environment and economy, but also for society, considering that 795 million people worldwide suffer from hunger (FAO, 2015). For the economy at large, the total cost of global FW in 2007 accounted approximately to \$750 billion (FAO, 2013). According to studies conducted in the UK, individual cost of FW per person are estimated to be £680 per year (WRAP, 2011). In the EU, the food sector accounts for one-third of the total greenhouse gas emissions (Garnett, 2011). Research shows that a substantial share of these greenhouse gas emissions can be directly attributed to FW activities (Scherhauer et al., 2018). Recognizing that almost half of the total FW produced in Europe originates from households (Stenmarck et al., 2016), the role of consumers becomes pivotal in achieving the UN Sustainable Development Goal 12.3. This goal aims to achieve a 50% reduction in FW at the later stages of the food supply chain (Porpino, 2016; Scherhauer et al., 2018). Despite the growing development of public awareness on the topic (Neff et al., 2015), and the negative perception of wasting food (Schanes et al., 2018), there remains a necessity for guided action and consumer-level change (Papargyropoulou et al., 2014).

Several researchers have examined FW-related consumer behavior at the household. For instance, Koivupuro et al. (2012) evaluated the influence of socio-demographic, attitudinal, and behavioral factors on household FW. Stefan et al. (2013) analyzed different household practices that contribute to FW. Graham-Rowe et al. (2014) identified motivations and barriers of consumers to minimize household FW. Moreover, Schanes et al. (2018) underline in an extensive systematic literature review that consumer FW is a complex issue that results from a dynamic interplay of personal norms, individual behaviors, and some socio-demographic factors. To move beyond analysis and toward practical solutions, scholars call for more diverse research on interventions aimed at decreasing consumer FW (Aschemann-Witzel et al., 2015; Nisa et al., 2019). Prevalent interventions aimed at reducing FW in private households applied, for example, environmental psychological based interventions (Schmidt, 2016) and the Theory of Planned Behavior (TPB) (Graham-Rowe et al., 2015; Stefan

et al., 2013; Visschers et al., 2016). Still, scholars conclude that merely increasing awareness and educating consumers on the impacts of FW is inadequate to effectively address the problem (Von Kameke & Fischer, 2018; Stöckli et al., 2018). Following that notion, Nisa et al. (2019) highlight that behavioral interventions and other non-traditional policies have gained momentum in the area of sustainability and consumer FW. To further broaden the range of interventions aimed at reducing consumer FW at the household level, the current study focuses on nudging as a form of intervention.

Nudging has gained popularity as a smart and cost-effective approach to stimulate individuals to adopt socially desirable behaviors (Reisch et al., 2021). Built on the findings by Kahneman (2011), Sunstein & Reisch (2014) postulate nudging as an effective approach to achieve behavioral change among individuals through altering their choice architecture. The application of nudges has been proven to show success in several areas, such as energy-saving, the use of public transport, and healthier dieting (Von Kameke & Fischer, 2018). In the area of FW, nudging has been applied to encourage consumers to use recycle bins at home, consume smaller portion sizes in hotel restaurants, and improve household practices that are related to FW prevention (Kallbekken & Sælen, 2013; Nomura et al., 2011; Schmidt, 2016).

The current study makes use of a specific subset of nudges, namely reminder nudges. Reminder nudges intend to prompt individuals to engage in a specific behavior and counteract inattention and forgetfulness (Karlan et al., 2016; Sunstein, 2014). So far, only few researchers attempted to analyze the influence of reminder nudging on consumer FW (Reisch et al., 2021). Among the conducted studies, most focused on utilizing physical prompts to encourage consumers towards sustainable choices, such as recycling food or adopting waste-preventive household behaviors (Shearer et al., 2017; Van der Werf et al., 2021). In contrast to physical prompts, digital reminders, such as text messages, showed success in achieving sustainable behavior choices in other fields, such as health-prevention (Vervloet et al., 2012). In the modern tech landscape, the success of straightforward text message reminders for reducing FW and promoting preventive actions could pave the way for the broader expansion of sustainability-related applications in the digital sphere. This has potential significance for both private enterprises and policymakers, considering the growing interest in automated chatbots, smartphone apps, and AI-powered smart tech (Almeida & Santos, 2020). However, according to the author's best knowledge, no study has yet examined

the effects of a digital reminder as a form of nudge to reduce consumer FW in their households.

To address this research gap, this study specifically focuses on the effects of a text message reminder nudge on consumer FW at the household level. In addition, the current study seeks to overcome two shortcomings associated with the current research of reminder nudges and FW. Firstly, it focuses on a single type of reminder nudge, since researchers have been calling for intervention studies that focus on the effect of single nudge approaches (Nisa et al., 2019; Reisch et al., 2021). Such results can help to better isolate the effects of a single intervention and to build an evidence base for policymakers (Nisa et al., 2019). Secondly, it uses a diary study method to gain detailed insights into consumers' behavior over an extended period of time, as often the effects are not measured in sufficient detail over time (Nisa et al., 2019; Reisch et al., 2021). Most diary studies published so far measured consumer FW over one or two weeks and did not include interventions, such as nudging (Van Herpen et al., 2019). To sum up, the current study examines the following research question: *What is the effect of a digital reminder nudge on consumer FW at the household level?* It tests this research question in a diary study over a four-week period. As the issue of FW has to be solved throughout the entire food supply chain, this research contributes to an increased understanding of further downstream parts in the food supply chain and how waste management can be optimized at this stage. This research also contributes to theory, as nudging is still in its infancy and underrepresented in the area of FW (Hummel & Maedche, 2019).

The remainder of this work is organized in the following manner: Chapter 2 will provide an in-depth literature review to elucidate the theoretical constructs of consumer food waste and nudging. This will establish a conceptual foundation and serve to justify the research question and experimental design of this study. Afterwards, chapter 3 will elaborate the methodology, emphasizing on the diary study method. This also contains a detailed description of the content and implementation of the nudge intervention. Chapter 4 will describe the results gathered during the diary study and throughout further surveys conducted as part of this research. A comparison with existing findings from literature and an elaboration of implications for real-world practice will follow in chapter 5. A short conclusion will summarize and close this work in chapter 6.

2 Literature review

This chapter analyzes relevant studies and theories in the fields of consumer FW and nudging and will set the framework for this study. It reviews existing literature in order to motivate the research question and experiment of this research. Chapter 2.1 will focus on consumer FW, providing an overview of relevant terms, definitions, and classifications of FW as well as drivers and barriers to food waste reduction. Chapter 2.2 will introduce the concept of nudging and explore relevant intervention studies that combine nudge interventions with observations related to consumer FW topics.

2.1 Consumer food waste

Scientists argue that as much as half of the total food produced for human consumption is discarded before or after it reaches the consumer (Lundqvist et al., 2008). In developing countries, most of the FW occurs early in the supply chain. In developed countries, the largest share of FW can be observed in the later stages of the food supply chain (Gustavsson et al., 2011). Therefore, the role of consumers becomes critical in the discussion of preventing and managing FW.

2.1.1 Overview, definitions, and classification

The EU defines food as “...any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans” (Regulation (EC) No 178/2002, 2002). Food can be wasted or lost at any stage throughout the food supply chain (Papargyropoulou et al., 2014). As per the FAO (1981) definition, FW includes any edible material suitable for human consumption, which is discarded, lost, degraded, or consumed by pests at any stage within the food supply chain. Later, researchers started to further distinct between *food waste* and *food loss* (Östergren et al., 2014). *Food loss* refers to the reduction in the amount of food that was originally intended for human consumption at various stages before reaching the consumer level. These stages include harvesting, processing, and primary agricultural transformation (BCFN, 2012; FAO, 2011; Parfitt, 2011; Parfitt et al., 2010). *Food waste* describes the loss of appropriate food for human consumption that is discarded at the consumer or retail level downstream in the food supply chain (FAO, 2011; Parfitt et al., 2010; Rezaei & Liu, 2017). In this study, the main focus will remain on consumers at the household level. Therefore, the definition used by Calvo-Porrall et

al. (2017) and Visschers et al. (2016) will serve as a guideline, describing FW as purchased food that is not consumed and ends up in the bin.

FW at the consumption stage can occur at several places. In the food service industry, restaurants, cafés, and hotels can give rise to FW. In the institutional sector, food may be wasted in education institutions, such as schools and universities, or in hospitals and prisons (Papargyropoulou et al., 2014). According to Stenmarck et al. (2016), around 50% of the FW generated in Europe can be attributed to the household level. Figure 1 summarizes the food supply chain and activities that give rise to food losses and waste in different stages of the food supply chain.

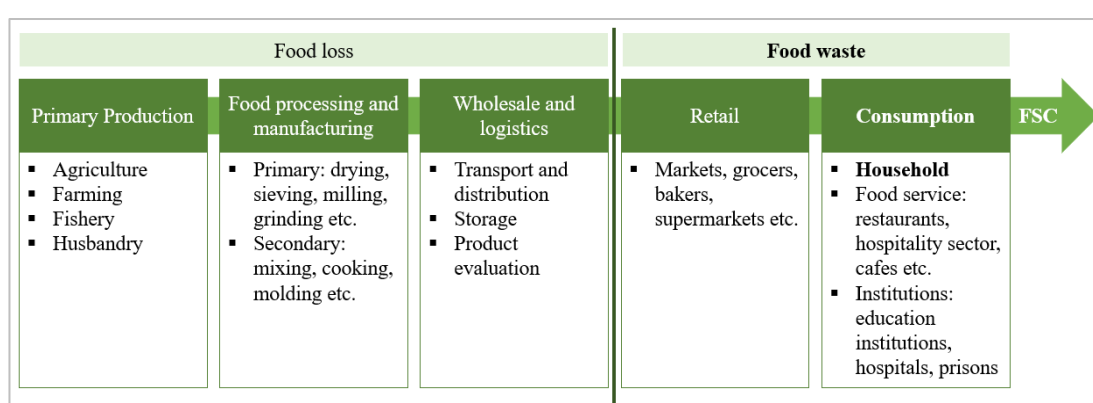


Figure 1: Food supply chain and activities that give rise to food losses and waste
Adapted from Papargyropoulou et al. (2014); Stenmarck et al. (2016)

When measuring FW, a distinction can be made between avoidable and unavoidable FW (Lebersorger & Schneider, 2011). Unavoidable FW refers to inedible preparations residues or leftovers that are not supposed to be eaten. This may include bones, rinds, eggshells, peels, and cores (Monier et al., 2010; WRAP, 2011). On the contrary, avoidable FW categorizes edible food that is either partly or wholly unused before it is thrown away (Kranert et al., 2012; Monier et al., 2010). Food that is intentionally given to animals and pets is also considered as avoidable FW (Stuart, 2009). The Waste & Resources Action Programme conducted some of the most extensive studies around household FW in the UK (Exodus, 2006; 2007; Lyndhurst, 2007; WRAP, 2009; 2011). In one specific study, the researchers collected waste from over 2,100 households in the UK and found that the majority of discarded food, approximately 61%, could be categorized as avoidable (WRAP, 2009). In Germany, Kranert et al. (2012) obtained similar findings with estimates indicating that 47% of FW was avoidable.

Another distinction can be made regarding the packaging and lifecycle stage of wasted food (Lebersorger & Schneider, 2011). Food can be discarded either in its original sales packaging or in other forms, for example, as a loose product or in individual packaging. For the purpose of this study, a differentiation among the packaging dimension will be only made between packed and unpacked/loose products. Figure 2 illustrates the categorization of FW among avoidability, lifecycle stage and packaging.

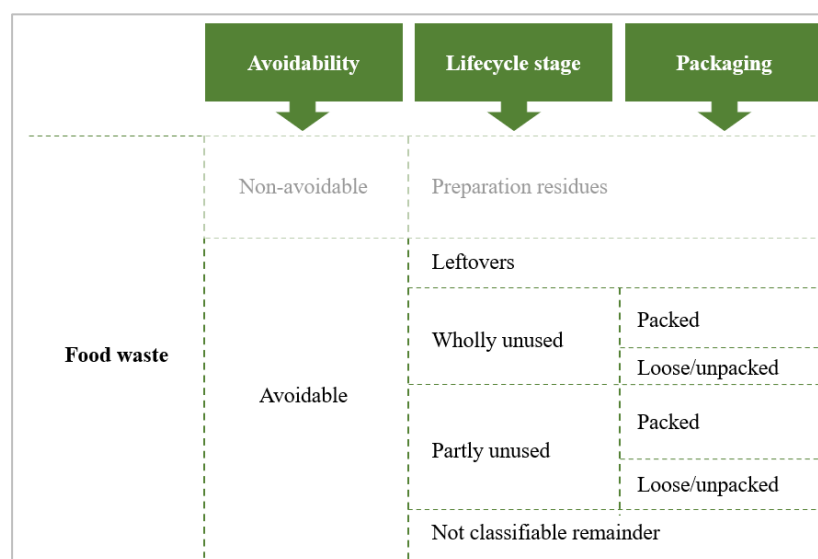


Figure 2: Classification of food waste among avoidability, lifecycle stage, and packaging
Adapted from Lebersorger & Schneider (2011)

Numerous studies have been undertaken to quantify the total amount of FW generated by consumers in their households. In the USA, Jones (2004) used food sector data along with compositional analysis and landfill site archaeology. He estimated edible FW per household per year to be 212 kg. In the UK, WRAP (2009) combined waste compositional analysis with household diaries and surveys, arriving at an estimate of 270 kg edible FW per household per year. For the EU, Stenmarck et al. (2016) utilized a combination of national waste statistics and previous research to estimate that a single person generates 173 kg of both inedible and edible FW, with 92 kg generated at the household level. Stenmarck et al. (2016) also included inedible parts of food in their calculations. The most commonly wasted type of foods are fruits and vegetables, followed by perishables like bakery and dairy products (Parfitt et al., 2010).

2.1.2 Drivers and barriers to food waste reduction

Consumer and household FW is a complex issue that is influenced on the one hand by demographical, cultural, and institutional elements and on the other hand by a variety

of behavioral and personal factors (Porpino, 2016; Schanes et al., 2018; Stangherlin & De Barcellos, 2018). Some scientists analyzed consumer and household FW from a psychological, moral, and demographic lens (Visschers et al., 2016). Others put their main focus on behavioral factors and especially household practices (Evans, 2012; Gangelbauer et al., 2013; Jörisen et al., 2015; Porpino et al., 2015; Stefan et al., 2013; Williams et al., 2012) or on both dimensions (Graham-Rowe et al., 2014; Neff et al., 2015; Quested et al., 2013). In an interview study conducted with 13 UK households, Graham-Rowe et al. (2014) concluded economic reasons as the main motivator for consumers' motivation to reduce FW. The waste of food is considered a waste of money, which triggers negative emotions. This finding is in line with Lyndhurst (2007) and Neff et al. (2015), who both rank waste of money as a top concern or a motivator for consumers to reduce FW. Graham-Rowe et al. (2014) found that "doing the right thing" (p. 18) is another motivator expressed by interviewees to reduce FW. This is consistent with findings by Abeliotis et al. (2014), who observed positive attitudes among Greek consumers towards reducing FW. Ethical reasons and moral attitudes are also highlighted by Neff et al. (2015). The findings of their survey, conducted with 1,010 US citizens, indicate that several factors serve as significant motivators to reduce FW. These include setting a positive example for children, considering the plight of hungry people worldwide, and experiencing feelings of guilt associated with waste in general. Environmental concerns seem to be a minor motive for food waste reduction (Neff et al., 2015). A possible explanation by researchers is that consumers are not aware of the link between the food they waste and the impact on the environment (Graham-Rowe et al., 2014; Quested et al., 2013; Stefan et al., 2013).

Instead of solely attributing consumer FW to individual motivation and attitude, Gangelbauer et al. (2013) propose that FW can be better explained by considering a wider range of factors, including daily behavioral practices at the household. So called household practices can be categorized into various dimensions, which include planning, shopping, storing, cooking, eating, and the managing of leftovers (Schanes et al., 2018; Stangherlin & De Barcellos, 2018). Indeed, planning behaviors, such as creating a shopping list, checking the fridge, freezer, and cupboards prior to shopping, and planning meals in advance have been found to be associated with a decrease in household FW (Jörisen et al., 2015). Farr-Wharton et al. (2014) argue that being informed about the current food supply decreases the likelihood for excessive

purchasing. Impulsive purchasing and over-purchasing can be categorized as waste-promoting behavior (Neff et al., 2015). How (i.e., temperature) and where (i.e., specific order system; storing food in the fridge or freezer) to locate food for proper storage and the creative use of food for cooking are also highlighted as major predictors of household FW by scholars (Farr-Wharton et al., 2014). Improved cooking skills are associated with reduced FW, since individuals are presumed to possess a better capacity to estimate cooking quantities and creatively use leftovers or ingredients nearing expiration (Gangelbauer et al., 2013; Graham-Rowe et al., 2014). The assessment of food edibility is another factor that is linked to household FW. Using the five senses instead of solely relying on the best-before-date is suggested to affect household FW (Williams et al., 2012). Finally, reusing leftovers is considered as one of the most effective household practices to decrease FW (Schanes et al., 2018).

The combination of subjective attitudes and behavioral factors that explain individual FW is often analyzed by applying the TPB (Graham-Rowe et al., 2015; Stefan et al., 2013; Visschers et al., 2016). The theory states that the intention to perform a specific behavior, i.e., reducing FW, is the main motivator for a behavioral change. The intention can be predicted by three factors, namely attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). In a consumer FW context, attitudes may relate to the general perception and moral attitudes towards FW. Subjective norms refer to the perception of FW within a specific context by the environment. Perceived behavioral control refers to an individual's belief in having the necessary skills and resources to carry out a specific behavior, like reducing FW, and feeling in control of that behavior (Stefan et al., 2013). In a large mail survey study, Visschers et al. (2016) analyzed the intention to reduce FW as the main predictor of self-reported FW. According to Stefan et al. (2013), however, the intention to reduce FW is not transformed into behaviors that lead to a reduction of FW. Graham-Rowe et al. (2015) extended the classical TPB model and found that self-identity and anticipated regret may also predict household FW. Overall, scientists agree that household FW is a complex issue that cannot be solely explained by individual habits, attitudes, and beliefs but rather by an interplay of these elements and further situational factors (Parizeau et al., 2015; Quested et al., 2013). As Hebrok & Boks (2017) aptly put it, "food turns to waste within a web of interrelated practices, tools, concerns, skills, knowledge and anxieties" (p. 20-21).

A common barrier to food waste reduction at the household level is the so-called good provider identity (Graham-Rowe et al., 2014; Visschers et al., 2016). According to researchers, humans tend to provide food in over-abundance as a means to express care and to minimize feelings of discomfort when food requirements cannot be met (Evans, 2012; Graham-Rowe et al., 2014). This behavior is especially noticeable among parents who want to ensure that there is enough food for their children, but it can also apply to other family members or guests in the household (Graham-Rowe et al., 2014). Reducing inconveniences can be a further barrier to food waste reduction. By stockpiling a large amount and variety of foods, the necessity to go shopping frequently decreases. The inconvenience of becoming sick due to food poisoning is decreased by throwing away food once it passed its best-before date, even if the food might be still edible (Graham-Rowe et al., 2014). The link between increased safety concerns and consumer FW is also highlighted by Evans (2012). A lack of priority and awareness on the issue of FW is a further barrier to food waste reduction (Graham-Rowe et al., 2014; Parizeau et al., 2015). Moreover, Williams et al. (2012) emphasize that packaging can be a reason for household FW. In their diary study, 20% of FW was attributed to packaging that was either too big or too challenging to empty.

There is no consensus regarding most socio-demographic characteristics and consumer FW (Schanes et al., 2018). For instance, in the study conducted by Jörissen et al. (2015), participants older than 60 years reported larger amounts of FW. In contrast, Quested et al. (2013) state that people older than 65 years waste less food. Further, there is support for both directions, whether FW is related to the gender (Schanes et al., 2018). Visschers et al. (2016) argue that young females with children and households with more than two residents generate more FW. The increased amount of FW in households with children might be explained by the unpredictability of childrens' eating preferences and the good provider identity (Neff et al., 2015). In a two-week diary study conducted among 380 Finnish households, Koivupuro et al. (2012) only found support for significant correlation between household size and the amount of wasted food. While the total amount of FW tends to be higher the larger the household, the FW per capita is smaller for single households (Koivupuro et al., 2012; Jörissen et al., 2015; Porpino et al., 2015). The Finnish researchers did not find any significance for the influence of education, employment, or income and FW. However, people that reported to frequently purchase discounted products wasted less food

(Koivupuro et al., 2012). Time constraints are also pointed out as a barrier to food waste reduction, suggesting full-time employment to be associated with more FW (Jörissen et al., 2015). Figure 3 provides a summary of the drivers and barriers to consumer food waste reduction at the household level discussed in this chapter.

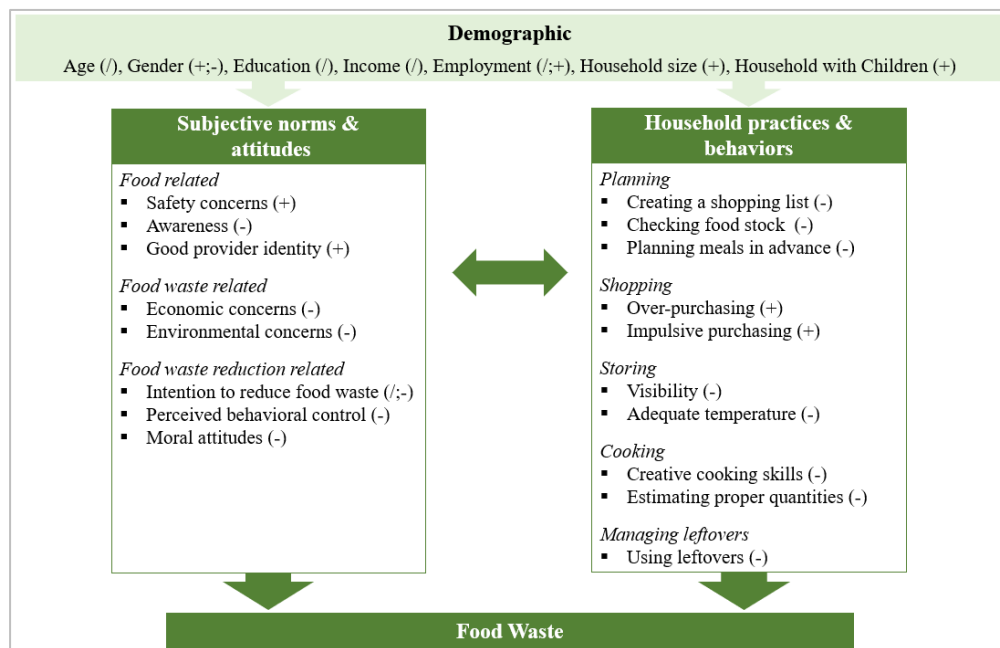


Figure 3: Drivers and barriers to consumer food waste reduction at the household level
(/) = No significant effect on food waste reduction; (+) = Barrier to food waste reduction; (-) = Driver to food waste reduction
Adapted from Stangherlin & de Barcellos (2018)

2.2 Nudging

Based on insights from cognitive and social psychology, behavioral economics deviates from the rationality assumptions of classical models and proposes that human decision-making is influenced by the situational context and behavioral biases (DellaVigna, 2009). Nudging is based on interventions and modifications in the choice architecture and decision environment of human beings, aiming to gently push individuals into socially and individually desirable directions (Thaler & Sunstein, 2008). Nudging has gained popularity in public institutions and businesses because it can yield significant effects without requiring implementers to invest substantial resources (Reisch et al., 2021; Sunstein, 2014; Thaler & Sunstein, 2008).

2.2.1 Overview, definitions, and classification

The originators of the nudging concept, Thaler & Sunstein (2008), define nudge as “[...] any aspect of the choice architecture that alters people’s behavior in a predictable

way without forbidding any options or significantly changing their economic incentives” (p. 6). The choice architecture involves the context or environment, including the physical reality and information basis, that influences an individual's decision-making process. This may include the number of choices available, the way in which choices are presented, and the default setting of different choices (Thaler & Sunstein, 2008). Examples of nudges can encompass a variety of scenarios, such as automatically enrolling employees into a pension plan, organizing food options in canteens to favor specific choices, and using nudges to encourage individuals to opt for sustainable transport options (Bornemann & Smeddinck, 2016; Sunstein, 2014). The main idea is to solve relevant issues regarding health, finances, and the environment in a simple, intelligent, and cost-effective way (Bornemann & Smeddinck, 2016; Ferrari et al., 2019). Thaler & Sunstein (2008) developed the theory of nudging based on Kahneman's (2011) observation that humans are equipped with two cognitive systems: the automatic system and the reflective system. While the reflective system takes slow, conscious, and controlled decisions, the automatic system is characterized by fast, unconscious, and uncontrolled decisions. The nudge approach uses the mechanisms of the automatic system by modifying the choice architecture to achieve a desirable choice in line with the natural flow of human nature (Thaler & Sunstein, 2008). Instead of supporting individuals to rationally evaluate the context and information, nudges leverage human cognitive biases to alter the choice architecture and push individuals gently into a desirable direction (Ferrari et al., 2019). The notion of desirable direction is crucial for the application of nudges. Thaler & Sunstein (2008) state that a desirable choice should be in favor of the consumer. That is, a choice that has generally healthy, economically, and environmentally favorable outcomes for the consumer and maximizes “the well-being for the recipients” (p. 16), as Von Kameke & Fischer (2018) state. Another condition that needs to be fulfilled for the application of nudges is that the recipient is aware of the nudge and can independently decide to avoid the nudge. As Sunstein (2014) states, nudges are “liberty-preserving” (p. 1). The nudge may steer the recipient into a certain direction, but without eliminating the option to freely make an own judgement and own choice. The German scientists Bornemann and Smeddinck (2016) identified five key criticisms concerning nudges: conceptual, normative, functional, empiric, and practical criticism (Von Kameke & Fischer, 2018). The conceptual criticism is

centered around the potential overlap between nudging and other intervention approaches, making it difficult to distinguish nudges from other methods that also aim to influence individuals' choice architecture. Even though the originators understand nudges as a liberty-preserving mechanism, normative critics argue that nudges deprive individuals from their own freedom and undermine objective decision-making. The functional criticism refers to the potential insufficiency of nudges to solve complex societal problems on a large scale. Further, the approach might hinder and dismantle the learning and decision-making processes of recipients in the long-term as a side effect. Empirical criticism refers to the question whether nudges are effectively working in a real-world context. Critics argue that most support for nudges arrive from laboratory settings. The final criticism of practicability stems from the empirical criticism described before. Real-world application of nudges would require a much more personalized approach as contexts and differences among individuals differ outside the laboratory. Both time and economic resources could outweigh the benefits of nudges (Bornemann & Smeddinck, 2016). Von Kameke & Fischer (2018) highlight that most of the five criticisms are referring to untransparent automatic default options, which are not in line with the original definition of nudges introduced by Thaler & Sunstein (2008). In consequence, most criticism can be overcome by ensuring transparent use and adequate planning of the nudges (Von Kameke & Fischer, 2018).

Different types of nudges exist, ranging from default rules to simplification, use of social norms, increase in ease and convenience, disclosure, pre-commitment strategies, reminders, eliciting implementation intentions, and informing people of the nature and consequences of their own past choices (Sunstein, 2014). Reminders represent a low-cost form of nudging that has been studied by scientists in various fields (Damgaard & Gravert, 2018). It has been proven that reminders can lead to behavioral changes in the context of gym attendance (Calzolari & Nardotto, 2017), personal savings (Karlan et al., 2016), adherence to medical treatments (Altmann & Traxler, 2014; Vervloet et al., 2012), and donating to charitable organizations (Damgaard & Gravert, 2018). The effect of reminders generally builds on the assumptions that human behavior is biased by a limited attention span, the tendency to post-pone tasks, and simple forgetfulness (Karlan et al., 2016; Sunstein, 2014). The application of reminders can prompt a specific behavior by refocusing the recipient's attention on the subject mentioned in the reminder (Damgaard & Gravert, 2018).

Sending electronic messages, for instance, serves as an effective and low-cost type of digital reminder and has been proven to be successful in the field of adherence to medical treatments (Vervloet et al., 2012).

2.2.2 Nudging and consumer food waste

As a low-cost instrument with promising effects on pro-environmental behavior, nudges have also gained a lot of attention in the area of FW (Barker et al., 2021; Nisa et al., 2019; Reisch et al., 2021). The fact that food purchasing, consumption, and handling are often results of automatic and unreflective habits suggests that nudges can be highly effective in influencing FW-related behavior (Lehner et al., 2016). Scientists have conducted tests on various household interventions to evaluate the effectiveness of different types of nudges (Linder et al., 2018; Nomura et al., 2011; Schmidt, 2016; Shaw et al., 2018; Shearer et al., 2017; Van der Werf et al., 2021).

The effectiveness of social norm nudges in the area of consumer FW has been tested by Nomura et al. (2011) as well as Linder et al. (2018). This type of nudge aims to inform people that a majority of people engage in a particular behavior (Sunstein, 2014). In both studies, the research teams conducted a field experiment to analyze the impact of the nudge on households' FW recycling behavior. Even though it is less effective than FW prevention, Papargyropoulou et al. (2014) classify FW recycling as one of several measures to manage FW. In both interventions, the researchers divided the sample population into one treatment and one control group. In the study conducted by Nomura et al. (2011), the treatment group households received a postcard that displayed a smiley or frown face, indicating how their street recycling efforts performed compared to other streets. After three months, results showed that the postcard-feedback received by the households had a modest positive impact on the recycling participation rate. The postcard was sent to households twice. In the study conducted by Linder et al. (2018), the treatment group received an information leaflet that offered guidance on recycling FW and encouraged households to participate in FW recycling, emphasizing the collective effort with their neighbors. Over a period of two years, the households' recycled FW was weighted through collection vehicles every two weeks. The recycled food quantities of households receiving the postcard were significantly larger, and the effect was still measurable eight months after the intervention.

Author, year	Aim of study	Nudge type	Data collection method	Sample size, country	Measurement	Time horizon	Comparison between groups	Result	Selected elements deviating from this study
Nomura et al. (2011)	Testing whether giving people feedback on their street participation recycling rate compared with others can promote recycling of FW	Social norm	Field experiment	9,082 households, UK	Participation in recycling scheme measured at three points of time	Three months	1x control group 1x treatment group	Feedback did have a modest positive impact on participation in the recycling scheme	Focus on FW recycling; social norm nudge; field experiment
Schmidt (2016)	Increasing the likelihood of household FW prevention by improving performance of food waste-preventing behavior	Pre-commitment	Diary study	217 households, Germany	Self-reported FW preventing behavior	Four weeks	1x control group 1x treatment group	Notable enhancement of self-reported implementation of recorded food waste prevention behavior	FW measured indirectly; pre-commitment nudge
Shearer et al. (2017)	Assessing the impact of using a sticker prompt reminder to encourage the separate collection of FW for recycling purposes	Reminder	Field experiment	64,284 households, UK	Collection vehicle monitoring and weighting	31 weeks	1x control group 1x treatment group	Significant increase in recycling FW in treatment group	Focus on FW recycling; sticker prompt used as a reminder nudge; field experiment
Linder et al. (2018)	Measuring the effectiveness of an information leaflet containing a social norm nudge to promote recycling of FW	Social norm	Field experiment	474 households, Sweden	Collection vehicle weighting every two weeks	Two years	1x control group 1x treatment group	Recycled FW quantities larger in treatment group, even 8 months after intervention	Focus on FW recycling; field experiment
Shaw et al. (2018)	Analyzing the influence of disclosing information regarding environmental and economic consequences of household FW on quantity of wasted food	Disclosure	Field experiment	60 households, UK	Weekly weight analysis of food waste set out in curbside-collected containers	Four weeks	1x control group 2x treatment group	No significant difference in the weekly total avoidable FW before and after the intervention	Focus on disclosure nudge; field experiment
Van der Werf et al. (2021)	Analyzing FW behavior by encouraging money-saving behavior through disclosure of economic effects of FW and behavioral tips on how to reduce FW	Reminder & Disclosure	Field experiment	112 households, Canada	Measurement of pre- and post-intervention curbside garbage samples	One month	1x control group 1x treatment group	FW was significantly lower in treatment households	Two types of nudges applied; sticker prompt used as a reminder nudge; field experiment

Table 1: Overview of intervention studies related to nudging and consumer food waste at the household level

The study by Schmidt (2016) is among the few nudge intervention studies that utilized diaries. The scientists conducted a diary study involving 217 German households and implemented a pre-commitment nudge as part of their intervention. Following a pre-survey to assess each household's FW prevention behavior, participants received a specific recommendation for the next four weeks. For instance, participants may have been advised to create a shopping list prior to shopping. During the study, participants were required to confirm their commitment to follow the waste prevention behavior on an online platform used for data exchange with the researchers. By setting a specific goal and committing to the recommended behavior, the self-reported performance of recorded FW prevention behavior of the treatment group improved significantly compared to the control group. The researchers chose to measure FW indirectly as they argue that participants in diary studies tend to underestimate FW.

The disclosure nudge aims at disclosing economic, environmental, or social cost of a certain activity or behavior (Sunstein, 2014). In a field experiment involving 60 UK households, Shaw et al. (2018) examined the effectiveness of disclosing information about the environmental and economic consequences of household FW on the quantity of avoidable FW generated by the participating households. One treatment group received an information leaflet disclosing economic impacts, and another treatment group received an information leaflet that disclosed the environmental impacts of FW. A third group served as a control group. With the support of curbside-container collectors, the FW was collected, analyzed, and weighted weekly over a period of four weeks. The information leaflets were distributed in the middle of the study, after the second collection. The researchers could not find significant differences in the weekly total avoidable FW before and after the intervention (Shaw et al., 2018). The researchers argue that the short post-intervention period of two weeks might have been too short to alter households' FW behavior and prove significant results.

Reminder nudges have been tested in the area of consumer FW by Shearer et al. (2017) and Van der Werf et al. (2021). Shearer et al. (2017) tested the impact on recycled FW of a sticker prompt that stated, "NO FOOD WASTE PLEASE" and further encouraged households to use their recycling caddy. In a large field experiment with 64,284 UK households, the researchers observed a significant increase of recycled FW in the treatment group. The food was monitored and measured by collection vehicles over a

period of 31 weeks. Van der Werf et al. (2021) developed an intervention package that aimed to reduce consumer FW at the household level by highlighting the potential to save money. In line with prior research (Graham-Rowe et al., 2014; Neff et al., 2015), participants stated that economic reasons are the strongest motivator to decrease FW. The intervention package included a postcard and fridge magnet, that stated, “Reduce Food Waste, Save Money”, and explained that an average household in the study area wastes 125 kg of food worth \$600 per year. Further, the postcard and magnet included tips on how to improve food planning, purchase, storage, preparation, and managing of leftovers (Van der Werf et al., 2021). As the researchers combined both tips on how to better manage FW and disclosed economic information on the post card and fridge magnet (visual prompt), this intervention included both a disclosure, and reminder nudge. The intervention field experiment was conducted over a period of one month with 112 households in Canada. The researchers observed significant less FW in treatment households compared to the control group.

Table 1 summarizes the characteristics of intervention studies related to nudging and consumer FW at the household level. Table 1 also highlights deviating elements to the present study design, which will be explained in detail in the next chapter.

3 Methodology

This research used a quantitative diary study design to examine the effect of a reminder nudge on consumer FW in an experiment involving 28 participants, primarily located in the area of North-Rhine-Westphalia, for a period of four weeks. Even though self-reported data on FW can be subject to biases, diary studies are commonly employed in the field of consumer FW research (Quested et al., 2020; Reynolds et al., 2019; Van Herpen et al., 2019). Diary studies enable researchers to obtain detailed insights into everyday events that would otherwise be inaccessible to them. The method was well suited for this particular experimental study since it allowed the collection of in-depth data over an extended period of time, allowing one to observe behavioral changes closely (Richter & Bokelmann, 2017). Diary studies are usually conducted for one or two weeks (Richter & Bokelmann, 2017). As this particular study aimed at analyzing the potential effects of a reminder nudge on a specific routine and habitual behavior, namely the consumer’s FW behavior, the diary study was conducted for an extended period of four weeks between the middle of May 2023 and the middle of June 2023.

3.1 Participants

Diary studies impose high effort on participants (Van Herpen et al., 2019). The reliability and validity of the data gathered during diary studies are closely linked to the active participation of respondents. Due to time and budget constraints, the researchers of this study chose a mixture of convenience and snowball sampling to recruit participants. As a consequence, the majority of participants were friends and acquaintances of the author. In light of this particular study, the relativeness between the author and participants ensured a high participation rate, which ensured a full set of data. Convenience sampling has been used priorly by other scientists in the area of intervention studies and consumer FW (Schmidt, 2016; Linder et al., 2018). The study conductor recruited the 28 participants within one month prior to the beginning of the diary study. Only participants who predominantly stayed at home and did not have extended physical absences during the study period were included to ensure data completeness and minimize the influence of significant outliers.

Category	Element	Quantity
Age	20-30	13
	30-40	4
	40-50	5
	60-70	6
Gender	Male	15
	Female	13
Household type ¹	Single	7
	Couple	11
	With children	5
	Shared	7
Number of residents per household	1	7
	2	11
	3	6
	>4	4
Number of rooms per household	1-2	7
	3-4	8
	5 or more	13
Type of education	High school degree or equivalent	2
	University, no degree	5
	Bachelor's degree	11
	Master's degree	10
Employment type ¹	Employed, part-time	7
	Employed, full-time	7
	Self-employed	6
	Studying	9
	Not employed	1
	Retired	2
	Not specified	1
Pets in household	Yes	5
	No	23

¹ Multiple choices possible

Table 2: Socio-demographic background of the sample (n=28)

In general, the sample population was not representative of the entire population of German households. The age range from 20 to 30 years old was over-representative due to the chosen sampling method. However, as some studies argue that elderly people tend to waste less food because of frugality and historical experiences (Schanes et al., 2018), studies focusing on sustainability and the younger generation might reveal important implications. Additionally, a large share of the sample consisted of working individuals, with only a few exceptions being pensioners, and the majority of participants were academics. In order to guarantee discreteness, the number of rooms per household served as an estimate for the household income. Nevertheless, some characteristics were congruent with an average German household, namely the number of people per household and the gender distribution (Statistisches Bundesamt, 2022; 2023). The socio-demographic background of the sample is summarized in Table 2.

3.2 Procedure

This subchapter elaborates the design and implementation of the nudge. Further, it explains the data collection procedure in detail. Besides the diary study, this research included two additional surveys: the initial survey one week prior to the diary study period and the final survey one week after the diary study period. The additional surveys functioned as an informational complement to contain reliable data and to maximize the robustness of the diary study (Richter & Bokelmann, 2017).

3.2.1 Nudge design

In their systematic literature review, Reisch et al. (2021) emphasize the need for intervention studies that specifically focus on single nudges, as the majority of existing studies employed designs involving multiple nudges. Nisa et al. (2019) also propose to single out interventions to isolate the main effects of the intervention. Therefore, this study implemented a single text message reminder as a nudge. To the best of the author's knowledge, this is the first diary study to test the effectiveness of a digital reminder in the area of consumer FW at the household level in an experiment over a period of four weeks. The participants were randomly split into two same-sized groups with similar characteristics. Over the course of the study, the treatment group (further referred to as nudge group (NG)) received a text message reminder, while the control group (CG) only received a neutral message each time the reminder nudge was sent.

The aim of the nudge was to reduce FW by preventing food from being forgotten in the fridge and potentially starting to spoil. Therefore, the nudge aimed to remind participants to regularly check their fridge for available food and items nearing expiration to facilitate mindful consumption and waste prevention. Furthermore, the nudge recommended performing the behavior before the next grocery shopping trip or cooking session. By specifically referring to the next grocery shop and cooking session, the nudge also intended to raise participants' awareness of the available food stock to avoid purchasing duplicate items or choosing to cook a fresh meal instead of using leftovers. This way, the following household practices could be potentially triggered: *checking food stock, using leftovers*. The nudge was distributed via WhatsApp, and the participants were addressed as "participants" in order to verify that the message was received as part of the study and not as a private message from the author. This study chose a simple and neutral nudge design since this has been proven to show the strongest effect in other intervention studies that used reminder nudges for medical adherence and health prevention (Altmann & Traxler, 2014; Vervloet et al., 2012). In particular, the text message stated:

Dear participants, have you checked your refrigerator today?
Do you know which foods are still in stock and which are about to expire?
Best check before you go cooking and shopping next time.
Thank you for your support!
[Initial wording translated from German]

The timing of a reminder is critical for its success (Sunstein, 2014). Studies prove that recipients of reminders often respond immediately or within hours after receiving the reminder (Calzolari & Nardotto, 2017; Damgaard & Gravert, 2018). To ensure that all participants were able to react immediately or almost immediately to the nudge, it was sent at 8 a.m., before participants left their house. Damgaard & Gravert (2018) also refer to the psychological and practical cost associated with reminders. Receiving repetitive messages aimed at triggering a certain behavior can result in perceived pressure to perform the behavior or guilt if the behavior is not carried out. Additionally, the message and subsequent behavior demand participants to spend time and to increase awareness. To minimize possible perceived cost and maximize the effectiveness of the nudge, it was sent out every two to three days in alignment with the self-reported shopping frequency of the majority of participants. This approach increased the probability of participants receiving the nudge before going shopping and checking their food stock, while also reducing potential annoyance costs.

Over the full period of four weeks, the nudge was sent out ten times to the NG. The sending schedule design was randomly created while adhering to a small set of constraints: There was a maximum of two consecutive days without a reminder, and no reminders were sent on public holidays. The first nudge was distributed on the second day of the diary study in order to not overload participants with information and tasks on the first day. Every time the NG received a reminder message, the CG also received a neutral message in order to minimize potential biases through increased traffic on WhatsApp with the study conductor. The neutral message asked participants if they had questions regarding the study procedure and also contained an acknowledgement for the support. All messages were distributed via WhatsApp “Broadcast”. This way, one message could be sent to all participants, or participants in one specific group, at the same time with the same content.

3.2.2 Data collection

All surveys in the study were conducted with Google Forms, a free software to create and distribute online surveys. One week prior to the start of the diary study, an initial survey was conducted. The initial survey served two main purposes: first, to collect data on demographic characteristics and FW-related behaviors, which could be used to provide context and complement the information gathered from the daily diary entries. Second, the initial survey ensured that the nudge content and frequency were in alignment with participants’ routines and habits, i.e., the shopping frequency, checking food storage prior to shopping, being responsible for grocery shopping, and the willingness to improve the sustainable use of food in their own household as a prerequisite to receiving the nudge. Participants received the link via WhatsApp and were given five days to fill out the survey. On the first page of the initial survey, a detailed explanation of the legal framework, the rights of participants and the study conductor, as well as the anonymity requirements, were listed. After signing a consent form and agreeing to the terms and conditions for the initial survey as well as all subsequent surveys, the next page of the survey opened. On the second page, participants created their personal ID, consisting of the third letter of the first name, the second letter of the last name, and the last digit of the birth year. The ID was created to facilitate the data analysis. The initial survey was split into five sections. The first section, as explained above, introduced the participants to the study and set the formal framework. In the second section, participants entered their demographical data. The

main demographics elaborated in 2.1.2 and listed in Table 2 were gathered. Additionally, participants were asked if they are mainly responsible for grocery shopping in their household, to verify the likelihood of reliable and complete data. The third section asked participants for their grocery shopping and dining habits, an area that has not been extensively researched in the context of consumer FW yet. Section four focused on FW-related household practices, which were included based on established research by Lyndhurst (2007), Stefan et al. (2013), and Von Kameke & Fischer (2018). The fifth section aimed at identifying participants sustainability behavior and willingness to improve the sustainable use of food in their own household. The last question served as a prerequisite to distribute the nudge. As explained in 2.2.1, nudges should be in line with the interest of recipients (Sunstein, 2014; Von Kameke & Fischer, 2018). Therefore, it was required that participants receiving the nudge were willing to improve their FW-related behavior. Table 3 provides an overview of the characteristics of the initial survey.

Part	Content	Item	Scale Type
1	Introduction	Consent form Participant ID	Agree/disagree Open
2	Demographics	Age Gender Household type Residents per household Education Employment Pets in household Mainly responsible for grocery shopping ^a	5 options ^d m/w/d 4 options ^d 6 options ^d 6 options ^d 7 options ^d Yes/no Yes/no
3	Shopping & dining habits	Buying groceries ^a Ordering food Go dining Cooking	4 Options ^e 4 Options ^e 4 Options ^e 4 Options ^e
4	FW-related household practices	Creating a shopping list prior to shopping ^b Checking food stock prior to shopping ^b Planning meals for the next days ^b Cooking a greater amount of food lasting for several days Purchasing more food than able to consume ^c	Likert 1-7 ^f Likert 1-7 ^f Likert 1-7 ^f Likert 1-7 ^f Likert 1-7 ^f
5	Sustainability related	Would you like to do more for the sustainable use of food in your own household? Are you a member of a nonprofit organization that works on sustainability issues?	Likert 1-5 ^g Yes/no

^a Von Kameke & Fischer (2018)

^b Stefan et al. (2013)

^c Lyndhurst (2007)

^d See Table 2

^e "Daily"; "Every two to three days"; "Once per week"; "Less than once per week"

^f "Never" (1) to "Always" (7)

^g "Yes, absolutely"; "Rather yes"; "Neither yes nor no"; "Rather no"; "No, definitely not"

Table 3: Characteristics of the initial survey
[Initial wording translated from German]

The daily survey formed the basis for the diary study and was sent out to participants every day at 6 p.m. throughout the four-week diary period. It consisted of five sections. In the first section, participants filled in their ID. Next, they stated whether food had been discarded at that day. The term “discarded food” was consciously chosen as “food waste” could have potentially triggered negative emotions, such as guilt. Section two asked participants for the product group. This study chose an exhaustive list of product groups mainly based on previous research by Jörisen et al. (2015) and Visschers et al. (2016) to ensure that all types of FW would be captured. Participants specified the packaging and lifecycle stage of the food in section three. In section four, participants stated the estimated weight in grams of wasted food. Prior research shows that FW recorded in diary studies tends to be smaller than the amount that is measured in waste-composition analysis (Schmidt, 2016; Van Herpen et al., 2019). However, as the goal in this study was to compare FW between treatment groups rather than quantify representative FW data for households in Germany, self-reported estimations were a valid method. In a comparison between multiple household measurement techniques, Van Herpen et al. (2019) prove that diaries correlate strongly with other methods, such as kitchen caddies and photo coding. The chosen method also required the least effort for participants and the study conductor. Additionally, by not using photos or caddies, participants were exposed to a lesser extent to the amount of food they wasted, potentially reducing the likelihood of triggering strong behavioral reactivity (Quested et al., 2020). In the last section of the daily survey, participants stated the reason for disposal. Table 4 summarizes the characteristics of the daily survey.

Characteristics of wasted food	Sub-categories
Product group	“bakery”; “meat, fish & tofu”; “dairy & eggs”; “wheat products (pasta, rice, cereal)”; “fruits & vegetables”; “nuts”; “sweets & snacks”; “bread spreads”; “aromatics, sauces, herbs & spices”; “cooked & ready meals”; “drinks”
Packaging and lifecycle-stage	“packed (unopened)”; “packed (opened)”; “loose/unpacked & disposed entirely”; “loose/unpacked & disposed partially”; “cooked leftovers”
Food waste in grams	Open
Reason for disposal	“moldy”; “best-before-date”; “looks or smells bad”; “cooked to much”; “served too much”; “stored too long in fridge”; “stored too long in cupboard”; “over-purchasing”; “spontaneous change of plans”; “other”

*Table 4: Characteristics of the daily survey
[Initial wording translated from German]*

Following the four-week diary study period, this study conducted a final survey to assess the perceived behavioral change of the participants resulting from taking part in the diary study, to analyze their perception of the nudge, and to measure control variables. Nisa et al. (2019) call for studies that examine the long-term effects of interventions and nudges after their implementation is completed. Hence, the final survey included questions to analyze participants' likelihood to be more aware of FW in the future. Due to time constraints in conducting this study, it was only possible to assess potential long-term effects by asking participants for their own subjective views and perceptions. Objective measurements of long-term effects were not feasible within the study's timeframe. Evaluation regarding the nudge included both positive and negative elements. This ensured a proper assessment of positive effects and negatively perceived cost on the side of the participants (Reisch et al., 2021). Control variables mainly addressed the inaccuracy of reporting, i.e., the time spent in absence from home and the completeness of captured FW data. Table 5 provides an overview of the characteristics of the final survey.

Category	Item	Scale type
Perceived behavioral change	I became more aware of food waste due to the study ^a	Likert 1-5 ^c
	I think that I have changed my behavior in the past four weeks due to the study ^a	Likert 1-5 ^c
	I intend to pay more attention to food waste in the future ^a	Likert 1-5 ^c
Evaluation of reminder nudge	The reminder has helped me check my fridge and food supplies more regularly	Likert 1-5 ^c
	The reminder has helped to plan my purchases better (e.g., more appropriate quantity, less impulse shopping)	Likert 1-5 ^c
	The reminder has helped me to use soon to expire, or soon to go bad food more often	Likert 1-5 ^c
	The reminder has helped me waste less food	Likert 1-5 ^c
	The reminder has contributed to me feeling annoyed ^b	Likert 1-5 ^c
	The reminder made me pay less attention to communication via WhatsApp (as part of the study) ^b	Likert 1-5 ^c
	Would you say that a regular reminder by message (e.g. as in the study) is an appropriate method to reduce food waste in private households?	Likert 1-5 ^c
Inaccuracy of reporting	Have you been away from home for more than three days at a time in the last four weeks?	4 Options ^d
	Possibly food was thrown out in my household without it being reported ^a	Likert 1-5 ^e
	I know exactly what other household members threw out in the past two weeks ^a	Likert 1-5 ^e

^a Van Herpen et al (2019)

^b Daamgard & Gravert (2016)

^c “Strongly disagree”; “Disagree”; “Neither agree nor disagree”; “Agree”; “Strongly agree”

^d “No”; “Yes, once”; “Yes, twice to three times”; “Yes, more than three times”

^e “No, never”; “Yes, rarely”; “Yes, sometimes”; “Yes, frequently”; “Yes, always”

Table 5: Characteristics of the final survey
[Initial wording translated from German]

3.3 Measures

As mentioned earlier, self-reported data in diary studies can be subject to biases, and previous research indicates that individuals often underestimate self-reported FW (Schmidt, 2016; Van Herpen et al., 2019). However, the primary goal of this study was to analyze the impact of a digital reminder nudge on the FW behavior of the participants. Therefore, the relative differences and developments of FW throughout the diary study between groups were more important than particular absolute measures. In consequence, the following hypothesis had been developed:

Hypothesis: *Reminder nudging decreases consumer FW.*

The food waste quantities (*FWQ*) collected in the daily survey were utilized to test the hypothesis. Initial independent t-test were applied to gain first insights on the effect of the *nudge* on *FWQ*. A two-way repeated measures ANOVA was conducted to examine the interaction effect of *nudge* and *time*. This was essential because the *nudge* targeted habitual behavior, which may require time to change and be replaced by new habits. In a next step, the variable willingness to increase the sustainable use of food in participants' households (short: *willingness*) and its effect on *FWQ* was analyzed. This analysis was based on promising results from previous findings provided by the TPB and consumer FW. A second two-way repeated measures ANOVA was employed to measure the interaction effect of *nudge* and *willingness*. Control variables were considered during calculations to minimize reporting biases, and significant outliers were removed. The method used by Schmidt (2016) was rejected because measuring FW preventive behavior daily could have inadvertently reminded participants in both groups to conduct certain behaviors, such as checking the food stock or using leftovers. This might have introduced more noise to the experiment, posing challenges to isolate the specific effect of the *nudge*. Next to the hypothesis test, the information on FW behavior gathered in the initial survey were compared with the *FWQ* observed in the daily surveys. Constructs outlined in Table 3 and Table 4 served as measurements for analyzing the influence of certain elements, i.e., *demographics*, *FW-related household practices* and *dining habits* on *FWQ*. Additional data collected in the daily survey, such as *product group*, *reason for disposal*, and *packaging and lifecycle stage*, were studied to contribute the findings of this study to existing research. Lastly, the study analyzed the subjective perceptions of participants who received the *nudge*, particularly focusing on its influence on selected *FW-related household practices* and

FW awareness. Figure 4 illustrates an overview of the measurement instruments used in the study and their interrelations among the different surveys.

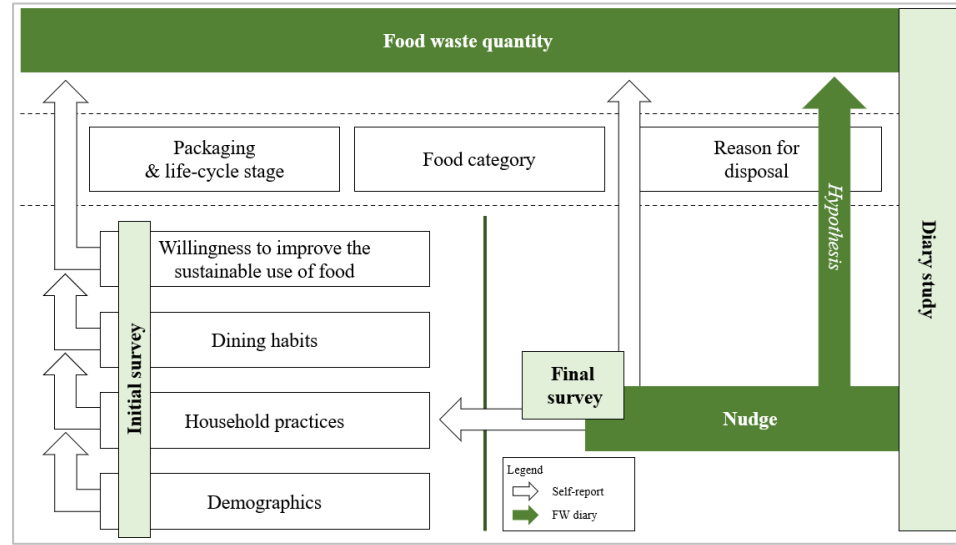


Figure 4: Overview of measurement instruments used in the study

4 Results and analysis

This chapter elaborates the results of the diary study and both additional surveys. It provides an overview of the sample and relevant descriptive statistics as a baseline before presenting findings and results concerning the research question of this study. This section tests and comments the hypothesis of this research by applying a two-way repeated measures ANOVA. It also outlines further observations and relevant findings that can be observed between variables, comparing them with data gathered in the final survey for a comprehensive perspective.

4.1 Descriptive statistics

As explained in section 3.2.2, the initial survey collected data concerning participants' *demographics*, *FW-related household practices*, and *dining habits* to gain first insights into possible influencing factors on FW behavior. Further, an overview of these variables helped to ensure the similarity between both study groups. Overall, there were no significant *demographic* or other differences regarding the aforementioned characteristics between both groups. The number of females and males were equal in both groups. The average *age* in the CG was 32 years and in the NG 31 years, respectively. In the NG, the average *number of rooms per household* and *residents per household* were slightly higher, but control variables ensured that this difference did

not influence the reported *FWQ*. The number of students was equal in both groups. Some *employment types* were slightly imbalanced between both groups. The CG contained three more full-time employees, while all self-employed participants ($n=4$) were part of the NG. The households *with children* were almost equally distributed between both groups. Characteristics concerning the frequency of *grocery shopping*, *cooking*, *ordering food* and *going dining* were similar for both groups. Most participants reported to *cook* almost daily, to *go grocery shopping* every two to three days and to *order food* or *go dining* once a week. Participants in both groups reported similar behavior regarding FW-related household practices in the initial survey. Participants in the NG reported slightly higher values for *creating a shopping list* and *checking food stock*, while participants in the CG reported higher values regarding *planning meals in advance* and *cooking for several days*. Both groups reported low values for *over-purchasing*. Figure 5 below presents selected FW-related household practices of participants in the nudge and control group.

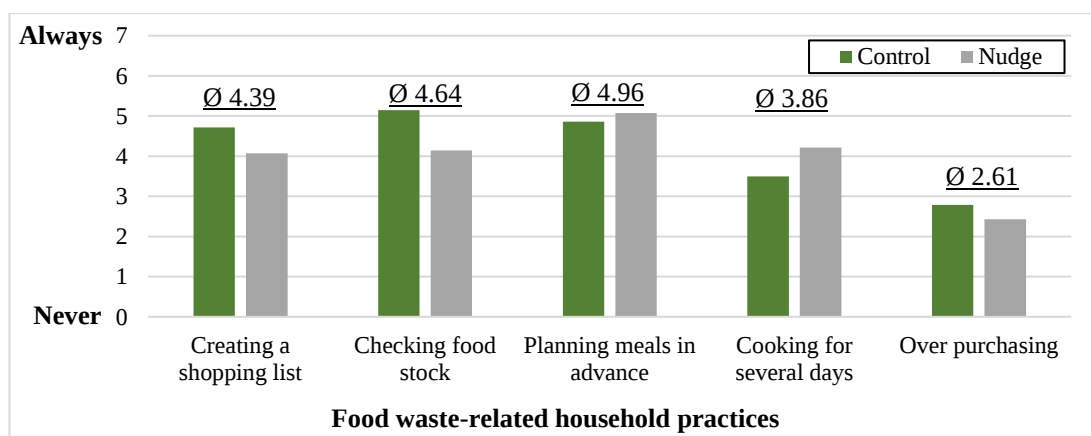


Figure 5: Selected FW-related household practices of participants in the nudge and control group

Over the four-week study period, a total of 42.84 kg of FW was reported. “Fruits & vegetables” accounted for the largest type of *product group* (17.92 kg), followed by “cooked food” (5.73 kg), “dairy & eggs” (4.75 kg), and “bakery” (4.49 kg). The main *reasons for disposal* reported were “moldy” (9.26 kg), “looks bad or smells bad” (8.10 kg), and “forgotten in the fridge” (7.70 kg). The majority of FW in terms of *packaging and lifecycle stage* resulted from “loose/unpacked & disposed partially” (12.83 kg) and “packed (opened)” food (11.54 kg). Among the above-mentioned three categories, some differences occurred between study groups. In both groups, “fruits & vegetables” accounted for the largest part of FW, while in total comparison, the NG reported more FW in this category. On a daily average base, however, the difference was not

significant ($M_N = 155.29$, $SD_N = 160.47$ vs. $M_C = 153.33$, $SD_C = 160.91$, $t(101) = 0.06$, $p = 0.47$). The NG reported higher *FWQ* in the categories “dairy & eggs”, “bakery”, and “meat, fish & tofu”. The CG reported significantly higher *FWQ* in the category “cooked & ready meals” than the NG ($M_N = 138.89$, $SD_N = 85.79$ vs. $M_C = 263.53$, $SD_C = 236.17$, $t(53) = -1.95$, $p = 0.032$). Some minor imbalances can be observed in the *product groups* “wheat products” and “aromatics, sauces herbs & spices”. Figure 6 illustrates the findings described in this paragraph.

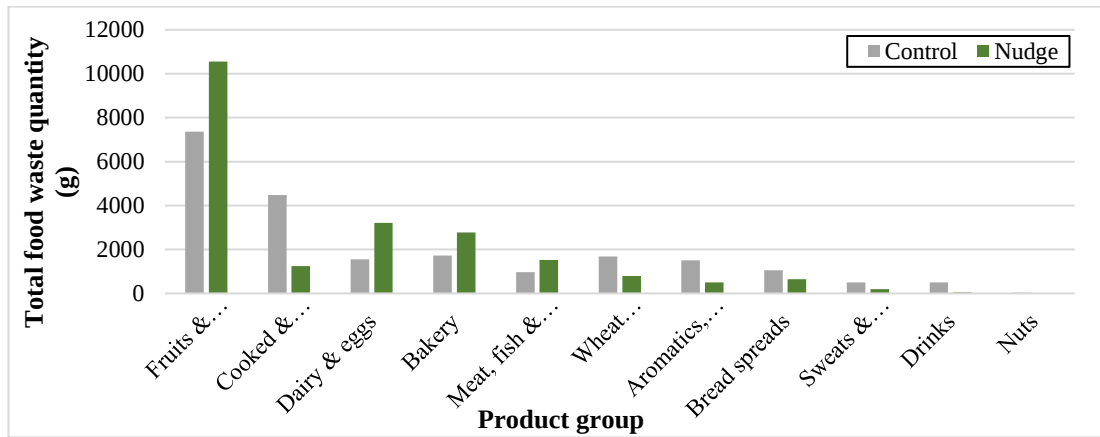


Figure 6: Total food waste quantity of the nudge and control group by product group

In terms of *disposal reasons*, some differences occurred between groups. Both groups equally reported “moldy” and “looks bad or smells bad” as the most frequent *disposal reason*. In comparison to the CG (2.18 kg), the NG (5.53 kg) reported a much larger *FWQ* due to “stored too long in fridge”, as can be seen in Figure 7. This finding is counterintuitive, as the *nudge* was aimed at reminding participants of food that might have been forgotten in the fridge. One possible explanation for the observed differences is the higher awareness of this type of *disposal reason* due to the reminder. Participants always had to choose between multiple *reasons for disposal*, which were not mutually exclusive. This may have influenced their responses and resulted in variations between the study groups. The frequency of diary entries for “stored too long in fridge” could support this explanation. Over the four-week period, the CG reported a total of nine diary entries, while the NG reported a total of 33 diary entries. Further, a large share of this type of FW in the NG resulted from a small number of participants, which can strongly influence results due to the small sample size. When observing the *disposal reason* “stored too long in fridge” over time, a steady decrease from week one to week three was observable in the NG. In week four, the *FWQ* in this category rose again but stayed below the quantity from week one. The CG did not

show a steady decrease between weeks for this *disposal reason*. Most importantly, there was no significant difference between both groups when considering the daily averages in this category ($M_N = 149.46$, $SD_N = 125.19$ vs. $M_C = 217.5$, $SD_C = 206.17$, $t(11) = -0.99$, $p = 0.17$). The CG reported larger *FWQ* for the *disposal reasons* “cooked too much” and “other reasons”, but differences were not significant.

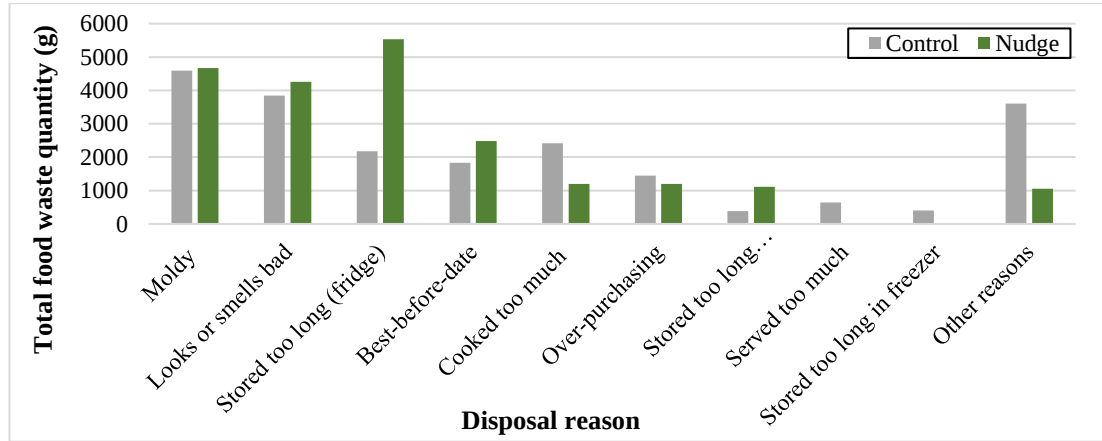


Figure 7: Total food waste quantity of the nudge and control group by disposal reason

Further group differences can be observed in the *packaging and lifecycle stage* of FW. Participants in the CG reported significantly higher *FWQ* for “packed” food products than participants in the NG ($M_N = 106.18$, $SD_N = 94.7$ vs. $M_C = 193.41$, $SD_C = 215.74$, $t(57) = -2.33$, $p = 0.01$). Participants in the CG also reported significantly higher *FWQ* for “cooked leftovers” ($M_N = 138.89$, $SD_N = 85.79$ vs. $M_C = 263.53$, $SD_C = 236.16$, $t(22) = 1.95$, $p = 0.03$). The NG reported higher *FWQ* for “loose/unpacked” food products, but the difference was not significant ($M_N = 137.98$, $SD_N = 155.99$ vs. $M_C = 122.78$, $SD_C = 176.59$, $t(68) = 0.42$, $p = 0.34$). Figure 8 compares the total *food waste quantity* of the nudge and control group by *packaging and lifecycle stage*.

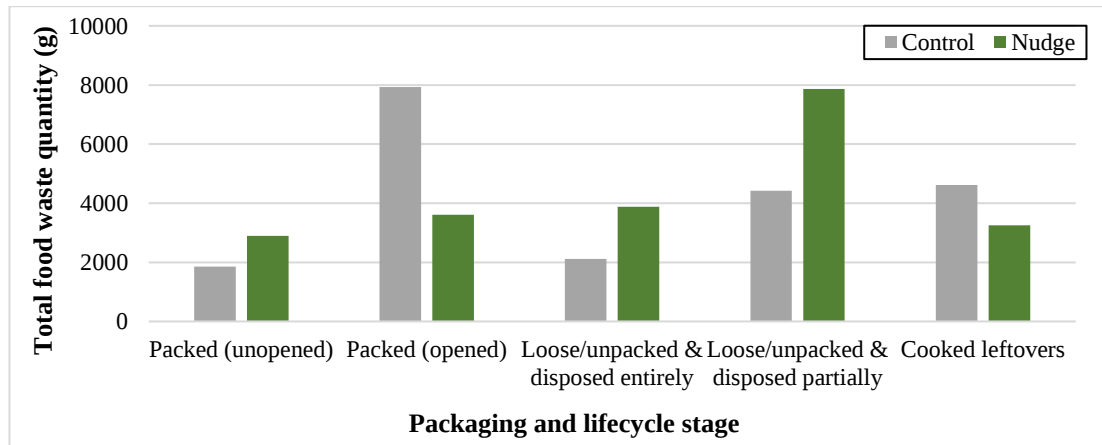


Figure 8: Total food waste quantity of the nudge and control group by packaging and lifecycle stage

Without considering the previously mentioned sub-categories, no noticeable differences in total *FWQ* between both groups could be observed at a first glance. The CG reported a total *FWQ* of 21.34 kg and the NG reported 21.5 kg of total *FWQ*, respectively. Data revealed minor differences in the size and quantity of diary entries between groups. In absolute terms, the CG reported higher *FWQ* in week one. In all subsequent weeks, the NG reported slightly higher *FWQ*. On a single-day basis, the CG reported higher *FWQ* than the NG on 16 out of 28 days. Both groups showed a slight decrease of *FWQ* throughout the study. When considering the entire sample, the average daily *FWQ* decreased from the first two weeks to the last two weeks. However, this decrease was not significant, as indicated by an independent t-test ($M_1 = 59.29$, $SD_1 = 49.99$ vs. $M_2 = 49.9$, $SD_2 = 56.42$, $t(53) = 0.64$, $p = 0.26$). Figure 9 illustrates the average daily *food waste quantity* of the nudge and control group throughout the study. A visual representation of all diary entries over time can be found in Appendix A, Figure A 1, and a weekly comparison in Appendix A, Figure A 2.

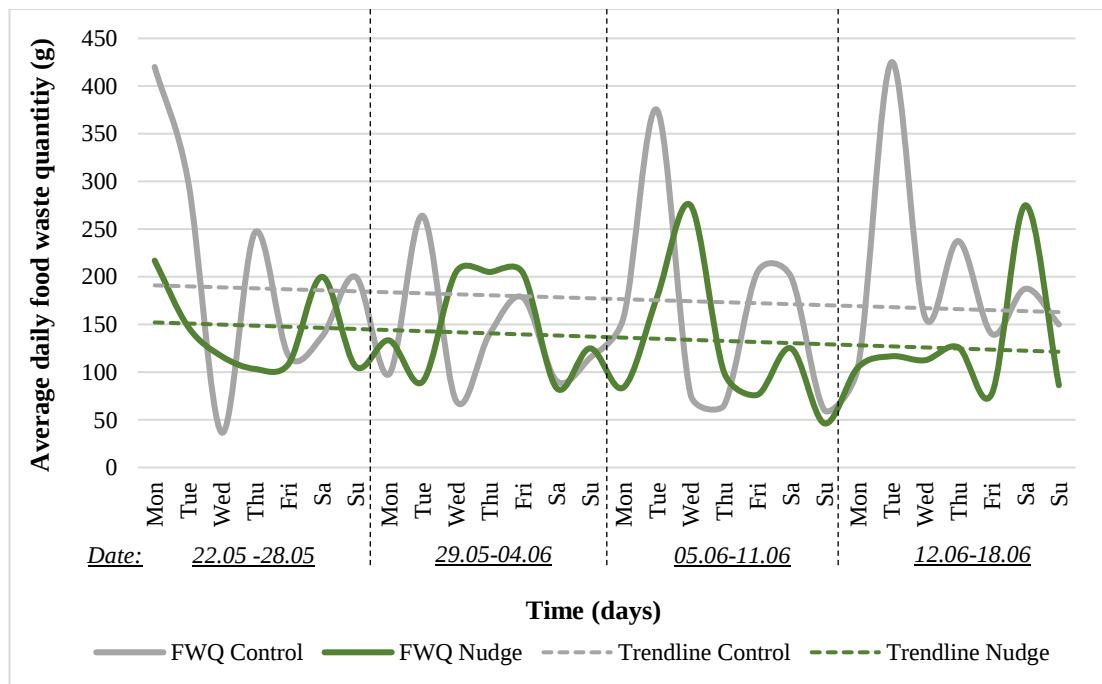


Figure 9: Average daily food waste quantity of the nudge and control group throughout the study

4.2 Testing of the effect of nudge on food waste quantity

To test the hypothesis of this research, whether a reminder *nudge* decreases consumer FW, this study compared the reported *FWQ* of both groups on a day-to-day basis over the four-week study period. As previously described in the descriptive analysis, there was no obvious difference observable when analyzing the weekly results between

groups. An independent t-test particularly based on average daily *FWQ* confirmed this first impression. The 14 participants receiving the *nudge* compared to the 14 participants in the CG showed no significant difference in daily reported *FWQ* ($M_N = 54.85$, $SD_N = 36.87$ vs. $M_C = 54.43$, $SD_C = 32.93$, $t(53) = 0.04$, $p = 0.48$). Since this study did not collect pre-intervention FW data, it applied an additional independent t-test to assess whether any distinct effects between the groups occurred over *time*. There was no significant effect of *time* on *FWQ* for both the NG ($M_{N1} = 58.11$, $SD_{N1} = 40.15$ vs. $M_{N2} = 51.58$, $SD_{N2} = 35.77$, $t(26) = 0.45$, $p = 0.33$), and the CG ($M_{C1} = 60.41$, $SD_{C1} = 40.44$ vs. $M_{C2} = 48.39$, $SD_{C2} = 25.09$, $t(22) = 0.94$, $p = 0.18$). A two-way repeated measures ANOVA (I) helped to confirm the findings from the t-tests and examine the interaction of *nudge* and *time*. The main effect of *time* was not significant ($F(1,27) = 1.16$, $p = 0.96$), as also indicated by the t-test. Most importantly, results of ANOVA (I) showed that there was also no significant interaction between the effects of *nudge* and *time* ($F(1,27) = 0.65$, $p = 0.91$). With regard to the results of ANOVA (I), the hypothesis could not be confirmed. Table 6 shows the results of the two-way repeated measures ANOVA (I) for the independent variables *nudge* and *time*.

Source of variation	SS	df	MS	F	P-value
Treatment	0.00	1	0.00	0.00	0.96
Time	0.61	27	0.02	1.16	0.26
Interaction	0.35	27	0.01	0.65	0.91
Error	14.22	728	0.02		
Total	15.18	783			

Table 6: Results of two-way repeated measures ANOVA (I):
Effect of *nudge* and *time* on food waste quantity

An additional post-hoc analysis assessed the effect of willingness to improve the sustainable use of food in the own household. The variable *willingness* was created from data gathered in the initial survey before the diary study period started. This analysis investigated whether the effect of *nudge* on *FWQ* varies for participants with high or low levels of *willingness*. The investigation was based on research from the TBP and consumer FW that states that the intention to conduct a specific behavior, such as reducing FW, is highly predicting the actual behavior. An initial independent t-test indicated that *willingness* might explain differences in *FWQ*. The 12 participants who reported high *willingness*, compared to the 16 participants who reported low *willingness*, demonstrated significantly lower *FWQ* ($M_H = 45.45$, $SD_H = 43.72$ vs. $M_L = 61.53$, $SD_L = 56.93$, $t(102) = 1.68$, $p = 0.048$). A second two-way repeated measures

ANOVA (II) provided deeper insights to this observation. The main effect of *willingness* was minor significant ($F(1,1) = 2.96, p = 0.09$), as also indicated by the previous t-test. Most notably, ANOVA (II) proved a significant interaction between the effects of *nudge* and *willingness* ($F(1,1) = 7.76, p = 0.006$). Table 7 below shows the results of ANOVA (II) for the independent variables *treatment* and *willingness*.

Source of variation	SS	df	MS	F	P-value
Treatment	0.00	1	0.00	0.12	0.72
Willingness	0.01	1	0.01	2.96	0.09
Interaction	0.02	1	0.02	7.76	0.006
Error	0.26	108	0.01		
Total	0.29	111			

Table 7: Results of two-way repeated measures ANOVA (II):
Effect of *nudge* and *willingness* on food waste quantity

While ANOVA (I) could not confirm the hypothesis of this work, ANOVA (II) provided valuable insights to the effect of the reminder nudge on participants FW behavior. A large difference between *FWQ* for participants in the NG with high *willingness* was observable within and between treatment groups. Within the NG, participants with high *willingness*, compared to those participants with low *willingness*, reported significantly lower *FWQ* on average per day ($M_{NH} = 30.77, SD_{NH} = 37.32$ vs. $M_{NL} = 72.9, SD_{NL} = 57.9, t(46) = 3.18, p = 0.001$). Between groups, participants with high *willingness* in the NG also reported significantly lower *FWQ* compared to participants with high *willingness* in the CG ($M_{NH} = 30.77, SD_{NH} = 37.32$ vs. $M_{CH} = 60.12, SD_{CH} = 42.73, t(53) = -2.69, p = 0.005$). These numbers are in line with the finding because they indicate that *willingness* as a single factor is only partially responsible for the lower *FWQ* in the NG. Hence, the results of ANOVA (II) demonstrate that *nudge* had a significant negative effect primarily on *FWQ* of those participants who reported high *willingness*. In fact, participants receiving no *nudge* and reporting high *willingness* showed slightly higher amounts of *FWQ* in the CG, but the effect was not significant ($M_{CH} = 60.12, SD_{CH} = 42.73$ vs. $M_{CL} = 50.16, SD_{CL} = 54.57, p = 0.23$). Interestingly, *FWQ* of participants with low *willingness* were moderate significantly higher in the NG compared to the CG ($M_{NL} = 72.9, SD_{NL} = 57.9$ vs. $M_{CL} = 50.16, SD_{CL} = 54.57, t(54) = 1.5, p = 0.07$). As ANOVA (I) revealed that *nudge* alone had no significant effect on *FWQ*, the difference might be explained by other factors that were not subject to this analysis. Figure 10 illustrates the interaction effect of *nudge* and *willingness* on average daily food waste quantity.

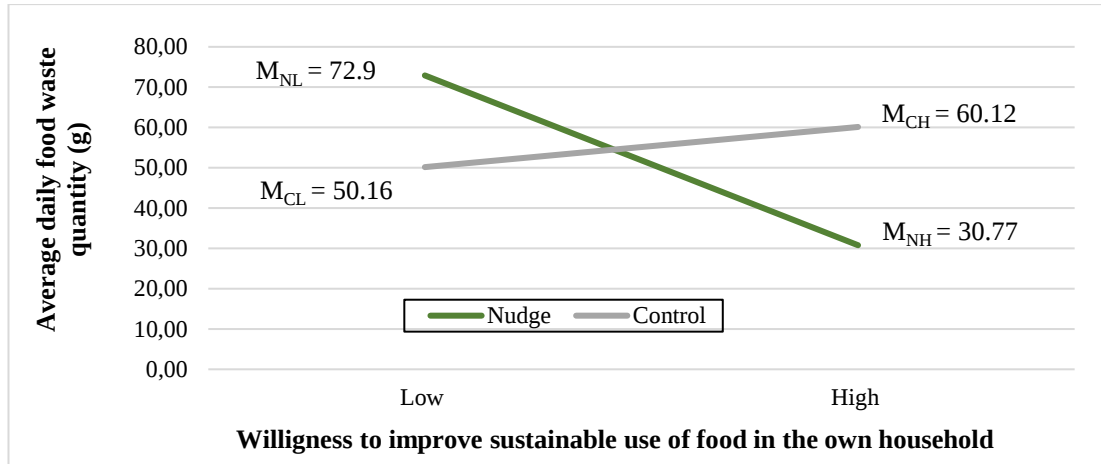


Figure 10: Interaction effect of nudge and willingness on average daily food waste quantity

4.3 Testing of the effect of nudge on food waste awareness and perceived behavioral change

The final survey questioned participants about changes in their *FW awareness* and *perceived behavioral change* in FW-related behaviors resulting from the study. Significant differences occurred between both groups. In terms of *FW awareness*, the NG reported significantly higher values compared to the CG ($M_N = 4.36$, $SD_N = 0.63$ vs. $M_C = 3.15$, $SD_C = 1.34$, $t(17) = -2.94$, $p = 0.004$). Even though the diary study did not reveal significant differences regarding *FWQ* between groups, these numbers indicate that participants receiving the reminder *nudge* became more aware of FW in general. Similarly, the NG reported notably higher values for *paying more attention to FW in the future* than the CG ($M_N = 4.36$, $SD_N = 0.63$ vs. $M_C = 3.15$, $SD_C = 1.41$, $t(16) = -2.83$, $p = 0.006$). Lastly, the NG reported significantly higher values for *perceived behavioral change* compared to the CG ($M_N = 3.71$, $SD_N = 0.91$ vs. $M_C = 2.38$, $SD_C = 1.26$, $t(22) = -3.12$, $p = 0.003$). Considering the variable *willingness*, participants with high *willingness* in the NG reported significantly lower values for *perceived behavioral change* than those with low *willingness* ($M_{NH} = 3.17$, $SD_{NH} = 0.98$ vs. $M_{NL} = 4.13$, $SD_{NL} = 0.64$, $t(8) = 2.08$, $p = 0.035$). This might be an indication that participants reporting a high *willingness* in the NG were already engaged in FW-preventive behaviors prior to the study. Nevertheless, as evidence regarding *FWQ* from chapter 4.2 suggests, the *nudge* likely contributed to a more thorough and consistent adoption of these FW-preventive behaviors. An opposite effect can be seen for *paying more attention to FW in the future*. Here, those participants with high *willingness* reported significantly higher values than those with low *willingness* in the

NG ($M_{NH} = 4.67$, $SD_{NH} = 0.52$ vs. $M_{NL} = 4.13$, $SD_{NL} = 0.64$, $t(12) = -1.75$, $p = 0.053$). No significant differences regarding *FW awareness* were observable when considering the *willingness* within the NG ($M_{NH} = 4.33$, $SD_{NH} = 0.52$ vs. $M_{NL} = 4.37$, $SD_{NL} = 0.74$, $t(12) = 0.12$, $p = 0.45$). Figure 11 displays the effect of *nudge* on *food waste awareness* and *perceived behavioral change* resulting from the study.

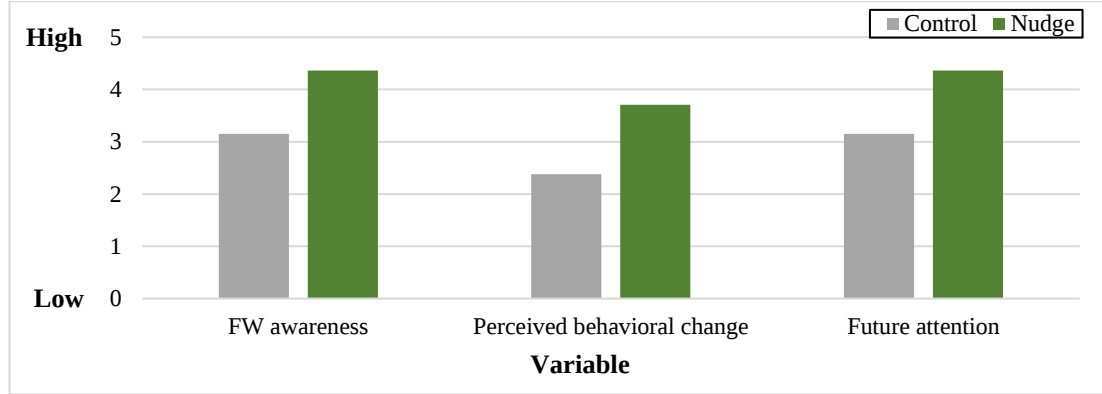


Figure 11: Effect of nudge on food waste awareness and perceived behavioral change resulting from the study

4.4 Testing of the effect of nudge on food waste-related household practices and evaluation of the nudge

In the second part of the final survey, participants of the NG evaluated the effectiveness of the reminder *nudge*. This analysis helped to comprehend whether and how the *nudge* contributed to reduced *FWQ* in specific areas. Results show that the *nudge*, as reported by participants, had a similar effect on the *FW*-related household practices *checking fridge* ($M = 3.28$, $SD = 0.79$), *planning groceries* ($M = 3.35$, $SD = 1.04$), and *using soon to be expiring food* ($M = 3.43$, $SD = 1.05$). Interestingly, participants reported higher ratings for the effect of *nudge* on *FW reduction* ($M = 3.93$, $SD = 0.88$) compared to the other evaluation categories. This finding is consistent with the earlier results and highlights that participants in the NG experienced a behavioral change that led to a reduction in *FW*. However, this reduction could not be confirmed by the *FWQ* collected in the diary study. Values concerning the *appropriateness of the reminder nudge to decrease FW* were similar to ratings regarding the three aforementioned *FW*-related household practices ($M = 3.35$, $SD = 1.17$). Notably, this rating is lower than the rating for *FW reduction*. This observation suggests that factors other than the *nudge*, which were experienced as part of the diary study, might have contributed to the perceived *FW reduction* for participants in the NG. Participants reported low values for both *annoyance* ($M = 1.79$, $SD = 0.77$) and *communication*

cost ($M = 1.79$, $SD = 1.01$) associated with the text message reminder. Figure 12 illustrates the evaluation of the reminder nudge.



Figure 12: Evaluation of the reminder nudge

4.5 Testing of the effect of socio-demographic characteristics on food waste quantity

Additional evidence on the effect of socio-demographic characteristics on *FWQ* can be found in the collected study data. In this sample, the *gender* of participants seemed to have an influence on reported *FWQ*. Across all participants, males reported significantly lower *FWQ* than females ($M_F = 70.52$, $SD_F = 51.3$ vs. $M_M = 40.87$, $SD_M = 35.9$, $t(21) = -1.75$, $p = 0.048$). The same effect, but minorly weaker, was observable within the CG ($M_{FC} = 74.24$, $SD_{FC} = 57.53$ vs. $M_{MC} = 32.45$, $SD_{FC} = 39.55$, $t(11) = -1.7$, $p = 0.059$). Most notably, the effect could not be observed within the NG. Even though females reported higher *FWQ* than males, the difference was not significant ($M_{FN} = 62.68$, $SD_{FN} = 46.99$ vs. $M_{MN} = 48.24$, $SD_{MN} = 33.22$, $t(9) = -0.64$, $p = 0.27$). This observation indicates that the *nudge* may have exerted a strong enough effect on female participants to counterbalance the effect of *gender*. The *housing type* is another factor that seemed to have a strong influence on *FWQ* in this study. Couples both with and without children reported significantly higher *FWQ* than participants living in single or shared flats ($M_C = 72.42$, $SD_C = 35.76$ vs. $M_S = 36.85$, $SD_S = 45.5$, $t(25) = -2.22$, $p = 0.018$). This effect was similarly strong within the NG ($M_{CN} = 75.24$, $SD_{CN} = 35.64$ vs. $M_{SN} = 38.82$, $SD_{SN} = 31.0$, $t(11) = -1.91$, $p = 0.04$), and minorly strong in the CG ($M_{CC} = 70.31$, $SD_{CC} = 56.76$ vs. $M_{SN} = 34.23$, $SD_{SN} = 43.08$, $t(12) = -1.35$, $p = 0.1$). An overview of the results concerning *demographical data* gathered in this study and *FWQ* can be found in the appendix (Appendix B, Figure B 1 – 7). No significant effects on *FWQ* concerning *FW-related household practices*, *dining habits*, and the remaining *demographics* outlined in 3.2.2. could be derived from the data.

5 Discussion

This experimental diary study aimed to assess the effects of a digital reminder nudge on consumer FW behavior at the household level. Throughout the four-week study, participants received text message reminders every two to three days, designed to raise awareness about their food stock and prevent FW, especially by avoiding forgotten items in the fridge and potential over-purchasing. Daily self-reports on FW and other characteristics (i.e., reason for disposal, food type, packaging and lifecycle stage) served as a database for the evaluation. A two-way repeated measures ANOVA was employed to analyze the effect of the reminder nudge on FW generated by participants over time. The results indicate that the reminder nudge did not lead to a decrease in FW and therefore the hypothesis could not be confirmed. However, a post-hoc analysis showed that those participants with a high willingness to improve the sustainable use of food in their own households reported significantly less FW when they received the nudge. Both within the treatment group ($p = 0.001$) and between groups ($p = 0.005$) the effect was clearly measurable, as indicated by an additional two-way repeated measures ANOVA. As a consequence, this study suggests that a digital reminder nudge is particularly suitable to decrease consumer FW in private households when considering the willingness to engage in this behavior.

5.1 Implications for theory

In contrast to previous studies that tested the effectiveness of reminder nudges on consumer FW (Van der Werf et al., 2021) or food recycling (Shearer et al., 2017), this study could not support pre-existing findings. There are several reasons to explain why the reminder nudge in this study did not result in reduced FW. First, in the study by Van der Werf et al. (2021), the researchers provided participants both with tips on how to reduce FW and with information on the individual economic cost associated with household FW. This study only indirectly reminded participants of FW-reduction tips (i.e., check food storage, use leftovers) and did not provide additional information. It can be deduced that the disclosure of economic costs might have served as an additional motivator and potentially triggered participants' intentions to reduce FW. This is also suggested by Nisa et al. (2019), who state that behavioral interventions in combination with financial incentives can lead to stronger effects. Second, the design of this study differed in terms of the measurement method since it did not include the

collection of pre-intervention data. Potentially, a pre- and post-comparison for both groups might have revealed differences in *FWQ* between groups that were not observable in the chosen study design. Third, the previously mentioned studies utilized sticker prompts, while in this study, a digital text message reminder was utilized. This might indicate that physical reminders raise higher awareness than text message reminders. Another explanation might be the nature of behaviors addressed in this study. According to Nisa et al. (2019), behavioral interventions focused on single action behaviors may be more effective than those aimed at recurring behaviors. Since the reminder nudge in this study targeted specific household behaviors performed routinely, this could potentially explain why the nudge itself did not show a significant effect. Similarly, the time span of four weeks might have been too brief for participants to routinely adopt and follow new behaviors, as also suggested by Shaw et al. (2018).

From a theoretical perspective, the findings of this study offer valuable insights into research concerning consumer *FW* and the *TPB*. The variable *willingness to increase the sustainable use of food in the own household* can be considered as comparable to the variable *intention to decrease FW*, which is often applied in the *TPB* and *FW*, although the terminology varies slightly. In this study, the variable *willingness* was employed, which includes the avoidance or reduction of *FW*. While Visschers et al. (2016) argue that the *intention to decrease FW* is the main predictor of self-reported *FW*, Stefan et al. (2013) state that these do not transform into behaviors that will result in less *FW*. According to the results of this study, *willingness* showed a significant effect on *FWQ* for the *NG* and the sample as a whole. The effect of *nudge* itself did not lead to smaller *FWQ*. But when observing both variables *nudge* and *willingness* together, *nudge* turns into a direct predictor of *FWQ*. This is also in line with research by De Ridder et al. (2022), who state that nudges are only effective when they are congruent with recipients' preferences. Therefore, this study suggests that *willingness* works as a moderator variable between *nudge* (main predictor) and *FWQ*, as illustrated in Figure 13. Notably, *willingness* did not show any significant effect on *FWQ* in the *CG*. This is an important finding, considering the suggestion by Visschers et al. (2016). This creates room for an interpretation of how the reminder nudge manifested in participants' behavior. Applying the *TPB*, *perceived behavioral control* is one main construct that is positively related to *intention* when analyzing household *FW* (Stefan et al., 2013; Visschers et al., 2016). A possible explanation for the results of this study

is that *nudge* increased the *perceived behavioral control* of those participants that reported higher *willingness*. This would also clarify why *willingness* showed no effects on *FWQ* in the CG. Further, participants in the NG reported significantly higher values for *perceived behavioral change* due to the study, which further underlines the explanation above. Hence, it can be inferred that a reminder *nudge* has the potential to increase *perceived behavioral control* among consumers who possess the *willingness* to improve the sustainable use of food within their own households.

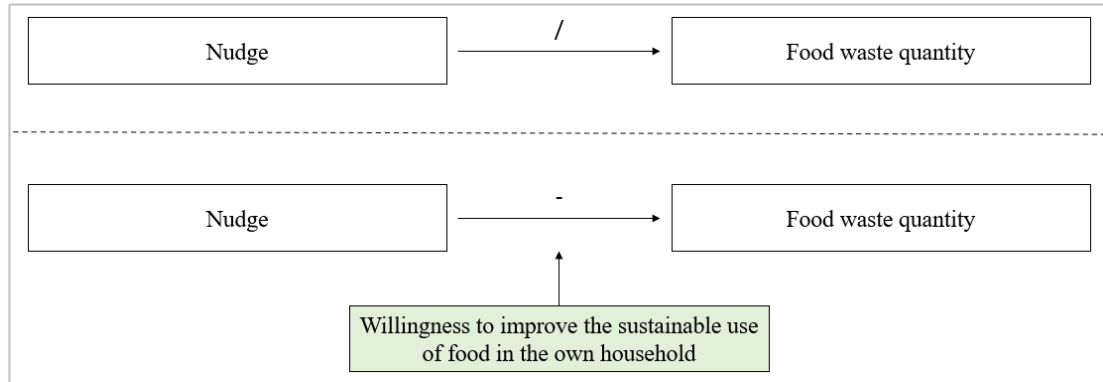


Figure 13: Moderation effect of willingness on nudge

Surprisingly, FW-related household behaviors, such as *planning meals in advance*, *checking the food stock*, *creating a shopping list*, and *over-purchasing* did not predict *FWQ*, and no significant differences between groups were observable. This finding contradicts prior research from Jörisen et al. (2015) and Stefan et al. (2013). Dissimilarities might be explained by the different measurement methods used because, in the previously mentioned studies, participants reported FW estimates in a one-time mail survey. Results concerning the *product group* of FW as well as *reasons for disposal* are in line with existing research (Jörisen et al., 2015; Parfitt et al., 2010; WRAP, 2009). Statements pertaining to *socio-demographic characteristics* should be interpreted with caution because of the small sample size in this study. Nevertheless, evidence can be found that women tended to report more FW, which is in line with Visschers et al. (2016) but contradicts other studies by Principato et al. (2015) as well as Secondi et al. (2015). Although it is widely acknowledged that single households generate the most FW (Schanes et al., 2018), households with couples reported the largest daily FW averages in the present study. Total FW per individual was much lower than those reported in prior research (Stenmarck et al., 2016), likely to differences in the measurement method.

5.2 Implications for practice

From a practical standpoint, the findings from this study can be valuable in facilitating the successful implementation of future nudge interventions in real-world settings. Despite doubt raised by some researchers about the efficacy of nudges in settings with low intervention control, such as private homes (Lehner et al., 2016), this study's results demonstrate that reminder nudges can effectively reduce FW for individuals with a high willingness to improve the sustainable use of food in their own household. For future intervention development, this implies two main points to consider. First, an understanding of the target audience is vital to invest efforts where success is most likely. As highlighted before, the success likelihood of nudges depends heavily on the individual preferences towards the targeted behavior (De Ridder et al., 2022; Lehner et al., 2016). Therefore, the distribution of reminder nudges in a digital realm should be targeted towards individuals that actively seek improvement in sustainable consumption behavior. This approach allows for maximizing positive outcomes while minimizing potential annoyance cost. Second, to increase the willingness for the sustainable use of food, reminder nudges need to be complemented by further levers. The study by Van der Werf et al. (2021) exemplifies that economic incentives are a large motivator for individuals to decrease FW. Hence, disclosure nudges might be an appropriate door opener to convince individuals to follow guidance provided by digital reminders. In this regard, social media and smartphone apps might play an important role (Young et al., 2017). These can create great opportunities for food companies, retailers, and NGOs to raise awareness on a large scale and create an educational foundation for customers, which would finally prepare the ground for complementary nudge implementation, such as digital reminders.

Smart technology might serve as another complement to leverage the effectiveness of reminder nudges (Lim et al., 2017). Smart fridges, for instance, offer possibilities to send automated and individualized reminders to consumers. This might yield higher success as consumers can be reminded about specific products that are at risk to mold or to pass the best-before-date. While this kind of reminder nudge does not actively foster the education of consumers, it can serve as an action-oriented approach, which some scientists argue is most effective (Lehner et al., 2016). Further applications in this domain of FW and smart technology are imaginable, such as automated shopping list creation, recipe recommendation for leftovers, and highly personalized functions.

5.3 Limitations and future research directions

Despite the valuable findings regarding the effectiveness of digital reminder nudging on consumer FW at the household level and the consequent implications for theory and practice, this study is not without its limitations, which must also be taken into account. The first limitation stems from the self-report measurement method that has been utilized in the diary study. Several researchers point to the fact that self-reported data on FW does not always correlate with the actual behavior (Linder et al., 2018; Reynolds et al., 2019). There is a chance that the data quality suffered from biases, such as the social desirability bias, which refers to participants reporting in a way that is generally accepted as favorable by society (Schmidt, 2016). Especially in a sensitive area, such as consumer FW, this effect has to be taken into consideration. In this study, full confidentiality was guaranteed to participants in order to incentivize honest and objective reporting. Further, control variables measured in the final survey controlled for missing data that could have resulted from a lack of memory. Still, future studies should consider this effect more thoroughly in the research design by either including social desirability scales or using measurement methods that are less prone to this bias, such as waste-compositional analysis (Von Kameke & Fischer, 2018; Reynolds et al., 2019). The second limitation relates to the sample of this study. The size as well as the socio-demographic composition were not representative of an average household in Germany or North-Rhine-Westphalia, respectively, which was mainly a result of the convenience sampling method used for recruiting participants. In a comprehensive meta-analysis on behavioral interventions to promote household action on climate change, Nisa et al. (2019) found that studies with small sample sizes tend to report significantly higher effects compared to studies with larger samples. In the present study, the sampling method ensured complete and reliable data because participants committed to support the study for a period of four weeks. Still, future research should aim to test the effectiveness of digital reminder nudging on consumer FW in larger and more representative samples to minimize potential small-study bias. The third main limitation concerns the time horizon of the study. While this study asked participants to report their intention to raise awareness about FW in the future, it is not obvious whether the intervention has created long-term effects. In terms of habit formation, which requires frequent repetition over an extended period of time, four weeks might not be enough to create new habits that will survive in the future (Nisa et

al., 2019; Shaw et al., 2018). This creates fruitful opportunities for future research that can benefit from extended as well as both pre- and post-intervention study periods to test the effectiveness of digital reminder nudging on consumer FW in the long-term.

Additional future research directions can be derived from the design of the reminder nudge. In this study, a simple text message reminder with reoccurring content has been used. Future research could analyze possible influences of alternating and personalized content that is targeted at individual preferences and behaviors of the recipients. To gain more insights into the interaction of different types of nudges, and to what extent disclosing information can increase the willingness of consumers to decrease FW, future research might test the effectiveness of digital reminder nudges between treatment groups with different levels of education on the topic of consumer FW.

6 Conclusion

This study tested the effect of a digital reminder nudge on consumer FW at the household level in a diary study over four weeks. Results indicate that the reminder nudge decreased FW among those participants that reported a high willingness to increase the sustainable use of food in their own households. This has important implications for theory, as it underlines existing research in the TPB and FW and suggests the intention to decrease FW as a moderator variable for nudging. Practitioners can benefit from these findings by acknowledging the importance of knowing consumers' preferences and intentions to conduct certain behaviors, such as reducing FW. This can give rise to the effective implementation of reminder nudges among apps and other digital channels. This study suffers from some limitations regarding the data collection, sample size and characteristics, as well as the time horizon. This creates promising opportunities for future research endeavors that can apply the reminder nudge used in this study in larger and more representative samples. Given the appropriate time and resources, more detailed data collection methods, such as waste-composition analysis, could extend the findings from this study. Moreover, future research that incorporates pre-intervention and extended post-intervention data collection periods on FW could provide valuable insights into the long-term effectiveness of digital reminders on consumer FW behavior. Lastly, future research should examine how varying levels of education on the topic of FW and its economic, environment, and societal implications impact the effectiveness of reminder nudging.

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Appendix A: Visualizations of food waste quantity by treatment group

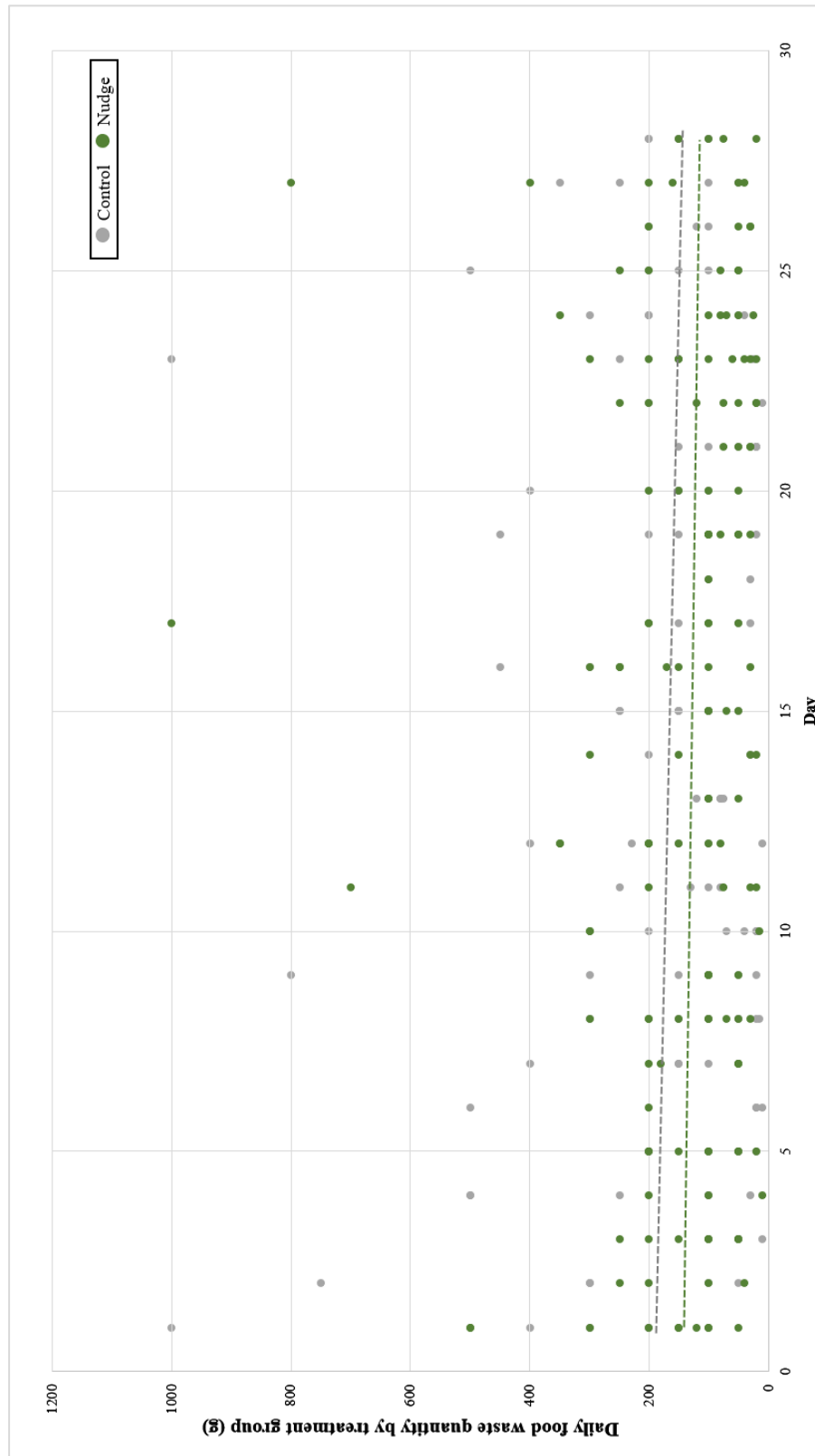


Figure A 1: Daily food waste quantity by treatment group

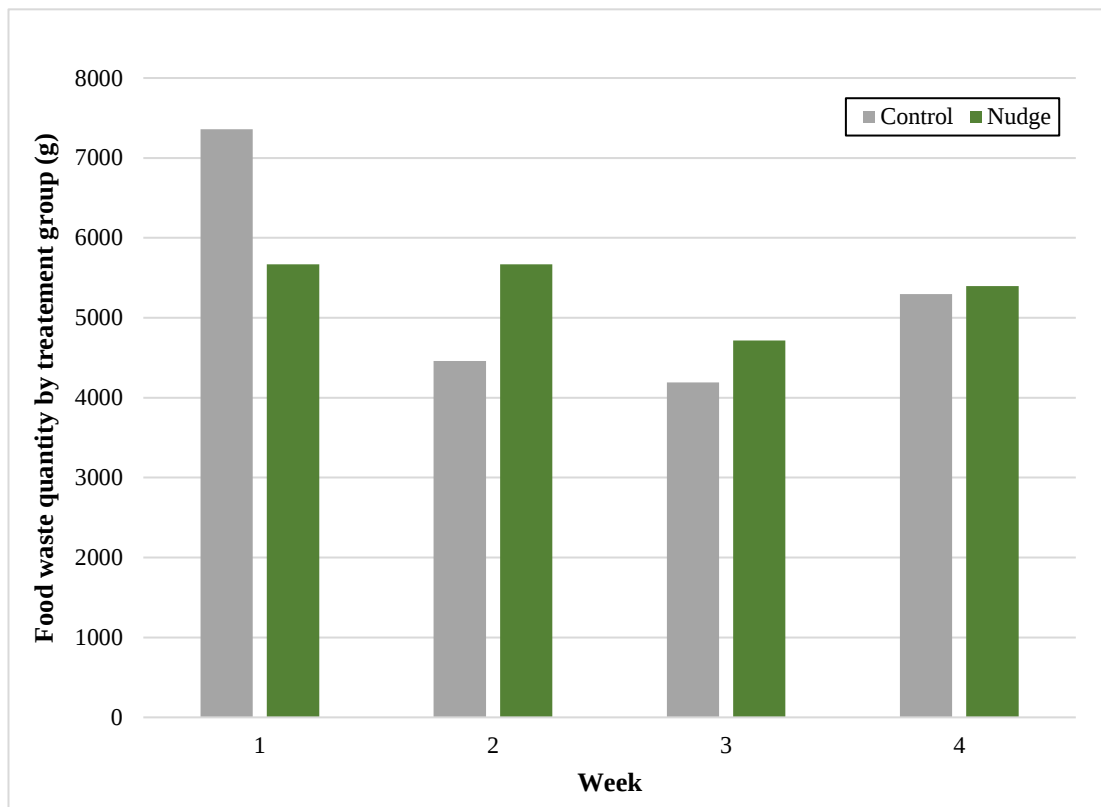


Figure A 2: Food waste quantity by treatment group, aggregated to the weekly level

Appendix B: Visualizations of food waste quantity by different socio-demographic characteristics

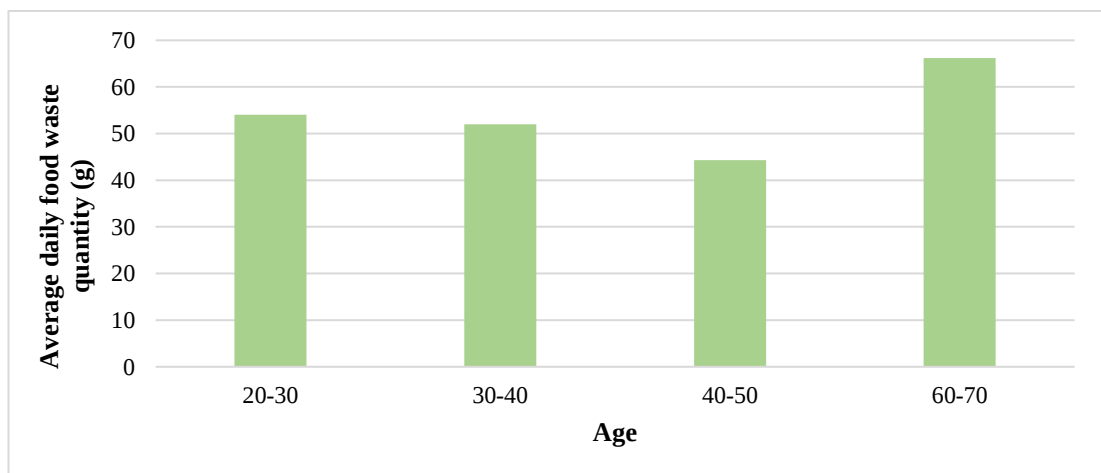


Figure B 1: Average daily food waste quantity by age

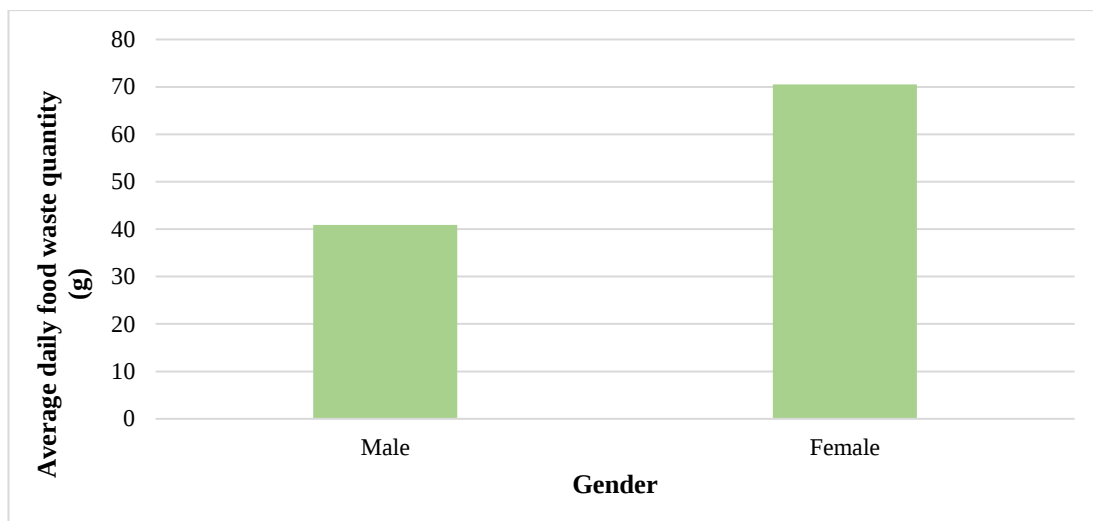


Figure B 2: Average daily food waste quantity by gender

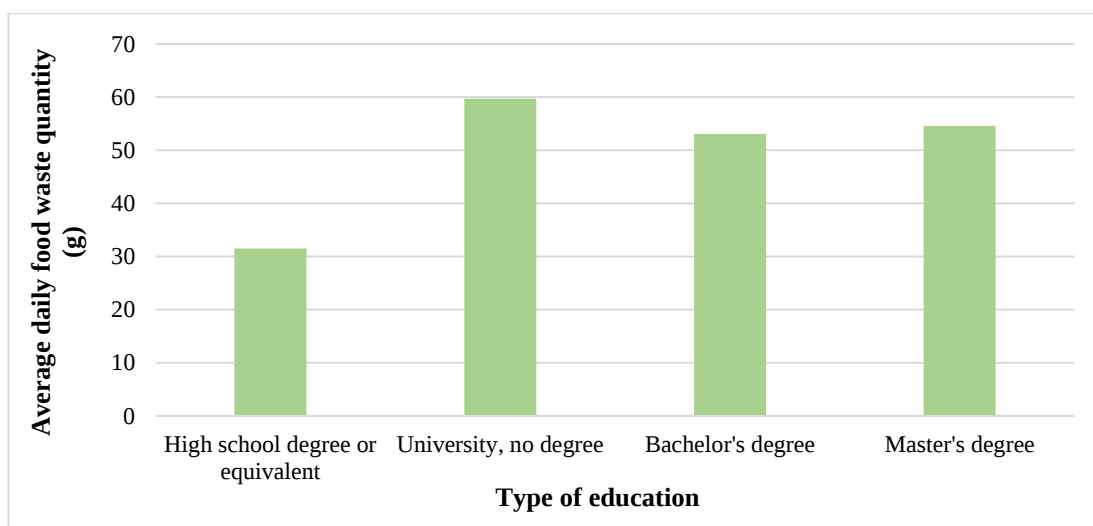


Figure B 3: Average daily food waste quantity by type of education

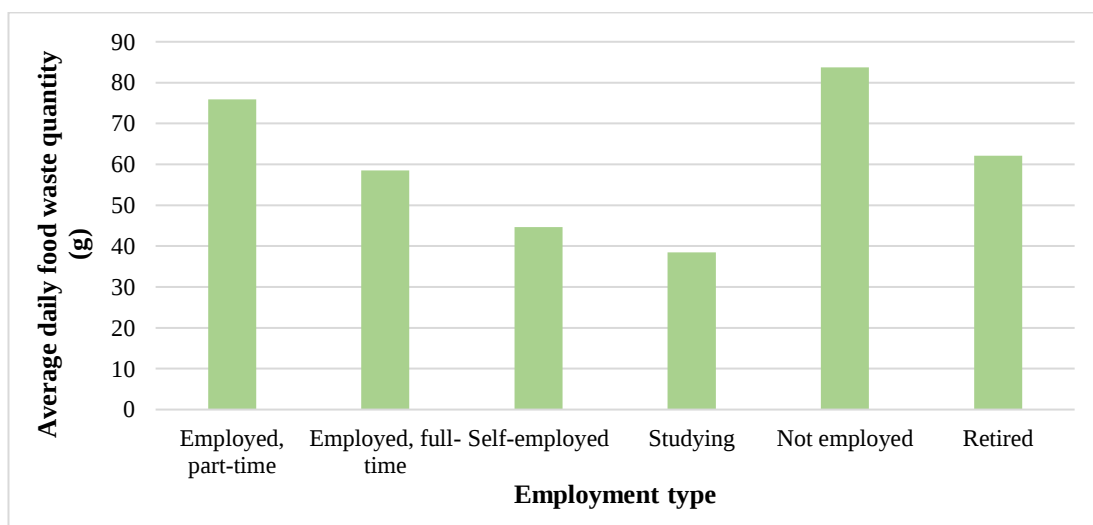


Figure B 4: Average daily food waste quantity by employment type

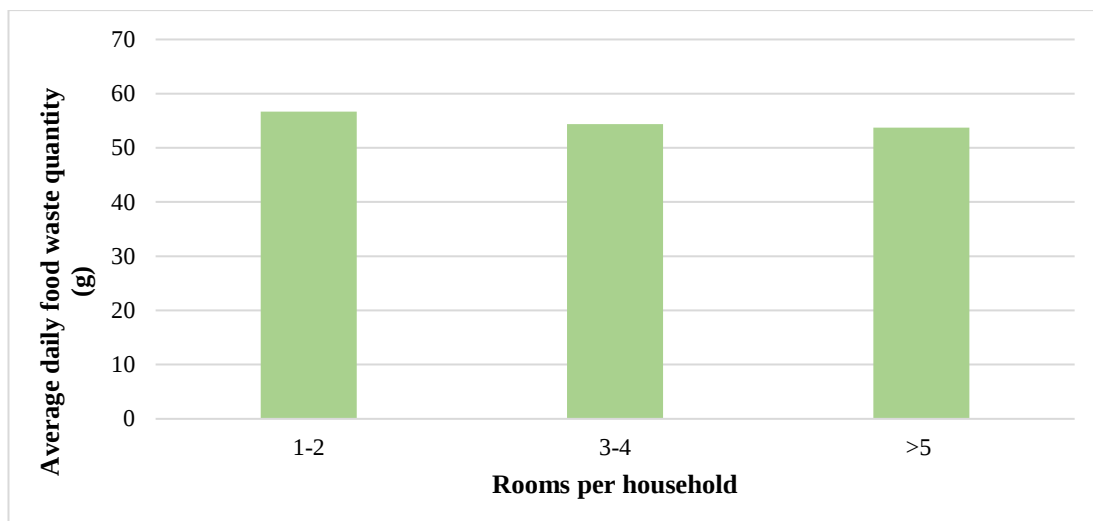


Figure B 5: Average daily food waste quantity by rooms per household

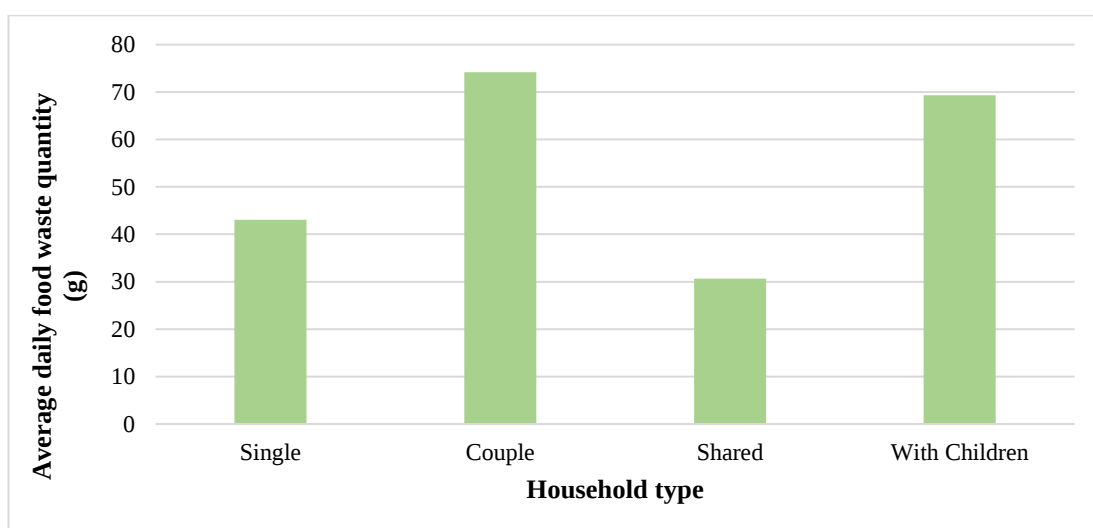


Figure B 6: Average daily food waste quantity by household type

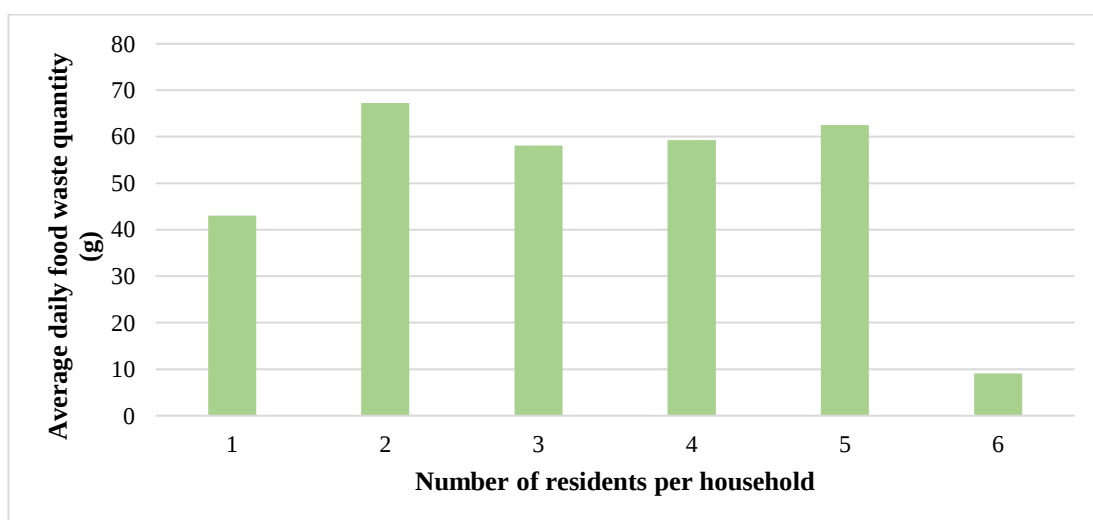


Figure B 7: Average daily food waste quantity by number of residents per household