# Deliverable 3.4

**0FLW IMPACT SCENARIOS**

CHORIZO PROJECT

D3.4

# 0FLW Impact scenarios

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## Glossary of terms and acronyms

| Acronym/Term | Description |
|---|---|
| **0FLW** | Zero Food Loss & Waste |
| **ABM** | Agent-based model |
| **CA** | Consortium Agreement |
| **CS** | Case study |
| **FW** | Food waste |
| **MOA** | Motivation-Opportunity-Ability |
| **PW** | Plate waste |

# 1 EXECUTIVE SUMMARY


The CHORIZO project is dedicated to enhancing the understanding of how social norms influence behaviours related to food waste generation. To reach this aim, two computer simulations have been developed. The work presented in this deliverable directly build upon the conceptual framework presented in D3.1 “Conceptual framework for behavioural change understanding”, which integrated the MOA and HUMAT frameworks that were adopted to develop the computer simulations. The project addresses how both individual and social influences shape food waste outcomes. CHORIZO’s modelling approach enables simulation of these influences, providing insights into how behaviours around food waste generation vary across different social contexts.

This deliverable builds on prior work by testing a set of what-if scenarios using two distinct models: the Establishment Diner model, focused on food waste in social dining settings, and the Home Cook model, focused on household food consumption and waste. These models are designed to reflect the roles of injunctive and descriptive social norms alongside other individual and social factors, helping to illustrate the factors driving food waste in both public and private contexts. The functioning mechanisms of the two models are described in D3.3 “Case-independent changing social norms predictive model”.

Deliverable 3.4 “0FLW impact scenarios” presents the methodology used to simulate what-if scenarios in the two models, and the results of these simulations. This deliverable remains highly technical in its content. Two main categories of scenarios were developed and applied within the models: intervention scenarios, which examine specific food waste reduction strategies (e.g., communication strategies, plate sizes), and population scenarios, which explore how different population characteristics (e.g., demographics, awareness levels) affect food waste generation. By combining these scenarios, it is possible to identify strategies that balance diverse behaviours to reduce food waste in different settings.

The document concludes with insights drawn from scenario outcomes, identifying effective strategies as well as challenges in model generalization due to the variability of behaviours and settings. Findings from both models underscore the critical role of tailored, context-specific interventions in effectively reducing FW. For hospitality settings, raising sustainability awareness broadly and focusing interventions on leisure guests can be highly effective, while combining plate size adjustments with positive messaging may further enhance FW reduction. In households, strategies that promote balanced consumption, awareness of storage practices, and informed decision-making around in-store promotions can curb FW generation. Together, these insights provide a foundation for FW reduction intervention and campaign planners – as well as food service professionals – for designing more effective and targeted FW interventions across various settings, supporting the CHORIZO project’s mission of achieving zero food waste. Finally, the report outlines potential areas for future work, including further adaptations to address unique settings such as schools, where different social dynamics and environmental constraints may impact food waste behaviours.

# 2 INTRODUCTION

## 2.1 Background

The CHORIZO Project, "Changing practices and Habits through Open, Responsible, and social Innovation towards ZerO Food Waste" is a Horizon Europe project, aimed at improving the understanding about how social norms influence behaviour linked to the generation of food waste (FW). The overall objective is to improve the effectiveness of supply chain actors' decisions in relation to FW reduction actions and interventions, towards the goal of reaching zero FW. This report presents the results of the implementation of what-if scenarios in two computer simulations, to understand the influence of specific individual and contextual factors on the generation of FW.

In CHORIZO, social norms are defined as rules/guides for actions perceived by individuals aspiring/belonging to the norm's target group as expected by others. As further specified, the definition of the norm's target group is related to expectations about social roles: for example, a good host is expected to serve food to the guests, or an individual with the context specific social role of business-person is expected to behave in a professional manner in settings in which this social role is their salient one. CHORIZO examines two types of social norms: injunctive and descriptive. Injunctive norms refer to beliefs about what actions are considered socially appropriate in a given situation. Descriptive norms, on the other hand, refer to common behaviours that reflect perceptions of how likely it is that others are engaging in those socially accepted actions. In non-observable and familiar contexts (as one's house), injunctive norms play a stronger role, as individuals rely on their knowledge of the behaviours that others expect of them. In contrast, in new and observable environments (as restaurants or hotels), descriptive norms become more influential, as people look to the behaviours of others to determine what is appropriate. Consequently, in these novel and observable settings, descriptive norms tend to be more fluid and adaptable, shifting based on the specific circumstances individuals find themselves in.

FW is a result of a series of intended and unintended behaviours driven by both internal (individual) and external (social and societal) factors. To address this complexity, previous project activities have focused on developing a conceptual modelling framework integrating the MOA framework and HUMAT (D3.1 Conceptual framework for behavioural change understanding). According to the MOA, consumers' information processing and decision-making are influenced by their personal motivations, opportunities, and abilities. Although these factors are tied to the individual's internal state, they are heavily shaped by the broader context in which consumers live, the context in which consumers live deeply influences those drivers. HUMAT is a dynamic model that explores human behaviour and adaptation to both social and non-social cues and aims to understand why agents make decisions by analysing the individual motives that an agent wants to fulfil.

To gain a deeper understanding, agent-based modelling (ABM) has been selected within the CHORIZO project as the simulation framework for studying how social norms, individual and collective behaviours interact, while representing various actors and food consumption settings.

Two models have been developed (D3.3 Case-independent changing social norms predictive model): the Establishment Diner model, which investigates food consumption and FW generation in a social context, integrating both descriptive and injunctive social norms; the Home cook model, which explore food consumption and waste at the household level, a private setting in which injunctive social norms are particularly relevant. The first model is an agent-based model, while the second one is a microsimulation. In developing these models, we aimed to capture a representation of reality. However, this representation is not intended to support or advocate specific behaviours or motives. For instance, aspects such as the motive of weight control, which influences an individual's decision regarding how much food to consume, are included solely for the purpose of simulating real-world behaviours and not to endorse these factors.

Although the CHORIZO theoretical framework highlights social norms as possible drivers of food waste-related behaviours, the specific aspects of these norms that influence such behaviours remain unclear. Should food waste interventions aim to change, create, or utilize social norms? Furthermore, what strategies or tools can be used to effectively leverage social norms to influence food waste-related behaviours and decisions? To address these questions, project activities focused on providing a conceptualisation of the intervention logic for food waste reduction interventions. Additionally, previous work considered the relevance of social roles and the characteristics of specific settings when designing interventions (D3.2 0FLW interventions). Interventions are defined as structured efforts and tools that are primarily implemented and evaluated to influence behaviours. The complexity behind consumer food waste necessitates targeted and varied approaches to encourage behavioural change. As a result, it is essential to consider not only social norms but also other influencing factors when designing FW reduction interventions, as presented in D3.2. This set of interventions, including awareness raising, nudging strategies, economic incentives/disincentives, served as a basis on which to co-design and implement scenarios within models.

## 2.2 Objectives

Building on the work carried out and described in the previous paragraph, T3.3 "Development of 0FLW impact scenarios & upscaling" focused on developing, integrating in the models and testing a set of what-if scenarios aimed at exploring different strategies to reduce food loss and waste (FLW). Our objectives have been threefold:

1) to explore various normatively focused communication strategies;
2) to simulate the implementation of social innovations across different contexts and population groups;
3) to assess the combined effects of different FLW reduction actions and social innovations.

Scenarios are defined as stories about diverse ways in which relevant issues might evolve (Bowman et al., 2013; Bradfield et al., 2005). Scenarios are not exact predictions of the future, but rather plausible stories about potential future developments, useful to isolate and identify factors whose impact we are interested in understanding. In this sense, scenarios are hypothesis, usually created in sets to combine different factors and investigate a range of hypothetical situations.

Therefore, what-if scenarios are hypothetical situations used to explore the potential outcomes of different decisions or events. Altering key parameters within a simulation allows us to examine how these factors might interact with each other and affect outcomes, in our case the eventual generation of FW in out-of-home and in-home settings, thus explaining a given outcome. On the other hand, what-if scenarios can also help decision-makers to assess the potential consequences of their choices and make more informed decisions. The scenarios developed and implemented in this report take this forward approach, as they aim at investigating the effects of potential FW prevention/reduction interventions or how different populations vary in FW generation.

What-if scenarios implemented in both models are of two main types: intervention scenarios focus on simulating interventions to assess their potential impact on the system (e.g., reduce plate size, use communication strategies within restaurants, enhance consumers skills related to the use of freezers); population scenarios focus on changing demographic or behavioural characteristics of the simulated population to explore implications for the system (e.g., altering the share of business guests, testing different types of households, vary individuals' level of sustainability awareness). Some of the what-if scenarios implemented in our work combine both intervention and population scenarios. By doing so, we can identify the most effective combination of actions and population's traits that can lead to a reduction in food waste, as well as strategies to avoid.

## 2.3 Structure of the deliverable

The deliverable is structured into two main sections, each dedicated to a specific model: "The Establishment Diner model" and "The Home Cook model".
Each section follows a consistent structure, beginning with a summary of the model, which recalls the more detailed description presented in the previous D3.3. In the following part scenarios and research questions are presented: first, the methodology and criteria for scenarios selection and development is described. Then, scenarios are narratively described, in order to contextualize them. The subsequent section covers model validation, including data inputs from case studies, optimization, consistency analysis, verification, sensitivity analysis, and calibration.
In the fourth sub-section, the specific values used to implement the scenarios in the models are described. Finally, the results of the scenarios are presented and discussed.

The document concludes with Section 5, offering a final summary of insights gained from both models and highlighting potential areas for further work.

# 3 THE ESTABLISHMENT DINER MODEL

## 3.1 Summary of the model

The Establishment diner is an agent-based model to investigate food consumption and food waste generation in a social context. In this paragraph, only a brief description of the main features of this model is provided. The extended presentation is delivered in D3.3 Case-independent changing social norms predictive model.

The Establishment Diner model simulates the dining behaviour of individuals in a commercial establishment (that is, the behaviour of individuals when having meals outside their houses). In particular, the setting is that of a breakfast buffet. The model tracks guests' meal behaviours over a daily cycle, including how much food they serve, eat, and leave behind. The population comprises individual guests with the following attributes: gender (male/female) and guest type (business-person/non-business-person).

The simulation models a typical **daily buffet cycle**, in which agents make decisions at various stages, from when they enter the buffet to how much food they take and how much they eventually consume or waste. The buffet is open for a fixed three-hours period (e.g., 7–10 a.m.), and agents can enter the buffet 5 minutes after it opens and must finish their meals before it closes. During this time, agents make decisions relating to:

1. The time they go for the meal;
2. The portion size they serve themselves at each round: Once inside the buffet, agents make decisions on how much food they will serve themselves. Portions come in three sizes: small (200 grams), normal (300 grams), and large (400 grams). Agents may also decide to take no food at all and leave without eating. Each time they serve themselves, agents go through a decision-making process to determine their portion size (Figure 1);
3. The number of times they go for other rounds of serving;
4. The amount of food leftovers they leave on their plates: Agents can decide whether to finish or leave food on their plates (Figure 2).

As mentioned, agents make decisions based on their personal attributes and a set of motivations: hunger, fullness, desire of weight control[1], desire to conform with other guests, level of indulgence, level of sustainability awareness. Additionally, agents' decisions are influenced by other factors, related to their abilities (i.e. self-control, ability to choose food) and to opportunities offered by the environment (i.e. time availability, plate size and food diversity offered by the commercial establishment)[2]. These motives, abilities and opportunities influence agents' decision-making at different steps of the cycle, as shown in Figure 1 and

Figure 2. For the extensive description of how decision-making works at each step, please refer to D3.3 Section 2.4 "Daily routine".

[1] This motive was originally phrased as "Desire of being thin" in D3.3. We decided to change it with "Weight control" in order to describe the intent to regulate weight, without implying a specific body ideal.

[2] The model is informed by the integration of two theoretical frameworks - as explained in D3.1 and D3.3. Here, motivations/motives, abilities and opportunities refer to the MOA framework: Motivations represent the intention of one or more individuals to carry out a set of actions(i.e. attitudes, awareness and social norms); Abilities represent the capacity of each individual to act by relying on personal skills and knowledge; Opportunities are defined as the possibility of one or more individuals to access external material and non-material resources (e.g., time, technology, infrastructures).

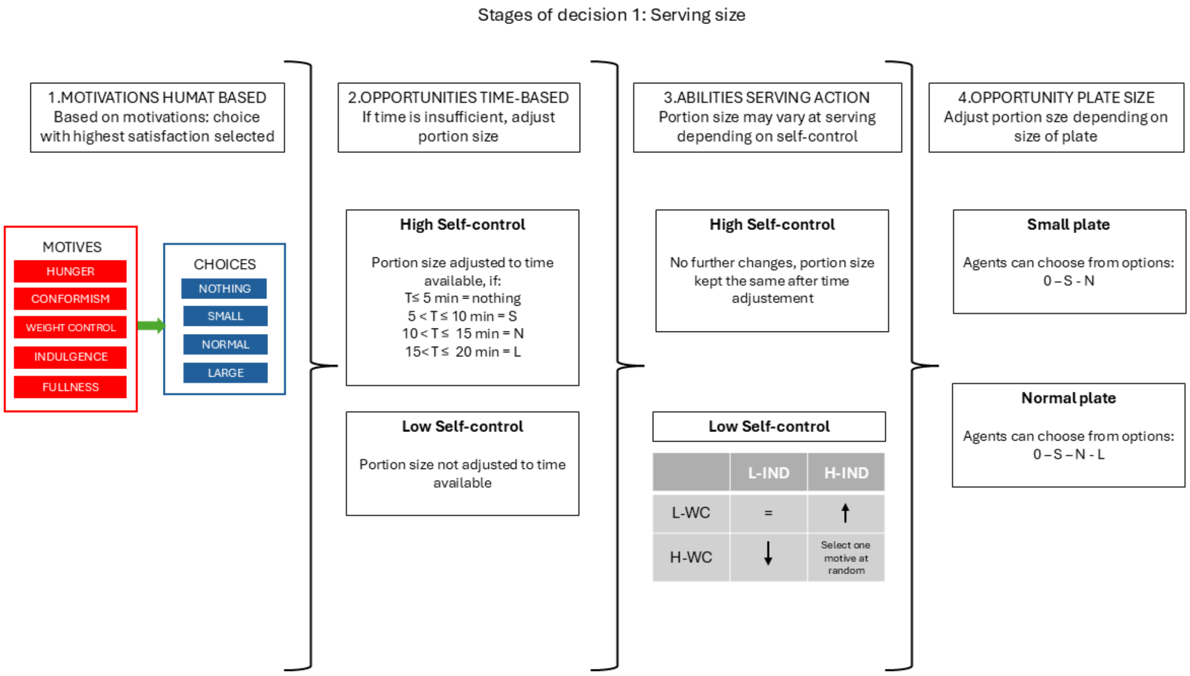


Figure 1: Decision process to select serving size

First, they select a portion size based on hunger, fullness, desire to control weight, indulgence, and conformity. Then, they adjust this choice based on available time and self-control. At serving, they may further modify it based on self-control and motivation to stay thin. Finally, the portion is adjusted to fit the hotel's plate size.

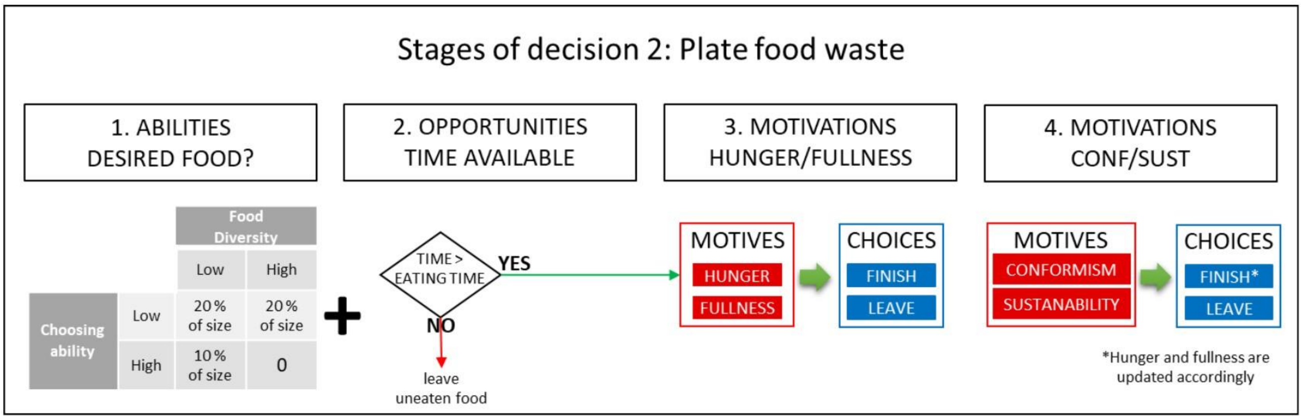


Figure 2: Decision process to decide on finishing food on plate

The amount of uneaten food left by the agent on the plate depends on specific abilities, time availability, and motivations and occur on the stages depicted in Figure 2.

## 3.2 Scenarios and research questions

### 3.2.1 Methodology and criteria for scenarios selection and development

In order to explore the potential applications of the developed model for understanding dining behaviour and food waste generation in buffet environments, we employed a structured scenario selection and development process. The methodology for scenario development was grounded in a co-design approach, where insights and feedback from different project partners were integrated, taking advantage of the diversity represented in the project consortium (including researchers, case study partners, and domain experts).

A co-design session was organized during the General Assembly of the project, held in Oslo on May 6th, 2024. The session was structured in different parts: during the first part, participants were provided with a common definition of what-if scenarios and their use to simulate interventions to assess their potential impact on FW generation. Then, the model was presented to project partners, including case study partner, in order to familiarize them with the model's structure and mechanisms and to delve into its specific features. The following part of the session was more precisely aimed at collecting feedback and ideas on possible interventions to be implemented in what-if scenarios from participants, leveraging their specific expertise to design both relevant and realistic scenarios. The goal of the session was to identify key variables, populations, and contexts that would be most interesting to simulate, ultimately guiding the design of a diverse set of scenarios.
Participants were asked to think about potential interventions that could be implemented in a buffet setting in order to reduce FW. The discussion was guided by three main questions:

1. How is this intervention reducing FW? Think about the behavioural change process and MOA framework
2. Would the change produced by the intervention work in the same way for all agents, or are there agents who will be affected more/less?
3. What stage of the model will be affected/what is going to happen in the model when you implement the proposed change?

The session led to several ideas on potential interventions to reduce FW (Table 1). Proposals can be divided into two main groups on behavioural change interventions: changing architecture choice and communication interventions. The former group involves altering the context in which individuals take decisions, for example by introducing fees, incentives, and changing the plate size provided by the commercial establishment. The latter group of interventions focus on using information, messaging and feedback to influence people's behaviour.

Table 1: Output of the Oslo session, FW interventions

| Changing choice architecture | Communication interventions |
|---|---|
| Reducing food variety (to decrease indulgence influence) | Use of written messages (CS2 hotel experiment) |
| Testing having breakfast included/excluded (changes in the feeling of entitlement to over-serve) | Communication about food donations (effect on sustainability awareness) |
| Testing serving only plant-based food | Communication about the origin of food (effect on attitudes) |
| Changing plate size | Communication about how much business-persons usually waste (triggering conformism) |
| Leftover fee | Self-weighting plate waste by guests (with scales showing immediately the environmental impact of the waste on a screen) |
| Positive incentives and gamification (e.g., collecting stickers and earning a prize for not leaving leftovers) | |

After the co-design session, the team working on the modelling activities assessed each proposed intervention to check its potential implementation in what-if scenarios. Interventions were assessed according to two main criteria:

- Feasibility: Can the intervention be realistically modelled with the available data and model structure?
- Relevance: Does the intervention address a significant research question related to food waste generation in a dining setting?

Through several rounds of discussion, four scenarios' categories were selected and then combined in what-if scenarios:

- Plate size provided by the commercial establishment (normal or large);
- Guest composition (share of business and non-business guests);
- Level of sustainability awareness of guests;
- Communication strategy implemented by the commercial establishment (no communication, positive message, provocative message).

Research questions related to each category are explained in section 3.2.3, while specific input values used for the simulations are presented in section 3.4.

### 3.2.2 Scenarios description

- *Baseline scenario #1 – "Standard Leisure Hotel" (baseline scenario)*

This scenario takes place in June, on a Friday. The setting is a renowned holiday destination, where many families, young people, and couples flock to enjoy their vacations. The hotel offers an inviting buffet breakfast every morning, from 7am to 10am. The hotel hosts a mixed group of guests, primarily made up of those on vacation enjoying the many opportunities offered by the destination, with a smaller proportion of business travellers who have work commitments to attend to. As the waiters and waitresses open the restaurant doors, guests begin to enter the room.

The buffet setup is familiar: large plates are provided, allowing guests to serve themselves freely without any reminder to reduce waste. The hotel's management has made no specific efforts to limit plate size or promote sustainability messages, opting instead for a more traditional approach.

Guests, regardless of their background, approach the buffet similarly. The key difference is that business guests, pressed for time due to work commitments, tend to make quick decisions, often grabbing food in a rush and consuming only what they can before leaving the room. Leisure guests, on the other hand, tend to linger, enjoying a more relaxed pace. Peculiarly, neither leisure guests nor business guests seem to pay attention to the behaviours of others.

The large plates offered by the hotel create the effect where guests feel they need to fill the available space. Even without specific communication reminding the guests to take only what they can eat, they seem to be aware of the negative impacts of food waste on the environment and society.

While the breakfast experience is undoubtedly pleasant for the guests, it results in an average level of food waste, with no measures in place to encourage reduction or more conscious behaviour.

Key characteristics: Large plate size – Mainly non-business guests (no differences for conformism) – Medium level of sustainability awareness (no gender differences) – No communication

- *Scenario #35 – "Carefree indulgence"*

It is a typical Thursday morning in July at a peaceful holiday resort. The hotel dining room opens at 7am for a buffet breakfast, and a mix of vacationers — including families, couples, and groups of friends — begin to gather. There are also a few business guests, though they are few compared to leisure travellers. These business guests tend to conform more to what other guests do, as they can be seen looking at what other people are doing while taking decisions. The only plates available at the buffet are large, and some people can be seen filling them to their maximum capacity. It seems that awareness of sustainability is generally low, though women show slightly higher concern.

As breakfast progresses, the atmosphere remains relaxed and carefree, with guests chatting and taking second helpings. Plates are left on the tables with unfinished food. By the time breakfast wraps up at 10am, the dining room is filled with satisfied guests—but also with a significant amount of food waste, the result of a morning spent indulging without restraint or reflection.

Key characteristics: Large plate size – Mainly non-business guests (business guests with higher level of conformism) – Low level of sustainability awareness (women with higher levels) – No communication

- *Scenario #7 – "Busy breakfast with a message"*

It is a typical Tuesday morning in early September, and the hotel dining room buzzes to life as the buffet breakfast opens at 7am. Primarily catering to business guests, the atmosphere is filled with a sense of urgency. These travellers move efficiently through the buffet, their choices influenced by the behaviours of those around them, reflecting a high level of conformity. The plates are of normal size, with the aim of promoting more moderate portion sizes. A positive message near the buffet reads: *"We care for the environment. Help us waste less food* ". This reminder resonates with some guests, particularly women, who demonstrate a slightly higher awareness of sustainability issues. However, overall awareness remains low among the majority.

As guests serve themselves, they tend to fill their plates based on habit and convenience, although the positive message encourages some to think twice about their portions. While the sustainability message does not significantly alter behaviour, it adds a mindful touch to the breakfast routine, allowing for a small shift in awareness among the busy travellers.

Key characteristics: Normal plate size – Mainly business guests (business guests with higher level of conformism) – Low level of sustainability awareness (women with higher levels) – Positive message

- *Scenario #18 – "Provocation meets leisure"*

On a Saturday morning in August, the hotel dining room fills with a lively mix of families, couples, and groups of friends enjoying their vacation. The buffet breakfast opens at 7am, inviting guests to indulge in a variety of delicious options. Among the crowd are a few business travellers, who exhibit a higher level of conformism as they observe the choices of leisure guests. The buffet features an array of dishes served on normal-sized plates, allowing for a reasonable selection. Prominently displayed near the buffet is a provocative message: *"Every time you waste food, you're wasting a part of the planet. Enjoy your food!"* This bold statement captures the attention of guests, attracting many frowning looks and a sense of discomfort and annoyance.

As guests serve themselves, they are often driven by the desire to explore the diverse offerings, with many filling their plates generously. Despite the intriguing message, most continue to take large portions without much reflection. The atmosphere is filled with laughter and conversation, yet the amount of food waste becomes apparent as the meal progresses.

Key characteristics: Normal plate size – Mainly non-business guests (business guests with higher level of conformism) – Low level of sustainability awareness (women with higher levels) – Provocative message

- *Scenario #27 – "Mindful mornings with an unsettling message"*

On a vibrant Sunday morning in September, the hotel dining room comes alive as guests filter in for breakfast. The atmosphere is a mix of business travellers and leisure guests, each group engaging in their morning routines. As the buffet opens at 7am, a wide array of dishes is laid out, served on large plates that invite generous servings.

The dining area features a provocative message prominently displayed: *"Wasting food is like stealing from the poor and hungry. Eat what you take!".* This bold statement captures the attention of many guests, who stop looking at it for a second. The message sparks discussions and discomfort among the guests, some of whom look visibly upset. Business guests, characterized by their higher level of conformism, tend to observe and adjust their behaviour to that of those around them, while leisure guests approach the buffet with enthusiasm and curiosity. The high level of sustainability awareness among the guests leads to more mindful choices compared to settings where such awareness is lacking. Many take a moment to consider their portions, aware of the environmental implications of their decisions. As the meal unfolds, the atmosphere buzzes with conversation and laughter, and the provocative message lingers in the air, still being discussed by guests eating at the same table.

Key characteristics: Large plate size – Equal share of business and non-business guests (business guests with higher level of conformism) – High level of sustainability awareness (women with higher levels) – Provocative message.

### 3.2.3 Research questions

The overarching aim is to understand how different factors, including individual motivations, social influences, external opportunities, and time constraints, contribute to food consumption and waste in these types of settings. By modelling individual and collective behaviours, it is possible to explore strategies to reduce food waste. With this aim, we developed the what-if scenarios described above in order to understand what are the more impactful factors to be addressed by FW reduction interventions. We have developed the following research questions:

***RQ1 Plate size:* Does the size of the plate offered by the commercial establishment influence the amount of FW generated by guests?**

The size of the plate can have a significant visual impact on how much food individuals choose to serve themselves, especially in settings where individuals have the freedom to fill their plates as much as they wish. When deciding how much to serve, individuals are influenced both by their usual consumption amounts, and by environmental cues such as the size of plates. The plate size offers a visual consumption norm, suggesting how much it is appropriate to take: large plates convey the norm that it is appropriate to eat more than smaller plates would suggest (Wansink & van Ittersum, 2013). In addition to the social cue conveyed by the plate size on the socially accepted amount of food, larger plates can also produce a visual illusion that produces biased perceptions of the quantity of food served (Van et al., 2011). In this sense, larger plates can create the visual perception that one's plate is not full unless more food is taken, often leading to over-serving. This, in turn, can contribute to higher levels of food waste when guests take more than they can realistically consume (Freedman & Brochado, 2010).
The influence of plate size on FW has been investigated in several scientific papers (Kallbekken & Sælen, 2013; Peng, 2017; Reynolds et al., 2019; Richardson et al., 2021; Wansink & van Ittersum, 2013; Zhao & Manning, 2019) and in relation to different settings. Results of these studies support the hypothesis that offering smaller plates to guests and clients lead to reduced amounts of FW. In particular, Kallbekken & Sælen (2013) and

Wansink & van Ittersum (2013) explored the effect of plate size in buffet settings: the former study found a 19.5% reduction in FW with the use of smaller plates, the latter show that individuals using larger plates served 52% more and wasted 135% more food than clients with smaller plates.
Building on these results, we are interested in simulating the impact that the plate size has on the amount of FW. Understanding the impact of changing the plate size provides relevant information on whether this type of intervention should be adopted by dining establishments in order to curb over-serving and, eventually, FW.

***RQ2 Guest composition:*** **Do differences in the share of business and non-business guests influence the amount of FW generated?**

The composition of guests, specifically the share of business and non-business guests eating at the buffet, is an important factor that can influence the amount of FW generated. By simulating scenarios that vary this factor, we are interested in gaining insights into how different social identities, time constraints and levels of conformism influence FW. In this context, it is important to recall that in our model, business and non-business guests differentiate in two main aspects: available time (i.e. business guests start having breakfast earlier and have less time to eat) and conformism (business guests are characterized by a higher level of conformism than non-business guests). These features can drive differences in behaviour that eventually influence FW generation.
According to social identity and self-categorization theories (originally developed by Tajfel & Turner, 1979), people derive a sense of identity from their group memberships. There are situations in which people consider themselves as individuals, with their preferences; in other settings, individuals mostly think of themselves as members of a particular group, whose characteristics and preferences may vary from the individual ones. Business and non-business guests represent distinct social groups, and their food choices at a buffet may reflect their different social identities. Specific literature on conformism influence on the behaviour of different typologies of guests is currently missing. Literature on the social self-categorisation of employees, though, suggests that there are circumstances in which workers are more likely to think of themselves as part of a collective (their professional social role) instead that as individuals (Ellemers et al., 2004). In this sense, in our model we assume that the salient social role of business guest is that of their professional role, making them more likely to conform to social norms (hence the higher level of conformism). For example, non-business guests may feel less pressure to conform to social norms that could constrain their freedom to fully enjoy their time. Business guests, by contrast, might adopt more efficient and deliberate behaviours aligned with their social role as professionals. Social proof theory (Cialdini, 1985) suggests that individuals look at the behaviour of others, particularly when they act in an ambiguous setting in which their behaviour is under the scrutiny of others[3].
In addition to conformism, we are interested in investigating the impact of time constraints on FW. The impact of time factors on decision-making is documented in the literature. Juvan et al. (2021) found that individuals that have breakfast earlier tend to waste less food, compared to those entering the buffet later. On the other hand, Cohen et al. (2016), Price & Just, (2015), and Wansink (2004) results suggest that an extended mealtime results in lower plate leftovers.
Business guests typically have less time for eating due to work obligations, thus they may act faster when choosing and eating their food. Time pressure could lead to more calculated decisions (e.g., taking only what they intend to eat, therefore reducing the likelihood of food waste), or result in higher levels of FW since they do not have enough time to finish what they took, even though they have lower indulgence levels than non-business guests. Conversely, non-business guests are not time constrained, so they can explore the buffet and indulge in larger portions of food.

[3] The concepts of observability and familiarity of different settings and their relationship with social norms is presented in D3.2 0FLW interventions (page 12-13).

***RQ3 Does the tone of messages given influence FW behaviour?***

Many hotel buffets now feature signs with messages from staff encouraging guests to eat responsibly and avoid food waste. These messages, carefully crafted by the staff, vary in tone - from polite requests to moral appeals and even subtle provocations.

Years of psychological research have examined how different types of messaging can influence behaviour, identifying which approaches are most effective in shaping actions related to food waste and other pro-environmental behaviours. In most cases, "nudging" techniques work quite effectively. For instance, Mertens et al. (2022) found a small to medium overall effect size for nudges in promoting behaviour change. However, they also noted that approximately 15% of interventions could backfire, leading to reduced or even reversed desired behaviours (ibidem). Similarly, Osman (2020) highlighted studies reporting failures in efforts to promote positive behaviours in environmental contexts.

Other studies indicate that aggressive messages are less effective in encouraging behaviour change (Yuan & Kuehl, 2023). This effect is particularly evident even among individuals who have committed to acting in specific ways. Banerjee et al. (2023) discovered that nudging people already motivated to eat sustainably, especially after they've made a pledge, can sometimes yield unintended negative outcomes. A similar reversal in behaviour may occur when nudges undermine a person's sense of agency (Bruns & Perino, 2023) or limit their freedom of choice (Langer & Rodin, 1976).

These "ironic" effects can be attributed to the phenomenon of reactance—a motivational state triggered when one's freedom of choice is threatened (Brehm, 1966; Brehm & Brehm, 1981). Research has shown that nudges can provoke reactance, especially when using forceful language such as "should," "ought," "must," and "need" instead of more flexible terms like "consider," "can," "could," and "may" (C. H. Miller et al., 2007; Quick & Stephenson, 2008). People tend to resist when they feel pressured; if a message seems to threaten their autonomy, they often respond by rejecting it outright (Fitzsimons & Lehmann, 2004; Silvia, 2006). On the other hand, when a message is well-framed, it can be highly effective (Mertens et al., 2022; in a FW context: Nisa et al., 2022).

Building on this knowledge, our goal is to simulate the impact of positive vs. provocative messaging on food waste (FW). Gaining insight into how message framing influences behaviour can help develop more effective communication strategies with hotel guests and reduce FW in buffet settings.

***RQ4 Sustainability awareness*: Does the sustainability awareness level of guests influence FW?**

When discussing food waste (FW) in hotel settings, such as breakfast buffets, it is crucial to consider that guests represent diverse cultures, countries, and value systems, all of which shape their attitudes toward food waste. Miller et al. (2022) demonstrated significant cross-country variation in environmental attitudes and pro-environmental behaviours across 11 nations. Similarly, Aoyagi-Usui et al. (2003) found structural differences in environmental values between Asian and Western countries. With guests from around the world, it is reasonable to anticipate varying levels of sustainability awareness among them.

People's attitudes toward sustainability in turn influence waste behaviour, with personal environmental values serving as strong predictors of food waste behaviour (Visschers et al., 2016). For example, individuals with strong environmental focus tend to produce less waste by making intentional dietary and consumption choices (Conrad et al., 2018). Similarly, Williams et al. (2012) highlights how attitudes toward food sustainability can influence waste, as awareness of food waste's environmental impact varies, affecting the likelihood of waste-reducing practices.

Consumer motivations and values, such as environmental concerns and attitudes toward sustainability, significantly affect food waste behaviours. Research by Stancu et al. (2016) indicates that individuals with strong personal responsibility and environmental values tend to waste less food, often due to better planning and avoidance of impulse purchases. Furthermore, people with a pro-environmental stance are more responsive to messages framing food conservation as a shared environmental responsibility, which reduces waste (Abrahamse & Steg, 2013). Leiserowitz et al. (2006) underscores the need for tailored interventions to address the distinct environmental attitudes and values influencing waste-related behaviours.

Based on these findings, we expect that guests' levels of sustainability awareness affect food waste, particularly in decisions about finishing their food or leaving leftovers.

## 3.3 Validation

Model validation ensures that a model works as expected and meets its goals. It involves testing and verifying that the model produces accurate results and behaves in accordance with its purpose. Here, we validate the model using data collected from Norwegian hotels.

### 3.3.1 Overview of hotel data

We used data collected across eight different Norwegian hotels involved in case study 2 activities [4]. This data consists of records of the number of business and non-business guests and the total amount of food waste generated each day at the end of breakfast time. The data was collected on days when the hotel displayed messages to raise awareness about food waste (positive or provocative messages) and days without messages (control days). For the first calibration, we considered only the control days.

We used the control database only days when all data were collected (days with missing information were ignored[5]). The final database comprises 493 days recorded in total (summing the days collected in each hotel). A descriptive statistical analysis revealed an average of 27.94 grams of food waste per guest, with a standard deviation of 15.41 grams per guest (Table 2 and Figure 3).

Table 2: Descriptive statistics of the control data collected across eight hotels in Norway.

| | Control | Positive communication | Provocative communication |
|---|---|---|---|
| **Days** | 493 | 348 | 109 |
| **Mean FW/guest/day (g)** | 27.94 | 22.81 | 32.46 |
| **Standard deviation** | 15.14 | 12.77 | 17.62 |
| **Minimum** | 0 | 1.43 | 4.84 |
| **25%** | 16.77 | 13.55 | 19.20 |
| **50%** | 26.32 | 20.06 | 29.96 |
| **75%** | 36.43 | 29.03 | 46.15 |
| **Maximum** | 104.27 | 81.08 | 100 |

[4] See D2.1 Case Studies' Strategic Plan and D2.3 Empirical evidence sensemaking for a throughout description of research question, methodologies, and results of case study 2 "Hospitality food waste".

[5] We considered as missing information days when one of the data was not collected (e.g., amount of business or non-business guests or the amount of food waste).

### 3.3.2 Model optimization

We used the amount of food waste measured in hotels to optimize the model and find the best parameters to fit the results. AnyLogic optimization function (genetic algorithm) was used to find the best parameter combination to generate about 28g of FW per agent per day (control data, business, and non-business guests).

It is important to highlight that the data collected at hotels is not from individual guests but from the average amount of waste produced by all guests. Based on this aggregate value, we decided to compare the data collected with the average of the model. We ran the optimization for 100 runs, 100 iterations each. The best set of model parameters, presented in Table 3, were used to estimate a starting number for the simulations, which were then calibrated to further enhance the model's accuracy.

Table 3: Parameters values found in the optimization analysis.

| Parameter | Value |
|---|---|
| Average desire of weight control | 0.4 |
| Average conformism | 0.2 |
| Average fullness | 0.5 |
| Average hunger | 0.236 |
| Average indulgence | 0.697 |
| Average sustainability | 0.35 |
| Choosing ability | 0.3 |
| Food diversity | 0.363 |
| Self-control | 0.446 |

Although most of the values found in the optimization are reasonable, the values for fullness and hunger are not. The model was developed to simulate breakfast at a hotel buffet, where it is expected that people will be hungry and not full in the morning. Therefore, a low value like 0.236 for average hunger and a high value like 0.5 for fullness are not plausible. However, we used these values to assess the influence of each variable in the model, and later, we performed a new optimization, keeping key parameters fixed.

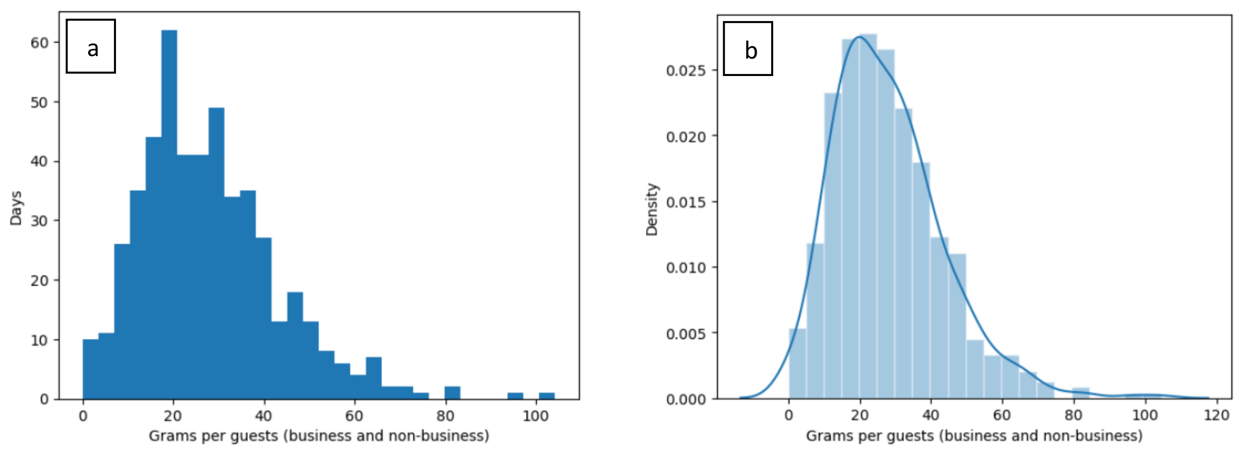


Figure 3: Distribution per days (a) and density (b) of the grams of leftover per guest in the hotel data for the control data.

### 3.3.3 Consistency analysis

We conducted the Vargha-Delaney A Test (Vargha & Delaney, 2000) to determine the number of replications needed to reduce uncertainty in the outputs caused by stochasticity. The model ran 9400 times, and the sample size groups were: 20 groups of 20, 100, 150 and 200.

The results show that between 100 to 150 replications are enough to reduce uncertainty in the model output (

Figure 4). The statistical software R (version 4.4.0) and spartan package (version 2.3) were used to perform the Vargha-Delaney A Test.

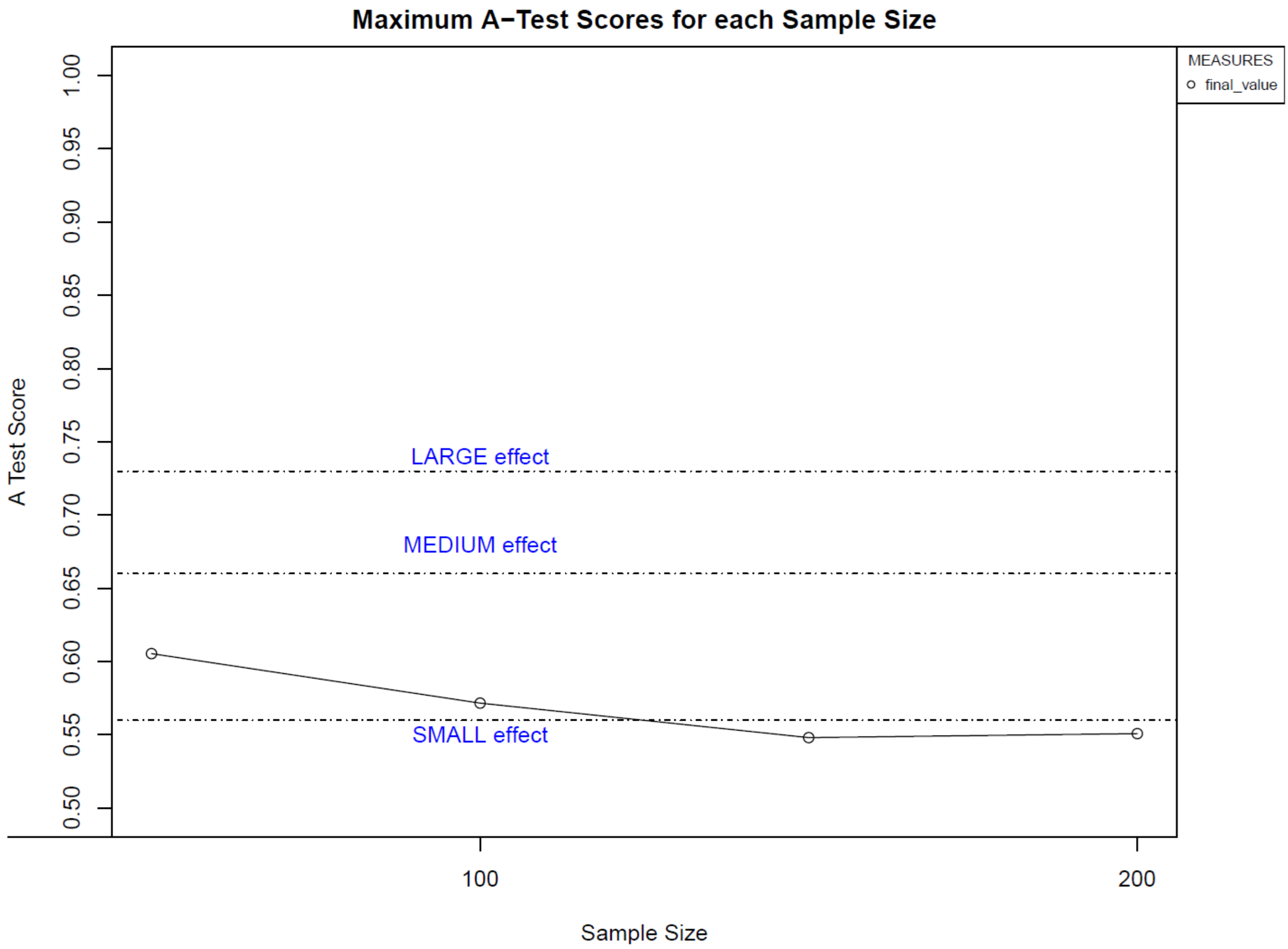


Figure 4: Maximum A-Test Scores for each sample size.

### 3.3.4 Sensitivity analysis

**a) Individual sensitivity analysis**

We ran the model, keeping a few parameters fixed (using values from the first round of optimization) to assess each parameter's influence on the model output (amount of food waste). The results are outlined below. For each one of them, we kept all the parameters fixed (Table 4) except for the one under analysis (averages self-control, fullness, hunger, indulgence, desire of weight control, conformism and sustainability), which we varied from 0 to 1 (0.01 interval). We ran the model 100 times for each one of them. It is worth noting that the only outcome we can infer here is the amount of leftovers because this is the data we collected in the hotels. The standard deviation of the parameters was 0.01.

Table 4: Parameters used for individual sensitivity analysis.

| Parameter | Mean value |
|---|---|
| Average desire of weight control | 0.4 |
| Average conformism | 0.2 |
| Average fullness | 0.5 |
| Average hunger | 0.236 |
| Average indulgence | 0.697 |
| Average sustainability | 0.35 |
| Business proportion | 0.3 |
| Choosing ability | 0.3 |
| Female proportion | 0.5 |
| Food diversity | 0.363 |
| Leftover percentage | 0.1 |
| Number of agents | 100 |
| Self control | 0.446 |

The ANOVA test ($\alpha = 0.01$) was performed for each set of runs for the values of 0.01, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1. The results show a significant difference between the groups for each set of runs. It is worth noting that the results were not compared between sets of runs (for instance, hunger was not compared with sustainability).

Although the model shows significant sensitivity for the variation of all the seven parameters (averages self-control, fullness, hunger, indulgence, desire of weight control, conformism and sustainability), average conformism and sustainability play an expressive influence in the model (Figure 5).

The Vargha-Delaney A Test (Vargha & Delaney, 2000) was run to verify model's sensitivity. It shows that large differences were identified mostly for lower values of conformism and sustainability (Figure 6). These parameters had a score lower than 0.29. According to this method, scores near 0.5 suggest robustness and low sensitivity to changes in parameter variations. Scores above 0.71 or below 0.29 indicate higher sensitivity of the results to the parameters.

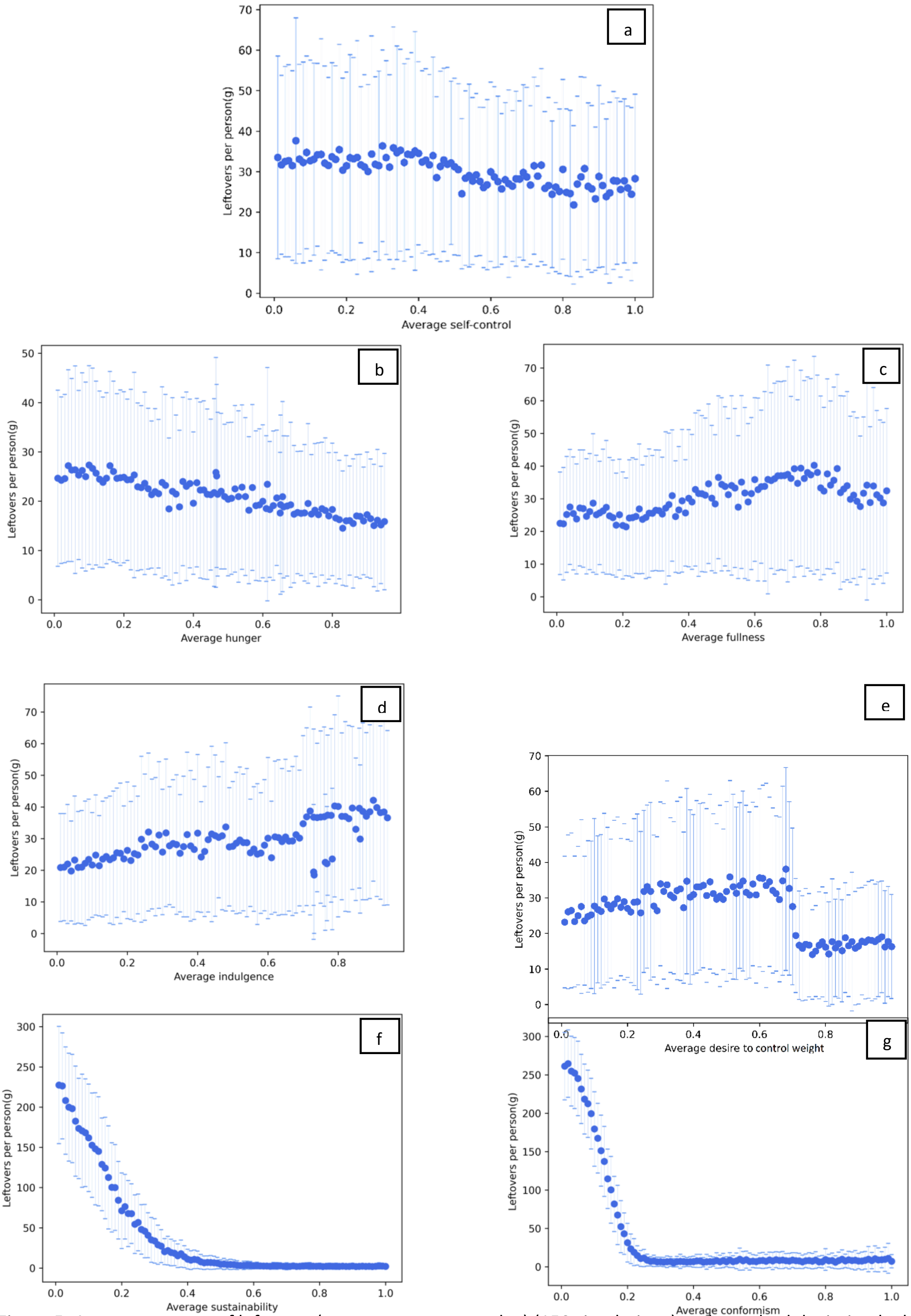


Figure 5: Average amount of leftovers (grams per guest per day) (150 simulations) and standard deviation by keeping parameters constant and varying one: average self-control (a), average hunger (b), average fullness (c), average indulgence (d), average desire of being thin (e), average sustainability (f), and average conformism (g).

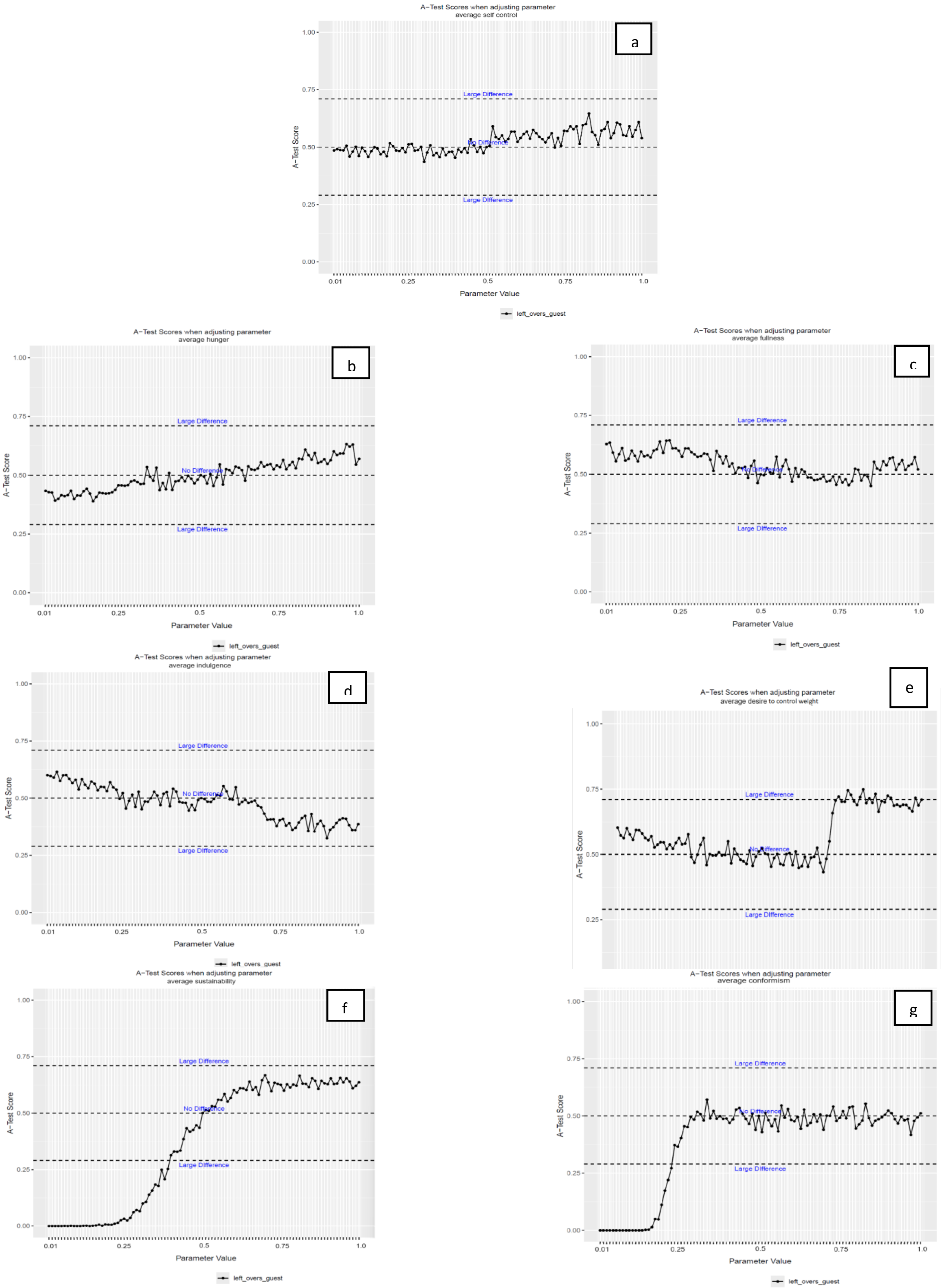


Figure 6: A-test scores (150 simulations) keeping parameters constant and varying one: average self-control (a), average hunger (b), average fullness (c), average indulgence (d), average desire of being thin (e), average sustainability (f), and average conformism (g).

We also run a sensitivity test varying combinations of sustainability and conformism (150 runs). The results are presented in Figure 7.

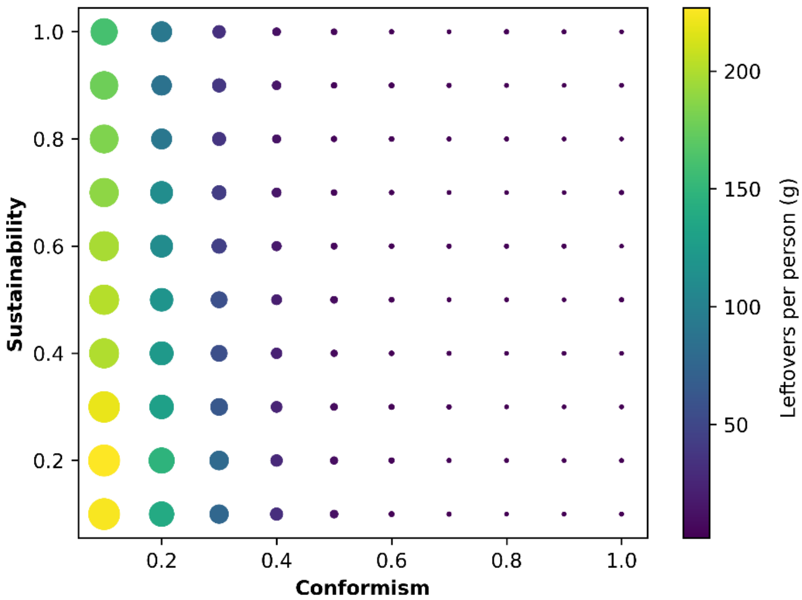


Figure 7: Amount of leftovers per guest for combinations of average sustainability and conformism.

### b) Global sensitivity analysis

Global sensitivity analysis examines how changes in a model's input factors affect uncertainty in its output. It identifies which inputs contribute most to variations in the results, helping to understand and manage the model's overall uncertainty. A few parameters were selected to be simultaneously disturbed for the global sensitivity analysis. We used the Latin Hypercube Sampling technique to generate 100 scenarios in the interval of each parameter (defined by the individual sensitivity analysis) (Table 5). The standard deviation of the parameters was 0.01.

Table 5: Maximum and minimum values for the Latin Hypercube Sampling for parameters used for the global sensitivity analysis.

| Parameter | Minimum | Maximum |
|---|---|---|
| Average desire of weight control | 0 | 1 |
| Average desire of weight control (females) | 0 | 1 |
| Average conformism (business) | 0.17 | 0.20 |
| Average conformism (non-business) | 0.17 | 0.20 |
| Average fullness | 0 | 0.5 |
| Average hunger | 0.5 | 1 |
| Average indulgence | 0 | 1 |
| Average indulgence business | 0 | 1 |
| Average sustainability | 0.2 | 0.3 |
| Average sustainability (females) | 0.2 | 0.3 |
| Self-control | 0 | 1 |
| Choosing ability (business) | 0 | 1 |
| Choosing ability (non-business) | 0 | 1 |

| Fixed parameters | |
|---|---|
| Female proportion | 0.5 |
| Left over percentage | 0.1 |
| Business proportion | 0.3 |
| Food diversity | 0.5 |
| Number of agents | 250 |

Each set of parameters was tested. The outcomes are displayed in Figure 8 and shows the parameters variation over the simulations. Combinations of parameters such as high indulgence, low sustainability, and low desire of weight control contributed to higher values of leftovers. However, various combinations of parameters can produce different results, demonstrating the robustness of the model.

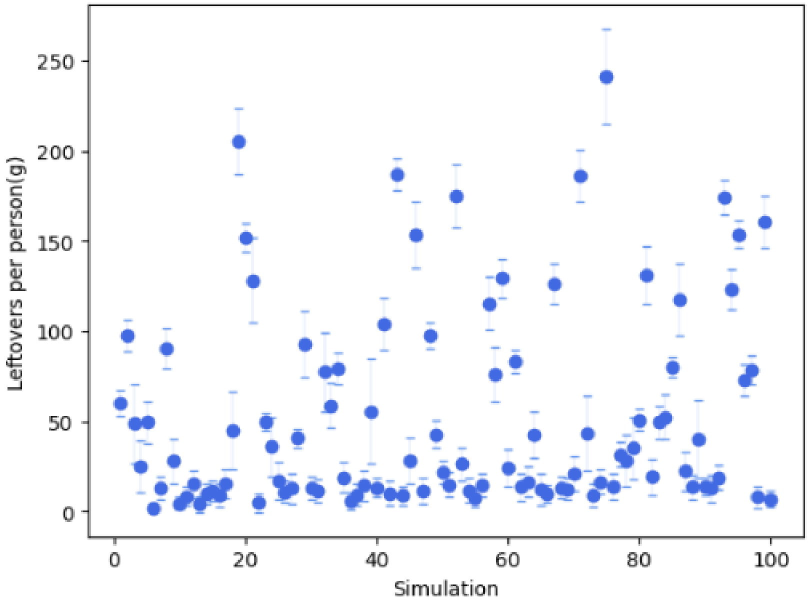


Figure 8: Results (average of 150 runs and standard deviation) obtained by running the global sensitivity analysis.

### 3.3.5 Model calibration

A second optimization was run after understanding the role of each motive and self-control in the model. The new values found are shown in Table 6.

Table 6: Values obtained in the second optimization.

| Parameter | Mean value |
|---|---|
| Average indulgence | 0.697 |
| Choosing ability | 0.3 |
| Food diversity | 0.363 |
| Self-control | 0.446 |

After the second optimization, the model was run for 250 agents, with 30% of the guests being business (data inferred from the control data collected at the hotels). The parameters are shown in Table 7. The standard deviation of the parameters was 0.01.

Table 7: Parameters used for model calibration.

| Parameter | Mean value |
|---|---|
| Average desire of weight control | 0.5 |
| Average conformism | 0.175 |
| Average fullness | 0.3 |
| Average hunger | 0.7 |
| Average indulgence | 0.7 |
| Average sustainability | 0.25 |
| Business proportion | 0.3 |
| Choosing ability | 0.6 |
| Female proportion | 0.5 |
| Food diversity | 0.156 |
| Left over percentage | 0.1 |
| Self-control | 0.446 |
| Number of agents | 250 |

The model was run for 493 replications (same number as the hotel data) (Figure 9). We found an average of 30.20 grams of leftovers per person with a standard deviation of 14.68 grams per guest (Table 8). A one-way ANOVA test comparing the hotel data results and the simulation results showed that the means are not significantly different at the 0.01 level.

Table 8: Descriptive statistics of the model results during calibration.

| | |
|---|---|
| **Days** | 493 |
| **Mean FW/guest/day (g)** | 30.20 |
| **Standard deviation** | 14.68 |
| **Minimum** | 3.44 |
| **25%** | 20 |
| **50%** | 27.60 |
| **75%** | 37.36 |
| **Maximum** | 108.40 |

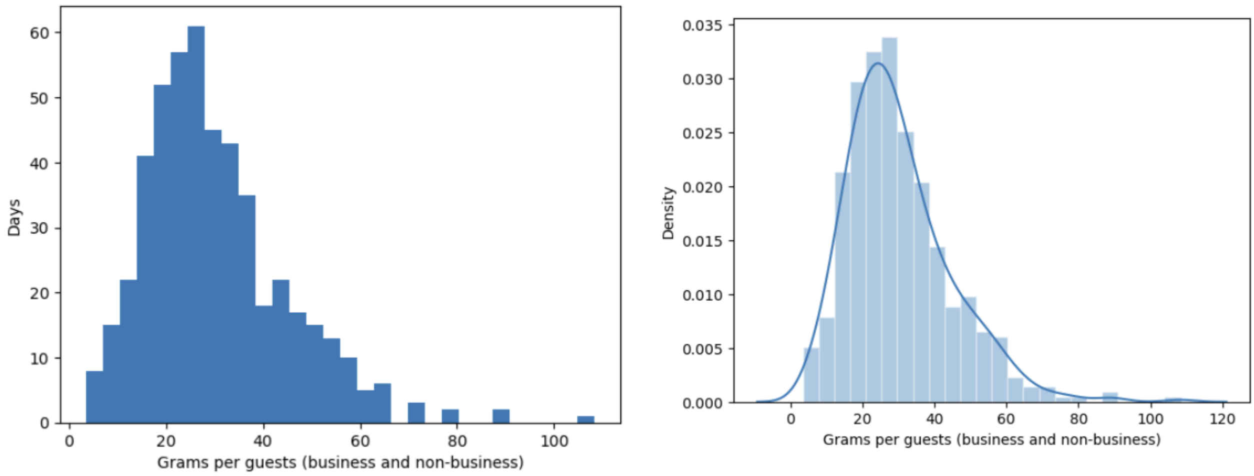


Figure 9. Distribution per days (runs) (left) and density (right) of the grams of leftover per guest in the simulation results.

## 3.4 Scenarios implementation in models

The results of the validation helped us shape the scenario analysis. The individual sensitivity analysis, for example, showed that the model is very sensitive to the levels of conformism and sustainability awareness. We tested four scenarios (presented in section 3.3.2), based on four scenario categories: plate size availability, guest composition, sustainability awareness, and communication strategy.

The baseline scenario serves as our starting point, where we calibrate the model using available data, that is, the results when no changes are made in the simulation (reproducing the experiments conducted for data collection). On the other hand, the what-if scenarios involve parameter variations to assess how the model's output (food waste) is affected. We expect this model's results to help propose interventions for reducing food waste in a hotel buffet. The key concepts of the what-if are elaborated upon below.

**a) Plate size**

Plate size, as the name suggests, represents the size of the plate available to agents. The hotel/buffet offers two plate sizes: normal and large.

The plate size is an opportunity, as it is outside agents' control, and agents can adjust portion sizes depending on the size of the plate. For normal plates: they can choose not to eat; small portion (200g); or a normal portion (300g). For large plates: agents can choose not to eat; small portion (200g); normal portion (300g); or large portion (400g). They decide on the portion size according to five motives: hunger, desire of weight control, indulgence, fullness, and sustainability.

We will test two different possibilities related to the plate size:

1. Only normal plates
2. Only large plates

The parameter influenced in this case will be the size of the plates offered by the establishment. Plates can be normal or large (Table 9).

Table 9: Plate size options.

| Plate size | Portion size | Amount of food (capacity of plate) |
|---|---|---|
| *Normal plate* | Small portion | 200g |
| | Medium portion | 300g |
| *Large plate* | Small portion | 200g |
| | Medium portion | 300g |
| | Large portion | 400g |

The implementation of different plate sizes is done when the model starts. Agents' decisions will vary according to the size of the plates available and their motives.

**b) Guest composition**

Agents in the model can be business or non-business. Business agents represent the agents staying in a hotel for work, for example, while non-business can be characterized as the ones staying in a hotel for leisure, holidays, etc. Business agents go for breakfast earlier than non-business, and they are time constrained. In the simulated scenarios, business guests show higher average levels of conformism and lower levels of indulgence than non-business guests.

Three population distributions will be tested here:

1. Mainly business guests: 70% business and 30% non-business
2. Equal part business and non-business guests: 50% business and 50% non-business
3. Mainly non-business guests: 30% business and 70% non-business (baseline scenario – data from hotels show 29% business and 71% non-business, average)

The variable that will be modified is the "Business_proportion", changing according to the scenarios. The change in the model for these scenarios will occur before the simulation starts, by defining the percentage of each population.

**c) Sustainability awareness**

The sustainability awareness motive is related to the decision made when an agent decides whether to finish its food - right after checking if it is still hungry or full. The decision is about eating all the food or leaving leftovers, and it is related to the responsible management of food resources to minimize waste and maximize efficiency.

Two levels of sustainability awareness will be tested in the scenarios:

1. High sustainability awareness (female $\mu$=0.50 and $\sigma$=0.01 and male: $\mu$=0.40 and $\sigma$=0.01)
2. Low sustainability awareness (female $\mu$=0.20 and $\sigma$=0.01 and male: $\mu$=0.10 and $\sigma$=0.01)

The variable that will be modified is the normal distribution of sustainability. The change in the model for these scenarios will occur before the simulation starts.

**d) Communication strategy**

Communication strategies are defined by how a message shown to customers while they are taking food at the buffet can evoke different reactions. We decided to include two types of messages: provocative and positive.

In the hotel experiment, the positive messages shown in the hotel experiments were:

*"Please, don't take more than you can eat"*

*"We care for the environment. Help us waste less food"*

The provocative messages shown were:

*"Everything we serve has its story. Born, grown, harvested, herded, packaged, and transported. What you leave on your plate will be wasted."*

*"Every time you waste food, you're wasting a part of the planet. Enjoy your food!"*

*"Wasting food is like stealing from the poor and hungry. Eat what you take!"*

Three types of communication are be considered:

1. No communication (choice threat = 0.5)
2. Provocative message (choice threat = 0.6)
3. Positive message (choice threat = 0.2)

To implement the communication scenario, we decided that each message has a level of choice threat. The value goes from 0 to 1: messages close to 0 are more positive, while messages close to 1 are more provocative. We used 0.5 as the scenario with no communication, that is, no message is displayed.

Each agent has a tolerance to choice threat sorted from a beta distribution (a=3, b=3). This tolerance is also correlated with self-control (higher self-control implies a higher tolerance, with a 50% correlation). Self-control is drawn from a gaussian distribution ($\mu$=0.50 and $\sigma$=0.05). The message of choice threat is the same for all agents, while tolerance is individual. In other words, individual agents respond differently to the same message based on their tolerance level.

We have established two distinct decision-making routes within the model, applying to both the decision regarding the portion size and the leftovers generation (Figure 10). If an agent's tolerance to choice threat is higher than the level of choice threat in the message, the agent will follow route one for both decisions. On the other hand, if the agent's tolerance is lower, they will follow route two, in which reactance plays a role by changing the importance of motives. It is important to note that these routes only apply when there is communication, as indicated by a message's choice threat level different from 0.5 (choice threat in case of no communication).

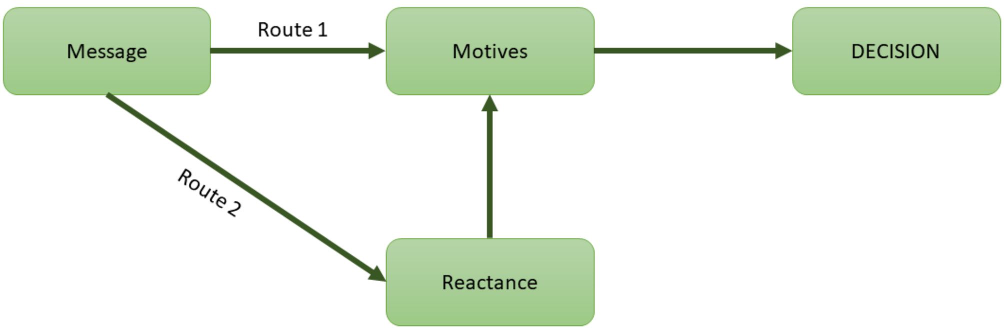


Figure 10: Decision making routes

Decision 1: Portion size

If the agent takes route one, it notices and cares to a certain extent for the content of the message: the importance of conformism and sustainability increases, and indulgence is reduced. The increasing or decreasing in importance is given by a modulator defined as:

$$Modulator\ 1 = 1 + \left(\frac{-1}{agent's\ choice\ threat\ threshold}\right) * message\ choice\ threat$$

However, if the agent takes route two, the content of the message activates reactance: the importance of conformism, indulgence, and desire to control weight are reduced. The decrease is given by a modulator defined as:

$$Modulator\ 2 = 1 + \left(\frac{-1}{agent's\ choice\ threat\ threshold}\right) * (message\ choice\ threat - 1)$$

Decision 2: Leftovers

For decision 2 (to eat all the food or to leave leftovers), the change in importance is reduced proportionally to the time the agent spent eating. This reduction is given by:

$$I_t = I_t \pm \rho * |I_{t=0} - I_t| * e^{-1*\sigma*breakfast\ time}$$

Where $I_t$ is the importance of the motive at the time $t$, and $\sigma = 0.0001$. We tested $\rho = 0.8$ and $\rho = 0.6$. The increase or decrease happens depending on the route: if it was reduced initially, $I_t$ increases over time and vice versa. The reduction or increase over time is also never lower or higher than the initial value.

If the agent takes route one, the influence of the message tends to diminish with time: the importances of conformism and sustainability increase, and the indulgence goes back to the initial value. On the other hand, if the agent takes route two, the importances of conformism and sustainability decreases, fullness increases, and the desire to control weight returns to the initial value. For all the decisions and routes, the value of motives' importance is never lower than 0 or higher than 1.

*Calibration*

We tested different levels of choice threat since the messages displayed at the hotel are different. The results are displayed in Figure 11. We decided to run the what-if scenarios with a) $\rho = 0.8$ .

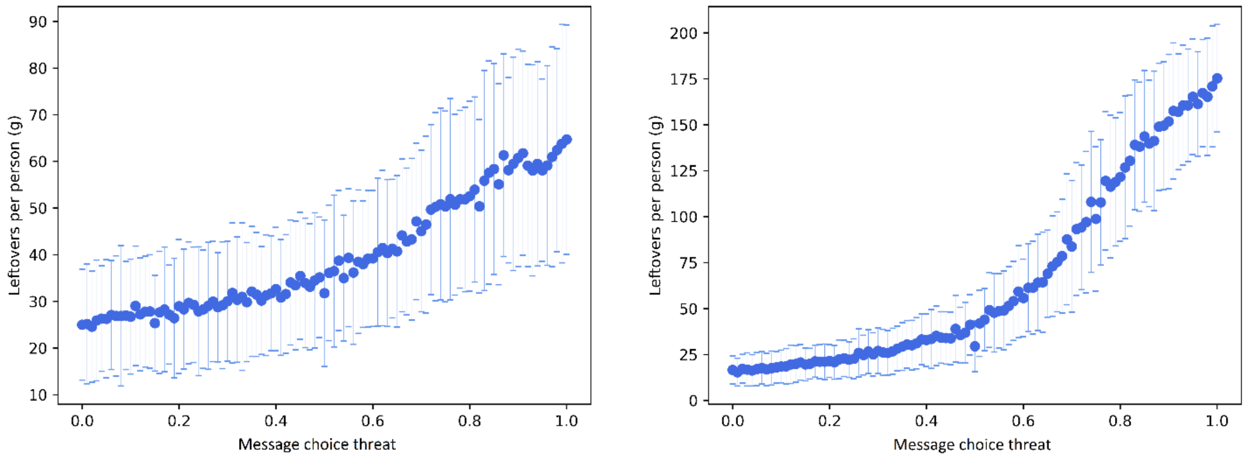


Figure 11: Amount of leftovers per person (g) for different messages. Left: $\rho = 0.8$ and Right: $\rho = 0.6$

## 3.5 Scenarios results

In this section, the results of what-if scenarios simulations will be presented and discussed.

Table 10 lists the values used for fixed parameters in all simulation scenarios, while Table 11 presents the varied values for parameters tested across different scenarios. The standard deviation of the parameters was 0.01.

Table 10: Values used for what-if scenarios simulations

| Parameter | Value | Standard deviation |
|---|---|---|
| **Average weight control** | 0.5 | 0.01 |
| **Average fullness** | 0.3 | 0.01 |
| **Average hunger** | 0.7 | 0.01 |
| **Average indulgence (non-business)** | 0.7 | 0.01 |
| **Average indulgence (business)** | 0.6 | 0.01 |
| **Choosing ability** | 0.6 | 0.01 |
| **Female proportion** | 0.5 | 0.01 |
| **Food diversity** | 0.156 | 0.01 |
| **Left over percentage** | 0.1 | 0.01 |
| **Self-control** | 0.446 | 0.01 |
| **Average conformism (non-business)** | 0.1 | 0.01 |
| **Average conformism (business)** | 0.25 | 0.01 |
| **Number of agents** | 250 | |

Table 11: Values used for parameters variation in what-if scenarios simulations

| Variable | Scenario | Average value |
|---|---|---|
| **Plate** | Normal | |
| | Large | |
| **Guest composition** | High business | Business proportion = 0.7 |
| | Equal | Business proportion = 0.5 |
| | Low business | Business proportion = 0.3 |
| **Sustainability** | High | For females = 0.5 |
| | | For males = 0.4 |
| | Low | For females = 0.2 |
| | | For males = 0.1 |
| **Communication strategy** | No message | Choice threat = 0.5 |
| | Provocative message | Choice threat = 0.6 |
| | Positive message | Choice threat = 0.2 |

36 what-if scenarios were run in the simulations, in order to test all possible parameters variation combination. They are described in the Appendix (Table A1). Figure 12 shows the resulting amount of FW for each scenario.

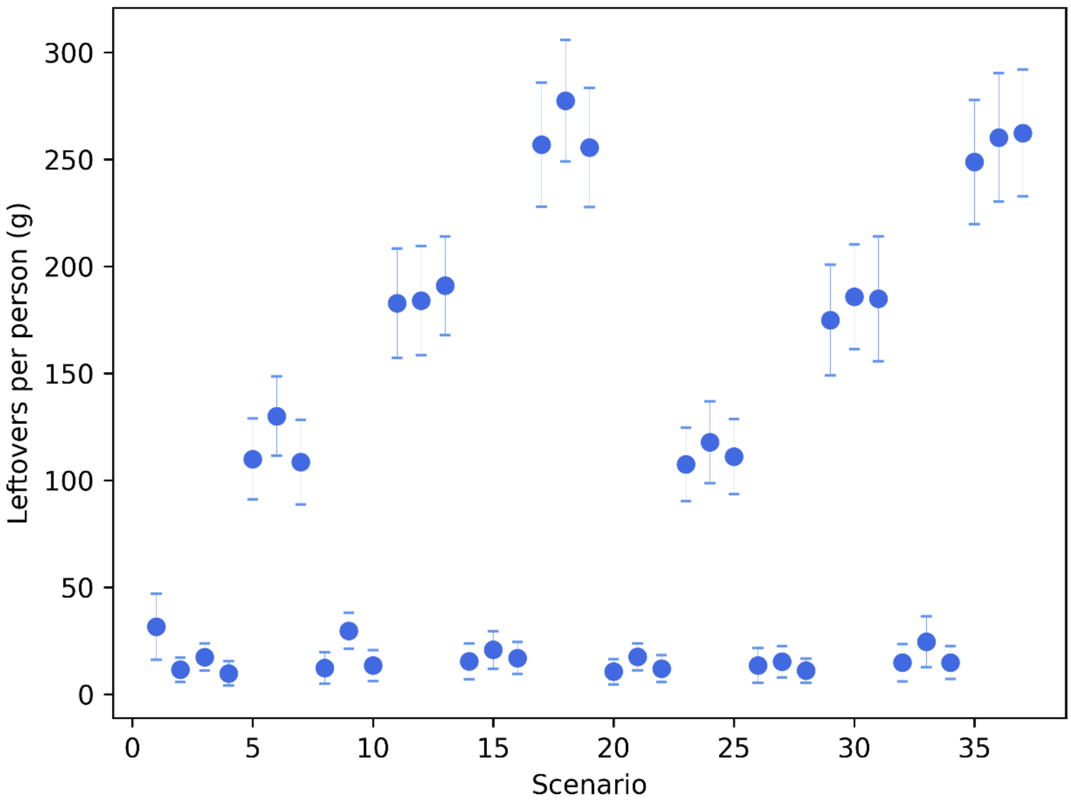


Figure 12: Amount of leftovers per person (in grams) in the 36 simulated scenarios.

As shown in the figure, scenarios are grouped into four categories based on the level of FW generated: Low FW (0g < FW < 100g), Medium-low FW (100g < FW < 150g), Medium-high FW (150g < FW < 200g), and High FW (200g < FW < 300g). When looking at Table A1, it is easy to notice that all scenarios in which the level of sustainability awareness is high are placed in the Low FW group, providing a first important result. Therefore, other parameters become of particular relevance in populations in which the level of sustainability awareness is low, contributing only to small variations when individuals are characterized by a high level of sustainability awareness.

From the complete list of 36 what-if scenarios, we selected 4 to be described in details. Scenarios were selected to ensure a good variability of the different parameters while also maintaining a range of food waste levels generated. Selected scenarios are presented in Table 12.

Table 12: Selected what-if scenarios, Establishment Diner model

| ID | Plate Size | Guest Composition | Sustainability awareness | Communication | Average Leftovers per guest and standard deviation (g) |
|---|---|---|---|---|---|
| **#7** | Normal | High business guest | Low | Positive message | 108.53 ± 19.75 |
| **#18** | Normal | Low business guests | Low | Provocative message | 277.41 ± 28.41 |
| **#27** | Large | Equal | High | Provocative message | 15.2 ± 7.25 |
| **#35** | Large | Low business guests | Low | No communication | 3.6 ± 29.03 |

As illustrated in Table 12:

- FW level: 1 scenario (#27) pertains to the Low FW group; 1 scenario (#7) to the Medium-low FW group; 2 scenarios (#18, #35) to the High FW group;
- Plate size: selected scenarios explore the impact of using a large plate size (#27, #35) and the influence of introducing a normal plate size (#7, #18);
- Guest composition: the three values of guest composition (low, equal, high) are all represented in at least 1 scenario;
- Sustainability awareness: acknowledged that all scenarios characterized by a high level of sustainability awareness are within the Low FW group, 3 of the selected scenarios (#7, #18, #35) explore what happens if the level of sustainability awareness is low;
- Communication: all three communication strategies are represented in at least 1 scenario.

In the following sub-sections, what-if scenarios' results will be presented and discussed in comparison with the baseline scenario (presented in section 3.3.5), in order to analyse how different factors influence FW. About the baseline scenario, it is important to remember that certain conditions differ from the other 36 scenarios. The main differences are as follows:

- Conformism: in the baseline scenario, business and non-business guests have the same average level of conformism (0.175, 0.01), without differentiation. In the other scenarios, however, the two guest types are characterized by different levels of conformism (0.25 for business guests, 0.1 for non-business guests);

- Sustainability awareness: the baseline scenario was simulated with an average sustainability awareness of 0.25 (0.01), with no gender differences. In other scenarios, however, awareness varies by gender, with women displaying higher awareness than men. In high-sustainability scenarios awareness values are 0.5 for women and 0.4 for men; in low-sustainability scenarios, they are 0.2 for women and 0.1 for men.

Additionally, the following sub-sections will include comparisons between the selected scenarios and other scenarios, in order to further investigate the influence of changing individual parameters. To check the statistical significance of the differences among scenarios, a Tukey test of means comparison was performed (Annex, Table A2).

The baseline scenario is characterized by not having any particular intervention implemented: plate size is large, there is no communication about reducing FW, guests are mainly non-business and they all have the same level of conformism, sustainability awareness is medium (0.25). The average amount of FW produced by each guest is 31.65 grams (SD 15.42 grams).

Before presenting the results of the scenarios, Figure 13, Figure 14, and Figure 15 display boxplots showing the distribution of average leftovers for different values of Plate size, Guest composition, and Sustainability awareness, respectively. These graphs provide an initial overview of the role these parameters play in explaining variations in food waste (FW).

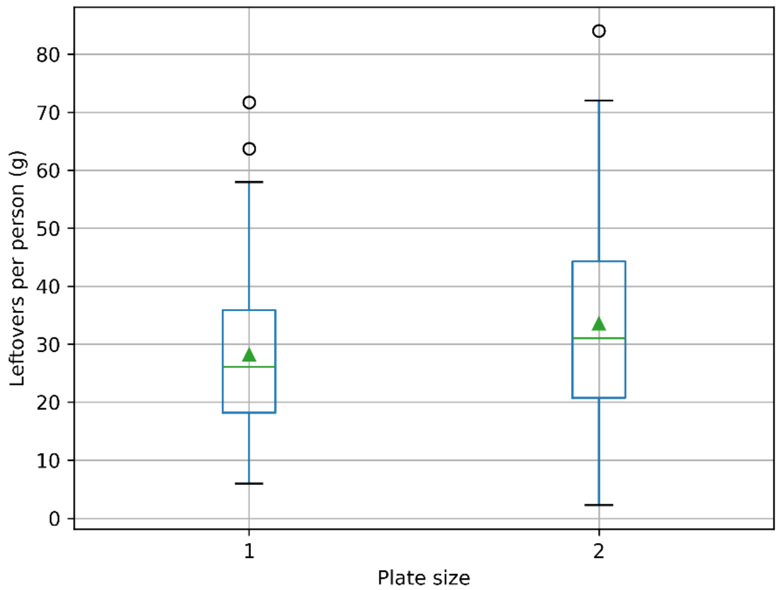


Figure 13: Boxplot of average leftovers per person (g) by Plate size categories (1=Large, 2= Normal)

Figure 13 compares average leftovers (per person, in grams) across Normal and Large plate sizes. Scenarios featuring larger plate sizes exhibit a slightly lower median (and mean) leftover amount compared to scenarios using normal plates. Both categories have similar interquartile ranges but Normal plate size group show a broader spread in the central 50% of the data. The group characterized by Normal plate sizes, moreover, shows more variability in larger leftovers, as indicated by the longer whisker on the upper size. This information suggests that the plate size alone may not be particularly relevant in explaining the differences in leftovers among scenarios.

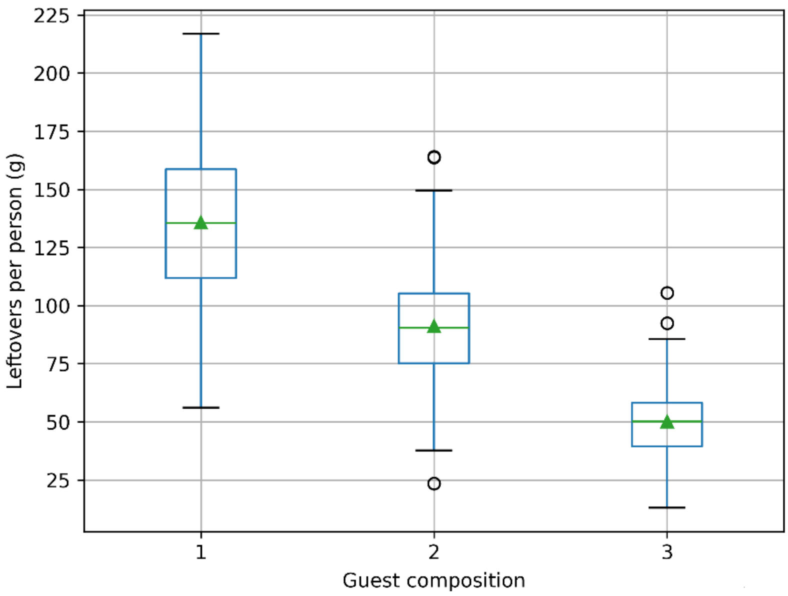


Figure 14: Boxplot of average leftovers per person (g) by Guest composition (1=Low business guests, 2=Equal, 3=High business guests)

Figure 14 compares average leftovers (per person, in grams) across scenarios featuring a low share of business guests (30%), an equal share of business and non-business guests, a high share of business guests (70%). Scenarios characterized by a low share of business guests have the highest variability in leftovers and a wider range of values, along with the highest median and mean values. Scenarios featuring a prevalence of business guests show the smallest range of leftovers values and the lowest median value (around 50 grams). The boxplot suggests that guest composition significantly affects the amount of food waste, with scenarios populated by a high share of business guests being the ones with less average leftovers.

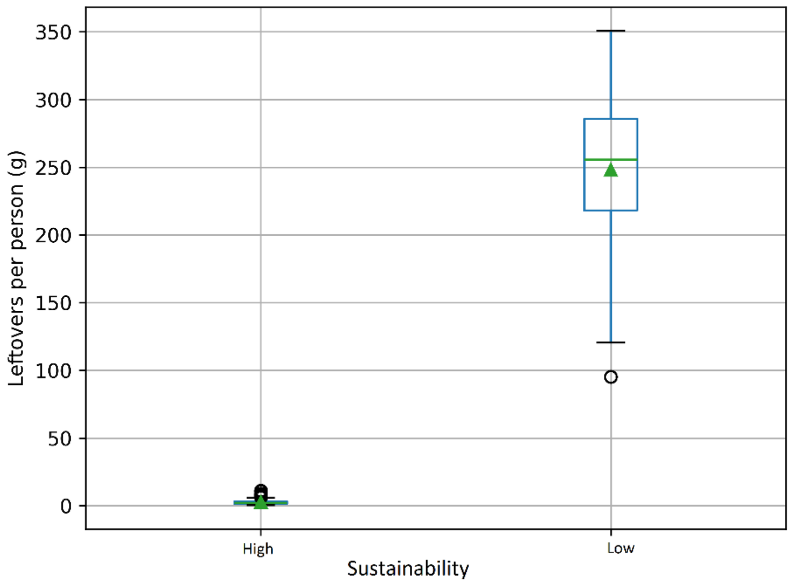


Figure 15: Boxplot of average leftovers per person (g) by level of Sustainability awareness)

Figure 15 compares average leftovers (per person, in grams) across scenarios in which the population is characterized by low and high levels of sustainability awareness. This graph further confirms what already presented before (Figure 12). Sustainability awareness has a significant impact on food waste. Scenarios in which individuals have a high sustainability awareness produce very low, consistent amounts of food waste, while those with low sustainability awareness produce considerably more food waste on average, with a wider range of values. This could imply that fostering sustainability awareness could be a key factor in reducing food waste.

### 3.5.1 Scenario #7 (Busy breakfast with a message) results:

This scenario takes place in a setting where two interventions have been introduced: the plate size has been reduced from **large to normal**, and a **positive communication message** encouraging guests to reduce food waste is displayed by the hotel. In this scenario, guests have a **low level of sustainability awareness** and are **mainly business guests** (70% of the total population).

This scenario yields 108.53 grams of FW per guest on average (SD 19.75 grams). This amount is significantly higher than in the baseline scenario, despite the two interventions implemented by the hotel (plate size and positive message). Compared to the baseline, this scenario is characterized by a higher share of business guests, who are more conformist than non-business guests.
One potential explanation for this outcome lies in the lower sustainability awareness levels, also differentiated between men and women in this scenario. While men and women are equally represented, the sustainability awareness level for men is significantly lower (0.1, SD 0.01) than in the baseline scenario (0.25, SD 0.01). As shown in the sensitivity analysis, sustainability awareness is an important factor influencing the amount of FW generated. In a population characterized by this level of sustainability awareness, the reduced plate size and the introduction of a positive message are not strong enough to offset the low sustainability awareness, resulting in the significant higher amount of FW compared to the baseline.

To further investigate this hypothesis, it is useful to compare Scenario #7 with two scenarios that maintain the same population (70% business guests, low sustainability awareness, with differences in conformism among business and non-business guests and sustainability awareness among males and females), but differ in terms of the intervention applied. The corresponding scenarios are Scenario #5 and Scenario #25 (Table 13).

Table 13: Scenario #5 and #25

| *ID* | *Plate Size* | *Guest Composition* | *Sustainability awareness* | *Communication* | *Average Leftovers per guest and standard deviation (g)* |
|---|---|---|---|---|---|
| #5 | Normal | High business guest | Low | No communication | 109.95 ± 18.96 |
| #25 | Large | High business guest | Low | Positive message | 111.08 ± 17.49 |

By comparing Scenario #7 with Scenario #5, results show that the Positive message in Scenario #7 leads to a slight reduction in FW, but the difference is minimal (reduced by 1.29%) and not statistically significant (See Table A2 in the Annex).

Scenario #25 differs from Scenario #7 only in terms of plate size (large vs normal): in the presence of a positive message, introducing a smaller plate results in a modest decrease of the average amount of FW from 111.08 grams (SD 17.49) to 108.53 grams (SD 19.75), reducing FW by 2.3%. This difference is also not statistically significant.
**Although smaller plates and positive messages appear to reduce FW slightly, the overall effect in this population remains limited and not significant, further emphasizing the prevalent effect of sustainability awareness in determining FW production.** If we look at the same scenario, but with a different level of sustainability (Scenario 4, Table 14), in fact, the amount of FW generated drastically reduces to 9.73 grams (SD 5.76) (reduced by 91.05%, statistically significant difference), supporting this hypothesis.

Table 14: Scenario #4

| *ID* | *Plate Size* | *Guest Composition* | *Sustainability awareness* | *Communication* | *Average Leftovers per guest and standard deviation (g)* |
|---|---|---|---|---|---|
| #4 | Normal | High business guest | High | Positive message | 9.73 ± 5.76 |

The fact that this scenario takes place in a conference hotel, hence the higher proportion of business guests, contributes to keeping FW levels below 200 grams. If this scenario had been characterized by the presence of primarily non-business guests, the amount of FW would have been 255.63 grams (SD 27.85)[6]. The difference in the average levels of FW between these two scenarios is statistically significant.

### 3.5.2 Scenario #18 (*Provocation meets leisure)* results:

This scenario explores the influence of **provocative messages** on a population primarily composed of **non-business guests**. As presented before, non-business guests are characterized by a lower level of conformism (0.1, SD 0.01), a higher level of indulgence (0.7, SD 0.01) and the absence of time constraints within the

[6] See Scenario #19 in Table A1 (Appendix)

restaurant opening hours. In this scenario, the level of **sustainability awareness is still low** and the hotel has introduced smaller plates (**Normal plate size**).

With 277.41 grams (SD 28.41), this scenario yields the highest amount of FW among all simulated scenarios. This output is significantly higher than in the baseline scenario, where overall sustainability awareness was higher, and no communication was implemented by the hotel. Compared to the baseline scenario, Scenario #18 is characterized by 70% of the population with a slightly lower level of conformism (0.1, SD 0.01), but 30% of the population with a higher level (0.25, SD 0.01). As discussed for the previous scenario, the higher level of FW generated in this case is a result of the lower level of sustainability awareness. Moreover, in this case a provocative message is implemented, with a level of choice threat higher than guests' tolerance[7]. When guests' tolerance level is lower than message's choice threat, reactance is activated and the importance of motives as conformism, sustainability awareness and desire to control weight is reduced. This mechanism could represent a possible explanation of the extremely high level of FW in this scenario. Looking at the effect of the message, in Scenario #17 (Table 15) – in which no communication is adopted to influence guests' behaviour – the FW amount is still high, but given that reactance is not activated, sustainability awareness, conformism and desire to weight control are not affected, leading to a FW amount lower by 7.4% (statistically significant). This suggests that when guests perceive a message as overly directive, they may reject the intended behaviour and waste more food.

Table 15: Scenario #17 and #36

| *ID* | *Plate Size* | *Guest Composition* | *Sustainability awareness* | *Communication* | *Average Leftovers per guest and standard deviation (g)* |
|---|---|---|---|---|---|
| #17 | Normal | Low business guest | Low | No communication | 256.89 ± 29.03 |
| #36 | Large | Low business guest | Low | Provocative message | 260.25 ± 29.98 |

When investigating the effect of the plate size intervention, thus comparing Scenario #18 with Scenario #36 (Table 13), results show an unexpected negative influence of normal plate size on FW: in the scenario with large plate size, the average FW produced is 6.19% lower (statistically significant). This unexpected finding may be linked to the behaviour of guests when smaller plates are used. A potential explanation is that smaller plates may encourage multiple servings, which in turn leads to overserving. Smaller plates might make guests underestimate how much food they have already taken. They might believe they are eating "small portions" and therefore justify multiple rounds at the buffet, leading to more total waste by the end of the meal. Looking at the model outputs related to the average number of servings, this hypothesis seems to be supported: in Scenario #18, where normal plates are used, the average number of servings is 4.14 (SD 0.15), while in Scenario #36, featuring large plates, the average value is 3.4 servings (SD 0.14). Nevertheless, these results are to be used with caution, as the model was not calibrated with empirical data on the number of servings.

These results further complicate the relationship between plate size and FW, indicating that interventions targeting plate size must also consider guest perceptions and compensatory behaviours.

[7] As presented in Section 3.4, the choice threat level for provocative messages is 0.6. See Section 3.4 for an explanation of how choice threat affects individuals' motives.

### 3.5.3 Scenario #27 (*Mindful mornings with an unsettling message*) results:

This scenario occurs in a context where an intervention has been implemented: the hotel displays a **provocative communication** message urging guests to reduce food waste. In this setting, guests exhibit a **high level of sustainability awareness**, with a balanced ratio of business to non-business guests. Only l**arge plates** are available.

In this scenario, we observe very low food waste, specifically just 15.2 grams per person (SD 7.25). **This amount is significantly lower than in the baseline scenario,** with a 95% confidence interval of [-24.5711; -8.335], representing the smallest food waste across all main scenarios.

The results are somewhat surprising. The presence of two factors that could significantly increase food waste—provocative messaging, which could induce reactance, and large plates that suggest it is appropriate to eat more—does not lead to a higher level of waste. Instead, food waste remains relatively low. It appears that sustainability awareness has mitigated the levels of food waste. The hypothesis that increased sustainability awareness negatively impacts the amount of food waste generated at breakfast buffets is supported.

The effect is notably strong, especially when compared to another scenario with provocative messaging (#18), where the message appears to have a substantial impact on increasing food waste. We can conclude that **sustainability awareness is the stronger factor influencing FW in these settings**.

It is unclear whether the high sustainability awareness blocks reactance or serves as a contributing factor (increasing sense of importance and urgency) for those already aware of sustainability. Further research is needed to explore this issue. The current literature presents mixed results. On one hand, Banerjee et al. (2023) discovered that nudging people already motivated to eat sustainably—especially after making a pledge—can sometimes yield unintended negative outcomes. On the other hand, some studies show that when injunctive norms are framed positively, food waste is better mitigated (Zheng et al., 2023).

### 3.5.4 Scenario #35 (*Carefree indulgence*) results:

This scenario takes place in a context where **no interventions have been implemented**. In this setting, guests demonstrate a **low level of sustainability awareness**, with a smaller proportion of business guests exhibiting less conformity compared to the baseline scenario. Only **large plates** are available.

In this scenario, **we observe very high food waste**, averaging 248.8 grams per person (SD 29.03). This amount is significantly higher than in the baseline scenario, with a 95% confidence interval of [209.0326; 225.2687], making it the second highest food waste across all main scenarios. This is not surprising, given the conditions that encourage guests to take excessive food on their plates and leave many leftovers without consequences.

It is important to emphasize that the conditions are quite similar to those in the baseline scenario. The primary difference lies in the level of sustainability awareness—medium sustainability awareness in the baseline scenario versus low sustainability awareness in scenario #35. This difference appears to account for the variation in food waste between these two scenarios. This again highlights how crucial sustainability awareness is. It seems that higher sustainability awareness significantly influences the amount of food waste generated in breakfast buffet settings, supporting the hypothesis that **individual sustainability awareness can effectively mitigate food waste**.

# 4 THE HOME COOK MODEL

## 4.1 Summary of the model

The Home Cook is a micro simulation model investigating food management, food consumption, and food waste generation in households. In this paragraph, only a brief description of the main features of this model is provided. The extended presentation is delivered in D3.3 Case-independent changing social norms predictive model.

In the model, it is assumed that households make purchasing and consumption decisions considering their composition (number of adults and children present), consumption routines, dietary preferences. Differently from the Establishment Diner model, the Home Cook model is a micro-simulation, thus households act independently from one another, and there is no interactions among them. In fact, a microsimulation models individual units independently, applying probabilistic rules to simulate changes over time without direct interaction between them. In contrast, an ABM simulates individual agents that interact with each other and their environment, allowing complex, emergent behaviours to emerge. While microsimulations focus on independent changes in individuals, ABMs allow dynamic interactions.

Each household is composed of a defined set of adults (1 to 5) and children (0 to 5), who are characterized by different consumption quantities[8]. Households can consume a maximum of meals per day at home, with the probability of preparing a meal defined as a model parameter. For example, households may only eat two meals out of three at home, with the third one eaten outside, thus beyond the model's scope.

Households have diverse shopping habits: to account for these differences, the frequency of grocery trips is a parameter. Purchasing decisions consider the available pantry stock, in order to supply it up to the desired pantry size. The pantry size is influenced by the preference for maintaining small or large food stock levels, which reflects their risk aversion to running out of food unexpectedly.

The pantry is composed of two main categories of food: perishable and non-perishable. Perishable food items are characterized by a best-before date and a spoilage date: depending on the household's food discarding strategy, items may be thrown away after the best before or upon reaching the spoilage date.

Depending on their dietary preferences, an household can decide to prioritize the consumption of perishable over non-perishable items, or opt to consume both types equally.

[8] Adults consume 1120 grams of food each day, while children consume 950 grams of food.

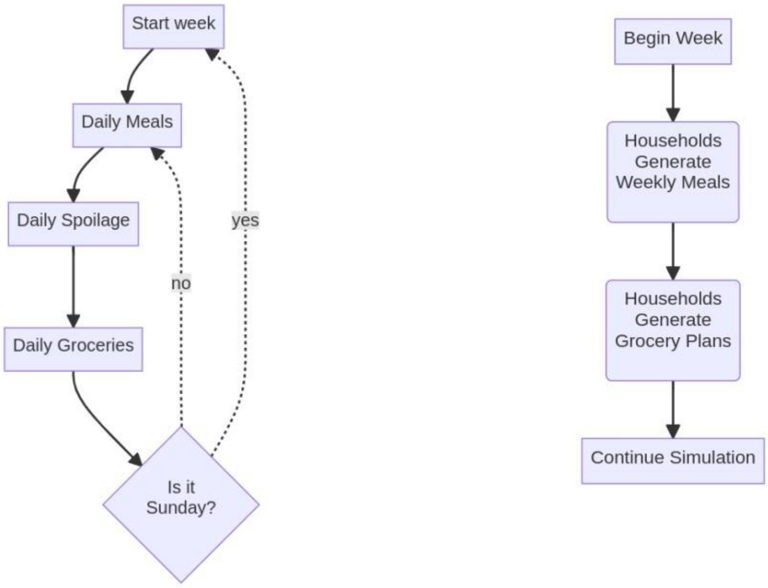


Figure 16: Home cook model cycle

To summarize the model cycle (Figure 16): each day, each household decides how many meals to have at home, what these meals are composed of (choosing among perishables and non-perishables), and the frequency and quantity of grocery shopping. From this cycle, leftovers and FW are generated. FW can derive from food wasted directly after meals (plate waste, PW) and food that spoils in the pantry (expired discards – including leftovers not consumed in time, stored in the fridge or pantry, and that eventually spoil).

## 4.2 Scenarios and research questions

In this section, the methodology adopted to develop the what-if scenarios is described, followed by a narrative of the two scenarios, whose results will be presented and discussed later.

### 4.2.1 Methodology and criteria for scenarios selection and development

For the Home Cook model, the co-design session was similar to that of the Establishment Diner model, with the goal of take advantage of the diverse knowledge and expertise within the project consortium. This session was held in parallel with the one organized for the Establishment Diner model at the General Assembly in Oslo. To ensure optimal use of partners knowledge and that the feedback remained aligned with the model's scope, the Home Cook model was enacted in a sort of role-playing game, requiring participants to stand and move around.

The workshop simulated a single week for one of the five hundred households modelled. Project partners were assigned roles that represented various components of the model: two participants acted as the household, responsible for purchasing and storing food, preparing three meals a day from pantry supplies, and deciding whether leftovers should be stored or discarded. Another participant assumed the role of the pantry, monitoring food availability and expiration dates. The remaining participants were designated as different types of food items, categorized as either perishable or non-perishable. Different areas of the room were designated as the store, pantry, and trash, enhancing the representation of household food management.

In the workshop scenario, the household would shop only once per week, selecting items and the quantity, and storing them in the pantry. Each iteration of the model began with the household purchasing a week's worth of food from the store, then using these pantry supplies to prepare meals over the course of the week. The model involved repeated cycles of meal preparation, food consumption and discarding expired items. This structured approach facilitated the identification of stages in the process where various scenarios could be implemented and tested within the model.

After the enactment of the model, the partners were divided into three groups brainstorming ideas on scenarios that could impact the amount of food wasted. Notes were taken in each group and speakers from each group shared key insights in plenary, as the workshop organizers combined ideas from all groups into plausible scenarios for the model. Once key scenarios were agreed upon, these scenarios and notes were later discussed internally within the modelling team to assess their feasibility from a modelling perspective. A final draft was then presented to the rest of the project consortium to ensure consensus on the final list of scenarios.

The final list of scenarios developed from the workshop included mobile apps, infrastructure enhancements and consideration of household differences. The mobile app scenario focused on supporting households in making better food choice strategies by tracking expiration dates and reducing the risk of overlooking varying expiration dates for different products and leftovers. The infrastructure scenario focused on effectively using storing technologies (as fridges and freezers) to extend the shelf life of perishable foods. Finally, household differences, such as fluctuations in the number of eaters, could be managed through various food management strategies. These very practical interventions had to be adapted by the modelling team to the mechanisms of the model, which focus more on exploring what would happen in terms of household behaviour if these interventions were adopted. In other words, for instance, the model did not directly implement the app that allows tracking expiration dates; instead, it incorporated the behavioural change that the use of such an application would enable, namely greater attention to expiration dates.

### 4.2.2 Scenarios description

In this section, a narrative of selected scenarios is presented. These two scenarios were selected to showcase two opposite situations: one in which households are motivated to reduce FW and have the ability to do so, and another in which they lack both skills and motivation to do so.

- *Scenario #2 "Fresh-first mindful storage households":*

Imagine a collection of households that implement careful food management practices. These families know exactly how to preserve and store their food in ways that maximize freshness and minimize waste. They are particularly careful with perishables like fruits, vegetables, dairy, and meats, keeping these items fresh by sealing containers, refrigerating produce correctly, or using vacuum storage to prolong shelf life. Their kitchens are well-organized, and they know the best spots to store specific items to avoid early spoilage.

When it comes to meal planning, these households make a point of prioritizing perishables, choosing to cook with fresh ingredients whenever possible. For example, if they have both fresh broccoli and fermented beetroots in jars, they'll opt for the broccoli, knowing that processed packaged goods have a longer shelf life. This habit of prioritizing fresh ingredients not only adds variety to their meals but also keeps their pantries and fridges organized, reducing the risk of items laying there until they spoil. In this way, these families maintain a natural flow between shopping, cooking, and storing, in a way that helps them to manage food effectively.

These households take expiration dates seriously and tend to take decisions based on them. This behaviour may stem from a heightened awareness of the importance of being aware of the food they have in their pantry or fridge, possibly encouraged by community programs or campaigns.

This high level of food management and waste reduction could be the result of various educational interventions. They could have attended community workshops that highlighted how to properly store perishables, or maybe local grocery stores hosted events teaching customers to rotate fresh and canned goods in their pantries. Some households may have received guidance from NGOs that promoted sustainable practices, such as reducing food waste through smart storage and prioritizing perishables. Additionally, these households could be taking advantage of mobile apps, that help them manage their pantry by keeping track of best-before and expiration dates, preparing shopping lists and proposing recipes on the basis of the food available at home.

Key characteristics: Much better storage conditions – Prioritizing the use of perishables in their meals – Discarding food after the best-before date

- *Scenario #9 "Unfocused pantry planners":*

In this scenario, households exhibit a chaotic approach to purchasing, preparing, and managing their food. Attracted by frequent in-store promotions offering discounts on items close to their expiration dates, these households regularly buy perishables at lower prices. They prioritize using fresh ingredients in their meals, but their focus is more on getting immediate deals than on organizing their food consumption based on best-before dates. As a result, items that require attention are often forgotten, and eventually reach actual spoilage, leading to high levels of food waste.
To help these households reduce food waste, targeted interventions could encourage them to adopt a more organized approach. Education campaigns on the importance of tracking best-before dates could be paired with strategies to enhance awareness of practical storage techniques for perishables. In-store reminders or app notifications to check best-before dates, combined with promotional messaging on responsible purchasing practices, could also prove effective. Additionally, implementing shelf-life extension solutions, such as vacuum-sealing or the effective use of fridges and freezers, may support these households in managing their food.

Key characteristics: In-store promotions reducing prices of foods close to expiration – Prioritizing the use of perishables in their meals – Discarding food only when spoiled

### 4.2.3 Research questions

Similarly to the previous model, the aim of developing scenarios is to investigate how different factors influence food waste generation at the household level, to simulate the potential influence of FW reduction interventions. We have developed the following research questions, grounded in the MOA framework and in previous literature exploring causes of FW. Additionally, research questions explore factors pertaining to different in-home consumption stages, as shown in Figure 17. The research questions are explored through the what-if scenarios, specifically by examining how each factor mentioned in the research questions influences FW at the household level.

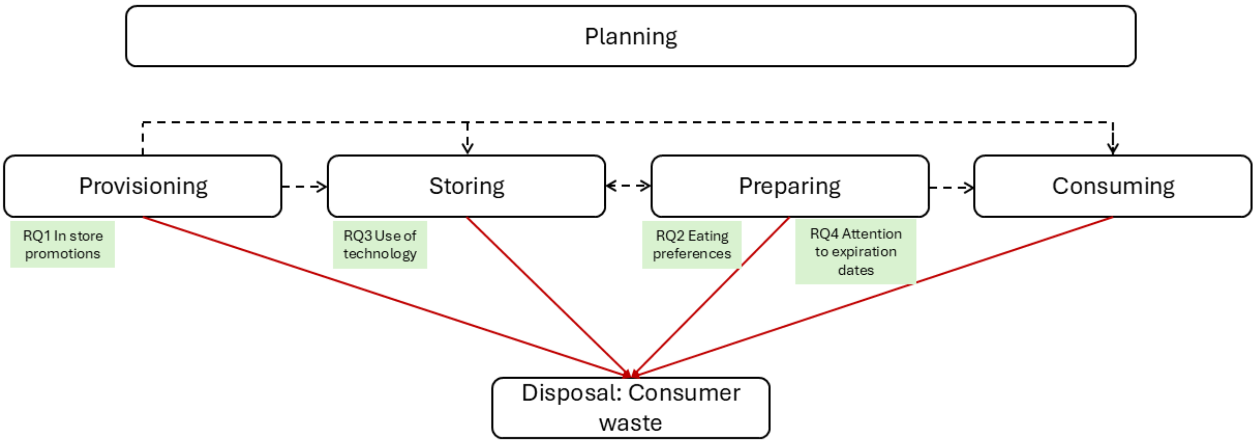


Figure 17: Consumer food management stages and research questions.
Adapted from Van Geffen et al. (2016)

***RQ1 How in-store promotions targeting close-to-expiration products influence FW?***

Food waste can be the consequence of actions taking place during purchasing. Among purchasing behaviours increasing the likelihood of wasting food, impulsive buying, buying packages containing too much food, and in-store promotions are the ones often identified by literature (Aschemann-Witzel et al., 2015; Koivupuro et al., 2012; Stefan et al., 2013; Williams et al., 2012b). Regarding in-store promotions, the lower price tempts consumers to buy more of that product, even if it is not needed. Here, we focus on a particular type of in-store promotion: expiration date-based pricing, meaning discounts on products approaching their expiration date (Amr Yassin & Soares, 2021; Aschemann-Witzel, 2018). These pricing tactics are intentioned to reduce FW generation at the retailing level but may result in a higher amount of FW generated within households. In fact, while close-to-expiration discounts can reduce food waste by promoting timely purchases, they also risk encouraging over-purchasing behaviours, in particular when consumers lack the skills to understand when a product is edible even if past its best-before date.

***RQ2 How do eating preferences at the household level influence FW? and RQ3 How do proper food storage techniques can help reduce FW?***

Household-level eating preferences, particularly those related to perishable fresh foods, play a role in shaping food waste generation. Research highlights that dietary preferences favouring fresh produce can contribute to increased waste if not managed properly (Hermanussen et al., 2022; Zhang et al., 2024). According to Janssen et al. (2017) households tend to waste more fresh products rather than the equivalent frozen ones. A possible explanation is that households that prioritize fresh foods often struggle with consumption timing, which can lead to spoilage and waste.

Looking at the primary data collected by CS1 in Belgium and Spain[9], 50% of Belgian respondents and 44.4% of Spanish respondents stated that they never waste completely unused food with a long shelf life, meaning non-perishable food items. On the other hand, the use of perishable foods has an impact on food waste generation, as their high perishability and short shelf-life often lead to more frequent disposal compared to non-perishable items. In CS1 survey, a high proportion of respondents indicated throwing away completely unused perishable food less than four times a year (37.5% in Belgium and 41.5% in Spain), with this frequency slightly higher compared to completely unused non-perishable foods (33% in Belgium and 37.1% in Spain). Looking at partially used perishable food, the trend in both countries shows a slight increase in the FW frequency. This

[9] For a detailed presentation of the results, refer to D2.3 Empirical Evidence Sensemaking.

phenomenon was particularly evident with leftover ingredients: while many consumers reported never throwing away leftover ingredients (28.1% in Belgium and 21.5% in Spain), a significant portion indicated wasting them at least four times a year (30.1% in Belgium and 29.8% in Spain). Moreover, the intention to consume stored leftover meals does not always translate into behaviour, as they are often forgotten or spoil during storage. This is reflected by the fact that 38.4% of respondents in Belgium and 38.6% in Spain reported experiencing this problem at least once a month. This highlights the need for improved storage practices and more mindful consumption to reduce FW related to perishable food products.
With this respect, the research question related to prioritizing perishable food is related to RQ3, concerning the effect of improper food conservation on FW generation. In fact, the proper use of refrigerators and packaging plays a role, as efficient storage can extend the shelf life of perishable items and reduce waste (Zhang et al., 2024). In conclusion, proper food storage can significantly reduce household food waste. Ananda et al. (2022) emphasize that techniques like correct refrigeration and understanding food labels help minimize food waste, especially in fruits and vegetables. Rasines et al. (2023) show that storing perishable foods like broccoli in bags at 5°C effectively extends shelf life, reducing waste and its environmental footprint.

***RQ4 How does a lack of attention to expiration dates while deciding what to cook influence household FW?***

Consumers' disregard for expiration dates has been widely identified as a critical driver of household FW. Hebrok & Boks (2017) argue that FW at the household level often originates from habitual behaviours, including the neglect of stock rotation and limited awareness about the edibility of food beyond best-before dates, leading to unnecessary disposal of otherwise consumable products. Toma et al. (2020) further emphasize that misunderstanding or lack of attention to date labels contributes significantly to FW, as consumers often rely on visual or habitual cues rather than informed decision-making to determine food usability. Porpino et al. (2015) illustrate those cultural practices and personal preferences, such as a reluctance to consume leftovers or a tendency toward bulk purchasing without appropriate planning, exacerbate FW in households. These behaviours are especially problematic when combined with lax attitudes toward expiration dates and inadequate management of food stocks. Vittuari et al. (2023) expand on these findings, identifying cognitive biases and low consumer awareness as pivotal drivers of FW. They suggest that tailored interventions, such as educational campaigns, could address these behavioural gaps by encouraging proactive food management. Secondi & Principato (2020) provide further evidence of the connection between lax expiration date strategies and FW. They note that perceived convenience, such as preparing meals based on preference rather than urgency of use, often overrides considerations of resource efficiency, increasing the likelihood of food spoilage and disposal. These studies collectively underscore the role of expiration date neglect in FW and highlight the potential for targeted behavioural and informational interventions to mitigate waste at the household level.

## 4.3 Verification

### 4.3.1 Consistency analysis

The Vargha-Delaney A Test (Vargha & Delaney, 2000) was performed to determine the number of replications needed to reduce uncertainty due to stochasticity in the outputs. We ran the model 12200 times for the following sample size groups: 20 groups of 10, 25, 50, 75, 100, 150 and 200. We used the statistical software R (version 4.4.0) and spartan package (version 2.3) to perform the analysis.

The outputs selected for this analysis were: leftovers, plate waste and expired discards. The results from the Vargha-Delaney A Test are displayed in Figure 18, showing that 100 runs are enough to reduce uncertainty in the model output.

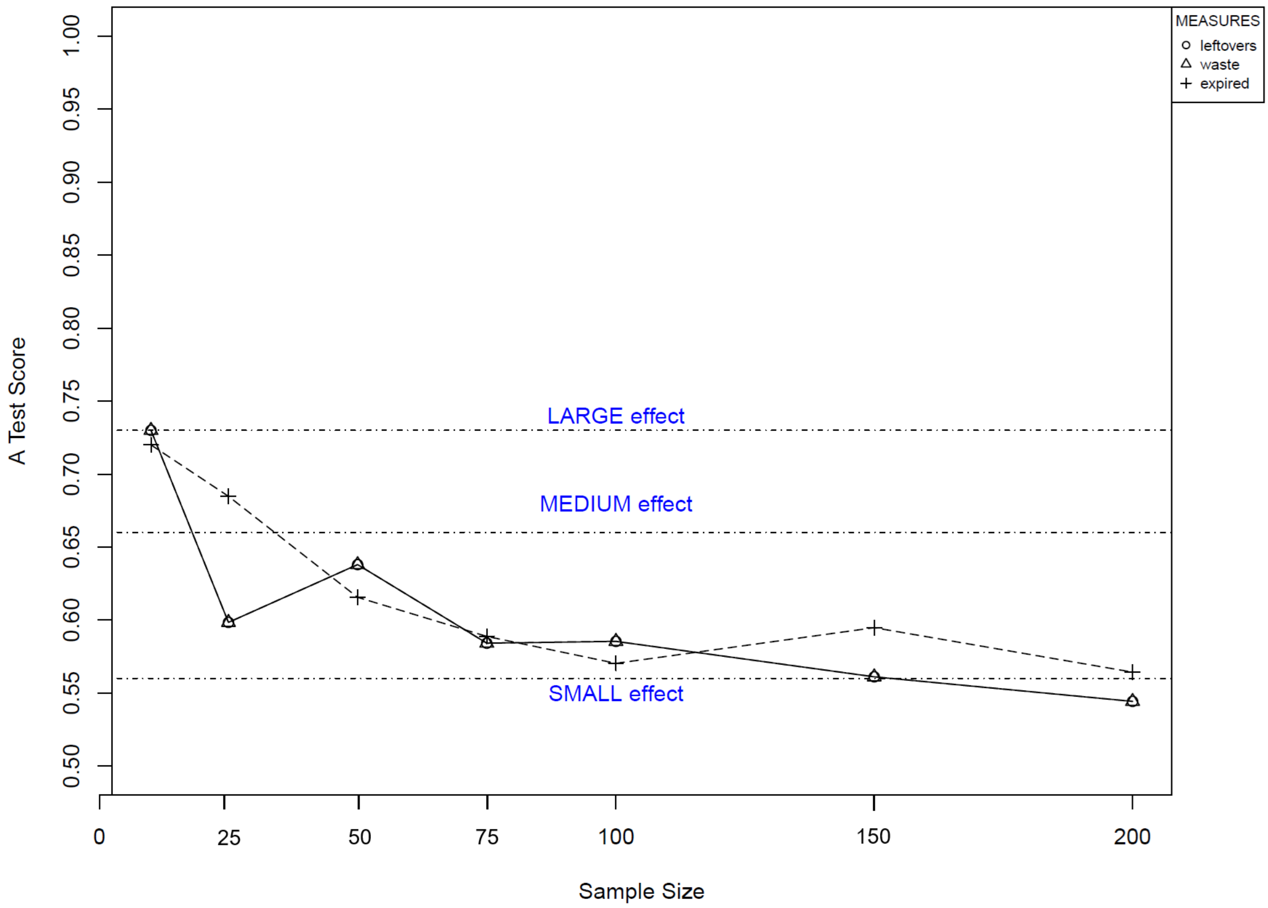


Figure 18: Maximum A-Test Scores for each sample size

### 4.3.2 Grocery runs overview

Households restock their pantry to maintain a stable inventory. Stock levels are given by the average expected weekly consumption (that is, the expected consumption between two grocery runs) plus the multiplication of the weekly standard deviation by the critical value. The higher the critical value, the more "risk-averse" the consumer becomes by holding onto larger safety stocks. There are also emergency takeouts when there is no food.

This strategy serves as the foundation for adaptation and learning in the simulation. If perishables spoil before consumption, households adjust their strategy to rely more on non-perishables. They learn from their pantry patterns.

To verify whether the model dynamics were producing the expected results, we simulated a household's pantry over 100 days. The results are presented in Figure 19 and Figure 20, which illustrate how the inventory increases after each grocery trip and decreases as food is consumed. Some weeks, the household consumes more, while other weeks, they have surplus food for the following week. Notice how some days households have all their meals at home and some days they have none. Also, perishable items are depleted the fastest.

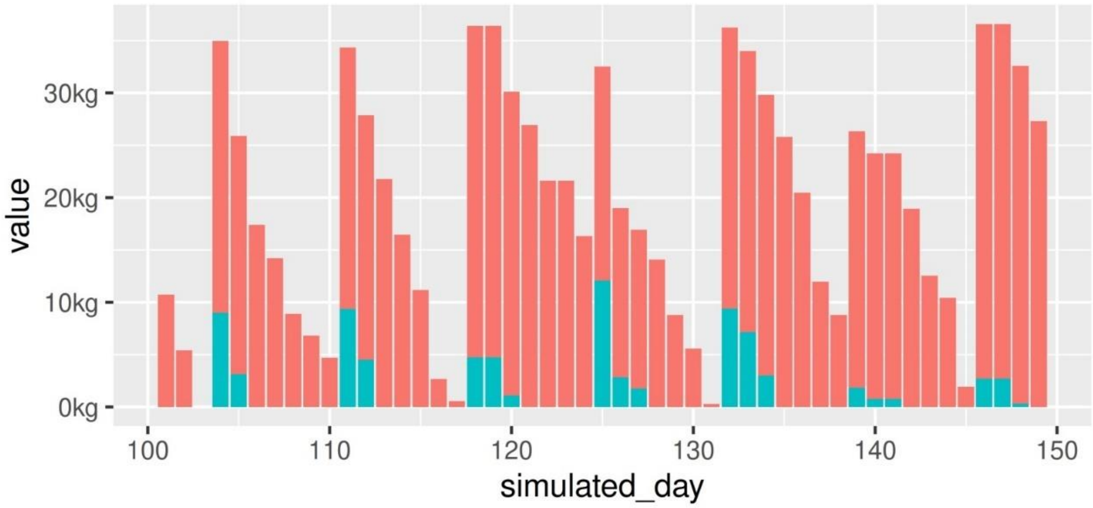


Figure 19: How much food is left at the end of the day. Blue = perishables; Red = non-perishables

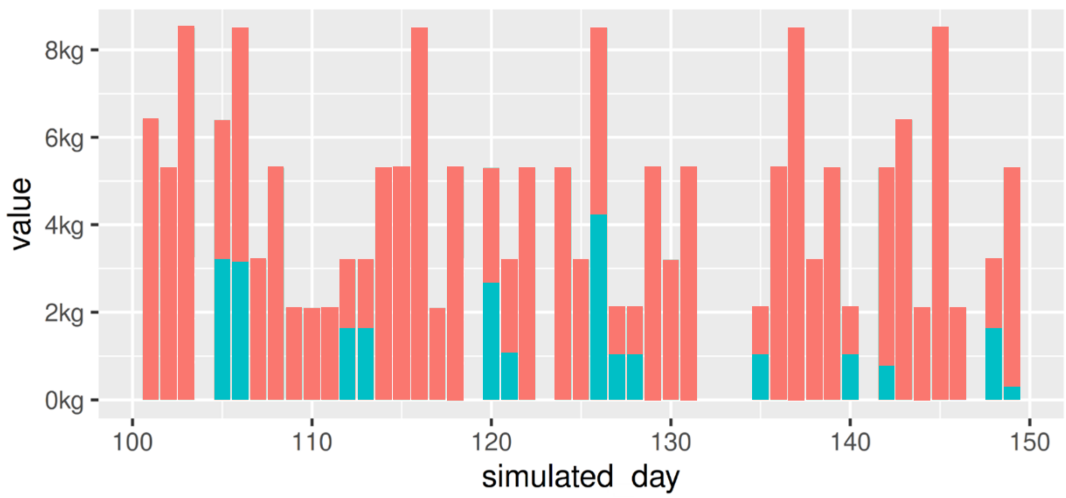


Figure 20: How much is consumed each day. Blue = Perishables, Red = non-perishables

## 4.4 Sensitivity analysis

Before implementing the scenarios, different situations were tested to verify how sensitive the model is to changes in the household behaviour. The tests are described below.

### 4.4.1 Basic runs

To understand the dynamics of the model, a few basic simulations were conducted. The first simulation varied two factors: eating habits (100% of meals prepared at home versus 50%) and preferences for perishables (eating all perishables first versus consuming 50% first).

The preference for perishables is a driving force in the simulation, creating a feedback loop. The more perishables you consume, the more likely you are to purchase them. This pattern results in a pantry increasingly stocked with perishable items, raising the likelihood of spoilage before consumption—a risk minimized if non-perishables were the primary focus.

Regarding eating habits, if all meals are eaten at home, consumption needs are easy to predict. However, if only about half are eaten at home, with each meal's location essentially a coin toss, the average weekly consumption may be lower, but the household is likely to stock up "just in case" for more home meals than usual.

These two dynamics reinforce each other: unpredictable dining-out habits lead to increased safety stock, and higher reliance on perishables means they increasingly make up that safety stock.

Ultimately, this combination can lead to waste during weeks with more dining out than expected. While prioritizing perishables may help reduce short-term waste, it risks longer-term spoilage as the pantry fills with items that may expire. Results are shown in Table 16.

Table 16: Perishable and discard rate varying the probability to have meals at home and the prioritization of perishable foods.

| Simulation | Perishable rate[10] | Discard rate[11] |
|---|---|---|
| 100% meals at home; 50% perishable target | 18.53% | 6.95% |
| 100% meals at home; perishables first | 36.98% | 13.92% |
| 50% meals at home; 50% perishable target | 19.21% | 17.00% |
| 50% meals at home; perishables first | 35.94% | 21.59% |

### 4.4.2 Baseline scenario

Based on these results, we adopted the baseline for sensitivity as the one with 75% of the meals made at home and the consumption of perishables first. The household distribution of the baseline is a random number of adults (uniform distribution ranging from 1 to 5) and children (uniform distribution ranging from 0 to 5). All scenarios were compared considering the average of 100 runs of the model.

The shopping frequency in the baseline scenario is once a week.

### 4.4.3 Consumption strategy

The model was also adapted to examine the effects of households adopting a more "relaxed" approach to food waste. In this scenario, rather than discarding food immediately upon reaching its best before date,

[10] The actual rate of perishables consumed as a proportion of total consumption (this is excluding emergency takeouts).

[11] Total food thrown away (from pantry) because it expired divided by total amount of food consumed.

households would only dispose of items once they exhibit clear signs of spoilage. This change allows perishables to be stored for an additional day, or potentially more, before being thrown away:

- Perishables last longer: By disregarding the best before date, households perceive perishables as remaining viable for longer, thereby extending the timeframe available for consumption.
- Shift in purchasing patterns toward perishables: As households consume more perishables, they tend to purchase more of these items to meet increased consumption levels, leading to a decreased reliance on non-perishable goods.
- Increase in discarding perishables: With the increased opportunity to consume perishables, households buy more perishables. However, given the short spoilage date of these items when compared to non-perishables, the amount of food expired discarded is much higher than the baseline.

The results are presented in Table 17. An ANOVA (95% of confidence interval) followed by a Tukey test showed that the baseline scenario is statistically different of the relaxed pantry scenario for all the outputs in Table 17.

In the baseline scenario, households are organized in their consumption habits: they prioritize perishables and consistently consume those closest to their expiration date first. The model was adjusted to test an alternative approach, so households still favoured perishables but selected items randomly within that category rather than based on expiration proximity. The simulation results revealed minimal impact from this change. Households were already accustomed to purchasing only what they realistically consume, and this strategic approach to consumption timing proved to be effectively resilient to minor alterations in selection behaviour for the expired discarded and the total food stored outputs. This outcome, however, might differ if the expiration dates of perishables were not normally distributed.
An ANOVA (95% of confidence interval) followed by a Tukey test showed that the baseline scenario is statistically different of the random consumption strategy for four out of 6 outputs in Table 17: total of non-perishables and perishables bought and the daily consumption of non-perishables and perishables.

Table 17: Results for the runs varying Consumption strategy

| Scenario | Expired discards (g) | Total food stored (g) | Total non-perishables bought (g) | Total perishables bought (g) | Daily consumption non-perishables (g) | Daily consumption perishables (g) |
|---|---|---|---|---|---|---|
| Baseline | 9.38 ± 0.53 | 23850.86 ± 464.37 | 2683.7 ± 53.66 | 2538.39 ± 49.46 | 2681.41 ± 53.84 | 1781.63 ± 35.12 |
| Relaxed consumption strategy | 682.84 ± 12.66 | 25958.28 ± 428.61 | 729.84 ± 15.31 | 4343.39 ± 75.2 | 756.19 ± 15.04 | 3706.24 ± 65.04 |
| Random consumption strategy | 10.99 ± 0.63 | 23761.11 ± 399.74 | 2758.12 ± 48.51 | 2453.97 ± 41.17 | 2755.98 ± 48.36 | 1705.21 ± 28.89 |

### 4.4.4 Pantry strategy

A primary factor contributing to waste in the model is the process of stocking food, predominantly driven by a desire to prevent shortages before their next grocery visit. The purchasing behaviour is influenced by three elements: the average expected weekly consumption (i.e., expected consumption between two grocery trips), the weekly standard deviation, and the critical value, which reflects the agent's risk tolerance. Higher critical values correspond to more risk-averse behaviour, resulting in larger food stocks. In the default setting, the critical value is 1.96, providing approximately 95% coverage of days between grocery runs, assuming a normal consumption distribution.

Two alternative pantry strategies were examined:

- Reduced risk aversion: setting the critical value at 1.64, thereby establishing a smaller buffer and a less cautious approach.
- Increased risk aversion: raising the critical value to 2.326, indicative of a highly cautious approach with a more substantial safety stock.

The results are shown in Table 18. The increased risk aversion scenario had more food stored than the reduced one and the baseline. An ANOVA (95% confidence interval) followed by a Tukey test showed that the baseline scenario is statistically different only for the total of food stored and the total of perishables bought when compared to both reduced and increased risk aversion. The reduced risk aversion is significantly different from the increased one for the same outputs (total food stored and total perishables bought).

Table 18: Results for the runs varying Food stocks

| Scenario | Expired discards (g) | Total food stored (g) | Total non-perishables bought (g) | Total perishables bought (g) | Daily consumption non-perishables (g) | Daily consumption perishables (g) |
|---|---|---|---|---|---|---|
| Baseline | 9.38 ± 0.53 | 23850.86 ± 464.37 | 2683.7 ± 53.66 | 2538.39 ± 49.46 | 2681.41 ± 53.84 | 1781.63 ± 35.12 |
| Reduced risk aversion | 9.34 ± 0.42 | 22632.86 ± 385.95 | 2679.32 ± 48.09 | 2431.77 ± 41.11 | 2677.57 ± 48.13 | 1787.78 ± 30.52 |
| Increased risk aversion | 9.6 ± 0.5 | 25321.1 ± 444.29 | 2684.63 ± 46.14 | 2691.38 ± 49.09 | 2680.98 ± 46.17 | 1799.17 ± 33.49 |

### 4.4.5 Shopping frequency

In the baseline scenario, households shop once per week. The expected dynamics regarding the frequency is: (1) as shopping frequency increases, the quantity of food stored at home should decrease, and (2) more frequent shopping should lead to increased purchases and consumption of perishable items.

Two primary factors drive this outcome. First, higher perishable consumption inherently heightens the risk of waste due to perishables' limited shelf life. Second, a nuanced effect emerges from the model's approach to food storage. With more frequent shopping, the variability in food consumption over shorter intervals (e.g., three days) increases, prompting households to maintain additional "just-in-case" stock. Interestingly, this reserve primarily consists of non-perishable items.

On the other hand, when households shop every 14 days, a higher level of waste might be expected. However, in the model there is not a significant difference in the amount of expired discarded for the waste when the three scenarios were compared between then (ANOVA followed by Tukey test, confidence interval 95%). All the other outputs were significantly different. The results are presented in Table 19.

Table 19: Results for the runs varying Shopping frequency

| Scenario | Expired discards (g) | Total food stored (g) | Total non-perishables bought (g) | Total perishables bought (g) | Daily consumption non-perishables (g) | Daily consumption perishables (g) |
|---|---|---|---|---|---|---|
| Baseline (once a week) | 9.38 ± 0.53 | 23850.86 ± 464.37 | 2683.7 ± 53.66 | 2538.39 ± 49.46 | 2681.41 ± 53.84 | 1781.63 ± 35.12 |
| Frequent (every 3 days) | 9.91 ± 0.48 | 14396.46 ± 252.28 | 624.29 ± 12.53 | 5029.44 ± 88.96 | 623.42 ± 12.55 | 3851.17 ± 68.53 |
| Infrequent (every 14 days) | 8.64 ± 0.38 | 36211.13 ± 735.87 | 4148.85 ± 85.22 | 310.91 ± 31.11 | 4079.61 ± 84.37 | 397.45 ± 29.17 |

### 4.4.6 Storage conditions

The model was tested with three variations for perishables: extending the spoilage and best-before dates by 1 day and 2 days and reducing it in 2 days. The extension of the spoilage and best-before dates led households to feel more confident in purchasing additional perishables. This cycle creates further shifts, as households respond by stockpiling more perishables.

Reducing the time by 2 days leads to an increase in the amount of expired items discarded. Statistical analysis (ANOVA at a 95% confidence level, followed by a Tukey test) shows that the baseline scenario differs significantly from the other three scenarios for all measured outcomes—except for the number of expired items discarded when increased by 1 or 2 days (Table 20).

Further analysis comparing scenarios that involve either increasing or decreasing the spoilage and best-before dates reveals that nearly all outcome measures show statistically significant differences. However, there is no statistically significant difference in expired items discarded between the scenarios of a 1-day and 2-day.

Table 20: Results for the runs varying Storage conditions

| Scenario | Expired discards (g) | Total food stored (g) | Total non-perishables bought (g) | Total perishables bought (g) | Daily consumption non-perishables (g) | Daily consumption perishables (g) |
|---|---|---|---|---|---|---|
| Baseline | 9.38 ± 0.53 | 23850.86 ± 464.37 | 2683.7 ± 53.66 | 2538.39 ± 49.46 | 2681.41 ± 53.84 | 1781.63 ± 35.12 |
| Increase 1 day | 8.52 ± 0.36 | 24814.61 ± 449.53 | 2072.05 ± 37.69 | 3186.65 ± 58.46 | 2070.58 ± 37.5 | 2395.34 ± 44.8 |
| Increase 2 days | 8.43 ± 0.37 | 25536.98 ± 368.7 | 1475.13 ± 23.38 | 3769.13 ± 56.04 | 1471.29 ± 23.09 | 2996.64 ± 45.13 |
| Decrease 2 days | 45.91 ± 2.03 | 22407.41 ± 370.39 | 3654.38 ± 59.26 | 1407.41 ± 25.76 | 3620.1 ± 59.16 | 849.16 ± 15.93 |

### 4.4.7 Leftovers and food waste rates

We also tested the sensitivity of the model for combinations of different rates of leftovers (0%; 5%; 10%; 15%; and 20%) and plate waste (0%; 5%; 10%; 15%; and 20%). Leftovers are defined as prepared food that is not consumed immediately and is stored for future consumption. Plate waste, on the other hand, refers to prepared food that is not consumed and is discarded directly after the meal. The results for daily leftovers and plate waste are presented in Figure 22 and Figure 21 (average of 100 runs). A Tukey test comparing each pair of results indicated that, at a 95% confidence level, 208 out of 300 pairs of averages showed no significant difference in daily leftovers comparisons and 131 out of 300 for plate waste comparisons.

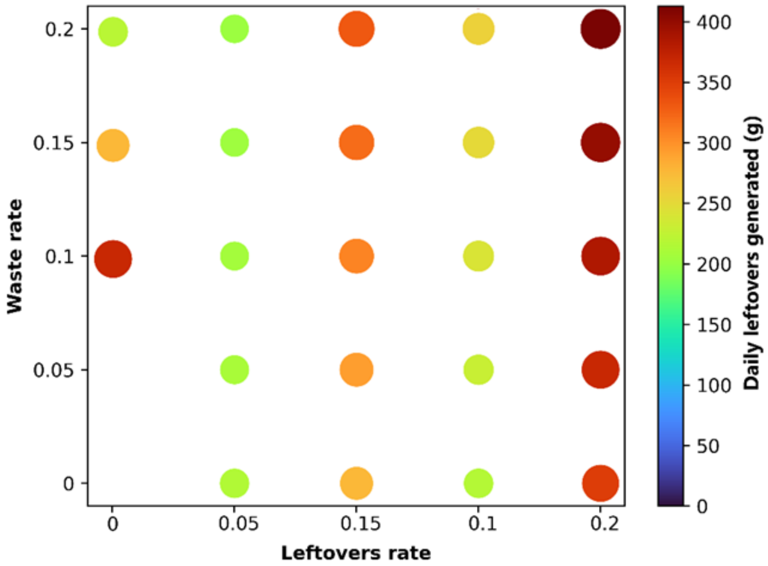


Figure 22: Sensitivity for the combinations of different rates of leftovers and plate waste on daily leftovers

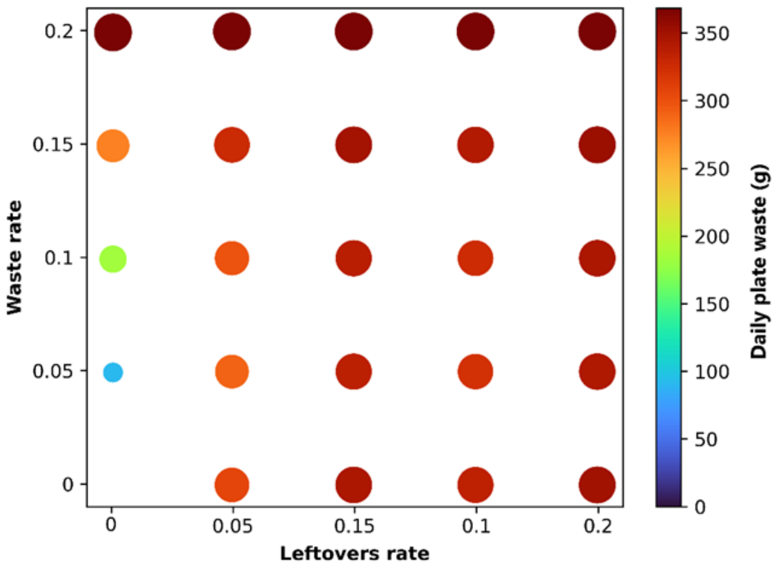


Figure 21: Sensitivity for the combinations of different rates of leftovers and plate waste on daily plate waste

## 4.5 Validation and calibration

### 4.5.1 Data

Data from Spain and Belgium was used to inform the model. These data were collected through two survey investigations, designed and implemented by the CHORIZO Case study 1[12] related to household setting.

The population in the model has the same distribution as the one from the data collected in Spain and Belgium. For the number of people in a household (including adults and kids), the probabilities of each number were used according to the data collected in each country. For the number of children, a table of probabilities was built based on the number of people per household and the correspondent number of children in the survey. The number of adults consists of the number of people minus the number of children. The number of people is never smaller or equal to the number of children in each household (see Table 21).

According to the survey, most Spanish households consume 75% of the food they prepare, leaving only 25% as leftovers. In contrast, Belgian households immediately consume 80% of their food, storing just 20% for later. These percentages were used to calculate the rate of leftovers in the model.

The survey also reveals that most households shop for groceries several times a week to once a week. For the model, this frequency was standardized to households shopping every 7 days.

### 4.5.2 Model calibration

The best-before date refers to the quality of a food item, which can usually be eaten even past that date. In this model, the best-before date follows a normal distribution with an average of 3 days and a standard deviation of 1 day for perishables. For non-perishables, the average is 50 days with a standard deviation of 10 days.

On the other hand, the spoilage date refers to the point at which the product becomes unsuitable for consumption. In this model, the spoilage date is always later than the best-before date. It is also drawn from a normal distribution, with an average of 5 days and a standard deviation of 2 days for perishables and an average of 100 days with a standard deviation of 20 days for non-perishables.

The simulation period is 30 weeks; however, the first 100 days were excluded from the analysis to allow time for the initial non-perishables to expire.

As mentioned, each household consists of adults, with some also including children. The daily amount of food prepared per adult is 1.120 grams, while for children it is 950 grams. These quantities were estimated based on two studies analysing habitual food consumption for various food items in Belgium (Bel et al., 2019) and Spain (Partearroyo et al., 2019), across different age groups. Both studies used data retrieved from cross-sectional studies of nationally representative samples of the Spanish and Belgian populations. Daily food amounts were manually calculated based on the food-specific quantities indicated in the studies. For adults, data from the 18-64 age groups were considered (both Spain and Belgium). For children, only Belgian data were used, as the Spanish study only included children aged 9 years and above. Average quantities for both adults and children were similar across the two samples, so a single average quantity was used for adults and another for children. Since the two national surveys provided data on food actually consumed, thus excluding plate waste, we needed to estimate a value for the percentage of plate waste. CS1 surveys included a question regarding food discarded right after the meal (expressed in percentages), with response options in 10% intervals. Most respondents reported wasting 0-10% of food directly after the meal. To refine this estimate, we consulted the literature and found a study (Partearroyo et al., 2020) that analysed data from the same

[12] For further details refer to D2.1 Case Studies' Strategic Plan and D2.3 Empirical evidence sensemaking.

national survey used by Partearroyo et al. (2019), finding that approximately 2% of prepared food is wasted. To conclude, in the model the average percentage of plate waste was 2%, with a standard deviation of 0.1%.

The model comprises 500 households, having 75% of their meals at home, and with a critical value order policy of 1.96.

## 4.6 Scenario implementation in the model

We tested four different what-if projections: country, storage conditions, eating preferences, and consumption strategy.

The baseline scenario serves as our starting point, where we calibrate the model using available data, that is, the results when no changes are made in the simulation. On the other hand, the what-if scenarios involve parameter variations to assess how the model's outputs are affected. The key concepts of the what-if are elaborated upon below.

**a) Country**

Simulations were conducted for two different populations, specifically two distinct household composition distributions. Household composition data were obtained from the Spanish and Belgian CS1 surveys. Therefore, in the remainder of this deliverable, references to the "Spanish population" and "Belgian population" will pertain to the household compositions derived from these surveys, rather than the actual populations of these countries.

Probabilities of the number of people in a household (including adults and children) according to the survey answers for Belgium[13] and Spain are as follows (Table 21):

Table 21: Probabilities of the number of people in a household (including adults and children) according to the survey answers for Belgium and Spain

| Number of people in a household (adults and children) | Belgium | Spain |
|---|---|---|
| 1 | 19.75% | 5.85% |
| 2 | 39.38% | 32.20% |
| 3 | 18.25% | 25.37% |
| 4 | 16.88% | 28.29% |
| 5 | 4.38% | 6.83% |
| 6 | 1.38% | 1.46% |

Table 22 shows the probabilities of the number of children in a household based on the number of people (adults and children) in that household. The probabilities were based on the survey data.

[13] We included only responses with consistent data. For this reason, we discarded all the observations in which the number of children was equal or higher to the total number of people in the household.

Table 22: probabilities of the number of children in a household based on the number of people in that household

| | | Belgium | | | | | | Spain | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total number of people in a household (adults and children) | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| Number of children in a household based on the number of people | 0 | 100.00 % | 41.38 % | 15.71% | 10.77% | 9.09% | 0% | 100.00 % | 90.91% | 19.23% | 12.07% | 35.71% | 33.33% |
| | 1 | 0% | 58.62 % | 66.43% | 5.38% | 9.09% | 0% | 0% | 9.09% | 71.15% | 1.72% | 7.14% | 66.67% |
| | 2 | 0% | 0% | 17.86% | 80.77% | 9.09% | 0% | 0% | 0% | 9.62% | 84.48% | 7.14% | 0% |
| | 3 | 0% | 0% | 0% | 3.08% | 72.73% | 0% | 0% | 0% | 0% | 1.72% | 50.00% | 0% |
| | 4 | 0% | 0% | 0% | 0% | 0% | 63.64% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 5 | 0% | 0% | 0% | 0% | 0% | 36.36% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 6 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

#### b) Storage conditions

Three different storage conditions were tested in the scenarios:

- Normal: normal spoilage dates
- Much better: increase in 2 days in the best before and spoilage dates for perishables, reflecting correct use of packaging and the fridge to store food items
- Worse: decrease in 2 days in the best before and spoilage dates for perishables. This condition reflects the presence of in-store sales that promote the purchase of products close to the expiration date.

#### c) Eating preferences

Two different conditions related to eating preferences were tested in the scenario:

- Perishables first: consume all the perishables first
- Proportional consumption: consume 50% of the perishables

#### d) Consumption strategy

Two pantry strategy conditions were checked within the scenarios:

- Strict strategy: consume checking best before date
- Relaxed strategy: consume after best before date and only throw away if spoiled

## 4.7 Scenarios results

In this section, the results of what-if scenarios simulations will be presented and discussed.

24 what-if scenarios were run in the simulations, in order to test all possible parameters variation combination. In particular, 12 scenarios were run on the Spanish population, while 12 on the Belgian one. They are described in the Appendix (Table A3 and Table A4). Figure 23 show the amount of expired discards generated by each scenario, for the Spanish and Belgian simulations respectively.

In the Home Cook model, we are interested in results related to food waste generated from purchasing and storage behaviours. Specifically, household decisions on portion sizes and actual eating behaviours were not explicitly coded in this model. This approach is reflected in the same rate of plate waste (mean 2%), which is not affected by individual behaviours. Consequently, in the results analysis, we will focus on outputs related to expired discards. These discards include both unused food items that expire in the pantry and leftovers that were initially intended to be consumed but were later discarded.

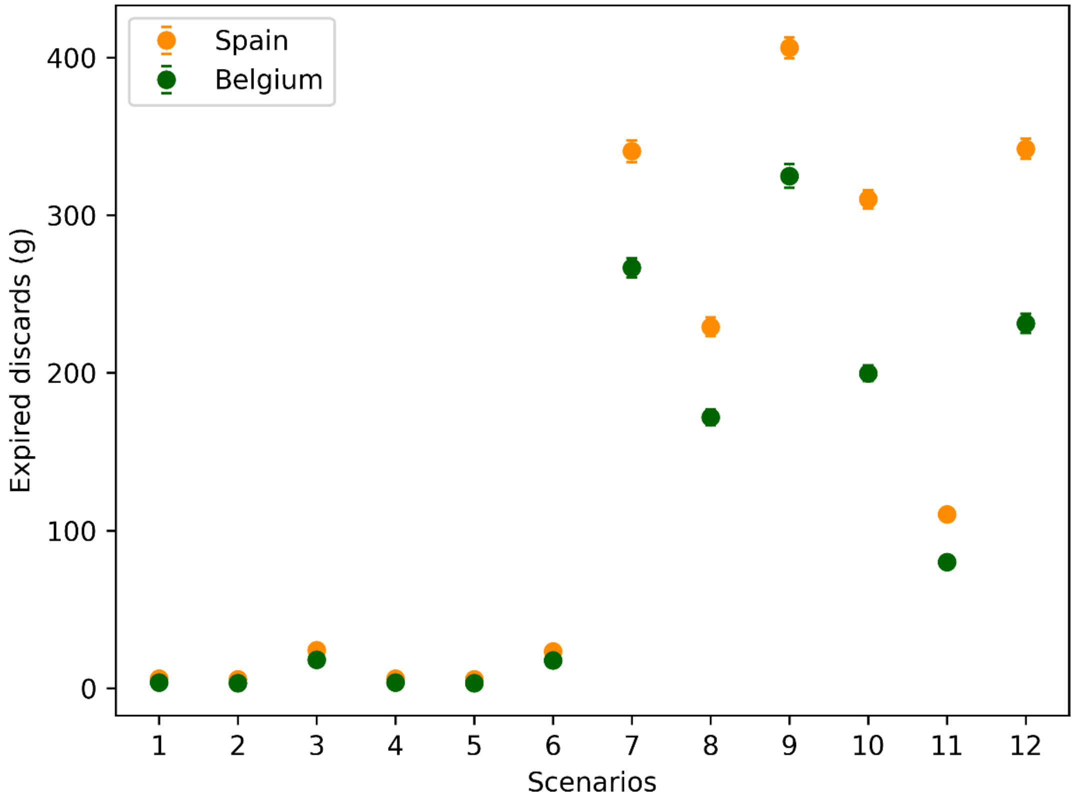


Figure 23: Expired discards (g, daily, per household) generated in the 12 scenarios with Spanish and Belgian household composition

As shown in the figure, the patterns are similar for the Spanish and Belgian cases: both indicate that half of the simulated scenarios generate higher amounts of expired discards than the other half. Looking at the table describing scenarios characteristics (Table A3), it becomes evident that scenarios with higher expired discards are those characterized by the relaxed consumption strategy. Other parameters have a smaller impact (in absolute terms) when the consumption strategy is relaxed, contributing only to minor variations in scenarios where households prioritize food consumption based on best-before dates.

When comparing Spanish and Belgian scenarios, the pattern of results remains consistent, with Belgian scenarios producing lower amounts of expired discards (daily/per household) in absolute terms. This is easily explained by the fact that Belgian scenarios are characterized by households with fewer adults and children, as described in section 4.6. Given that the analysis holds for both, we decided to describe results using scenarios based on the Spanish household composition.

From the complete list of what-if scenarios (Table A3, Appendix), we selected the more interesting and relevant ones. Scenarios to be described and analysed in detail were selected to ensure a good variability of the different parameters, while also maintaining a range of expired discards generated. Selected scenarios are presented in Table 23 and were narratively described in section 4.4.2.

Table 23: Selected what-if scenarios, Home Cook model

| Scenario | Country | Storage conditions | Eating preferences | Consumption strategy | Expired discards (g, per day, per household) |
|---|---|---|---|---|---|
| #2 | Spain | Much better | Perishable first | Strict | 5.62 ± 0.23 |
| #9 | Spain | Worse | Perishable first | Relaxed | 406.16 ± 6.52 |

### 4.7.1 Scenario #2 "Fresh-first mindful storage households" results

In this scenario, households manage their pantry with particular care, resulting in just 5.62 grams of daily expired discards, which is the lowest amount observed across all simulated scenarios. Household members – or the individuals responsible for food purchasing and management within the household – are not systematically attracted by in-store promotions selling close-to-expiration foods at a lower prices, and store their perishables and leftovers in a mindful way. Additionally, they prioritize perishable foods in their meals, and they carefully check products that are closer to the best before date, to make sure to prioritize their consumption. Table 24 summarizes other results for this scenario, related to purchasing and consuming.

Table 24: Scenarios #2, #3, #8

| Scenario | Storage conditions | Eating preferences | Consumption strategy | Expired discards (g, daily) | Daily consumption perishables (g, average 100 runs) | Daily consumption non-perishables (g, average 100 runs) | Total perishables bought (g, average 100 runs) | Total non-perishables bought (g, average 100 runs) |
|---|---|---|---|---|---|---|---|---|
| #2 | Much better | Perishable first | Strict strategy | 5.62 ± 0.23 | 1487.68 ± 23.11 | 729.5 ± 13.41 | 1871.22 ± 29.19 | 731.51 ± 13.36 |
| #3 | **Worse** | Perishable first | Strict strategy | 24.22 ± 0.94 | 420.16 ± 7.47 | 1797.97 ± 27.7 | 696.81 ± 11.94 | 1815.21 ± 27.9 |
| #8 | Much better | Perishable first | **Relaxed strategy** | 229.21 ± 5.95 | 2143.02 ± 40.44 | 75.65 ± 2.97 | 2250.84 ± 42.24 | 60.9 ± 2.81 |

It is useful to compare Scenario #2 with two scenarios that maintain the same eating preference, thus prioritizing perishable foods, but differ in storage conditions and consumption strategy, respectively Scenario #3 and Scenario #8.

In Scenario #3, households purchase food items close to their expiration dates, leading to an average of 24.22 grams of expired discards daily (SD 0.94), which is 331% higher than in Scenario #2. Despite this significant increase, it is worth noting that the overall quantities of expired discards remain relatively low. Examining the additional results in Table 24, we observe that reducing the spoilage date decreases household confidence in purchasing perishables, leading to a lower daily consumption of these items (1487.68 grams in #2 and 420.16 grams in #3) and a corresponding increase in the consumption of non-perishables. These eating preferences are reflected in the purchasing behaviour, with households buying more non-perishables and fewer perishables. In Scenario #3, the amount of discarded food remains controlled, as households maintain a strict strategy, thus they are aware they need to prioritize food items based on the best-before date.

In Scenario #8, households are perfectly able to maximize the storing conditions, but they do not decide what to prepare based on the best-before dates, adopting a more relaxed strategy. In this case, households are confident that they can still use food even after they best before date, so they purchase more perishables.

This leads to a huge increase in expired discards, 229.21 grams (SD 5.95). Given the short spoilage date of these items, this leads to a much higher amount of expired discarded products.

### 4.7.2 Scenario #9 "Unfocused pantry planners" results

In this scenario, households produce 406.16 grams of expired discards daily (SD 6.52), which represents the highest amount among all simulated scenarios. Households do not implement effective strategies to correctly preserve their food items and, additionally, they systematically take advantage of in-store promotions reducing prices of foods close to their expiration date. Furthermore, they do not decide what to consume according to the best-before date, allowing food to reach the final spoilage. They prioritize perishable foods over non-perishables in their meals.

Table 25: Scenarios #9, #12, #7

| Scenario | Storage conditions | Eating preferences | Consumption strategy | Expired discards (daily, g) | Daily consumption perishables (g, average 100 runs) | Daily consumption non-perishables (g, average 100 runs) | Total perishables bought (g, average 100 runs) | Total non-perishables bought (g, average 100 runs) |
|---|---|---|---|---|---|---|---|---|
| #9 | Worse | Perishable first | Relaxed | 406.16 ± 6.52 | 1197.78 ± 18.17 | 1009.84 ± 16.94 | 1581.46 ± 23.76 | 1009.91 ± 17.1 |
| #12 | Worse | **Proportional consumption** | Relaxed | 342.16 ± 6.37 | 910.2 ± 15.98 | 1305.05 ± 25.37 | 1184.19 ± 20.86 | 1317.11 ± 25.74 |
| #7 | **Normal** | Perishable first | Relaxed | 340.56 ± 6.83 | 1837.82 ± 32.81 | 375.2 ± 8.83 | 2154.2 ± 38.64 | 362.3 ± 8.97 |

Scenario #12 differs from Scenario #9 only in its eating preferences: in Scenario #12, households balance their meals equally between perishables and non-perishables. This difference results in a statistically significant reduction in expired discards, totalling 342.16 grams (6.37). Examining additional results (Table 25), we observe that a more balanced consumption of perishables and non-perishables also translates into a more balanced purchase of these two food categories. With fewer perishables stored, households have fewer food items with a reduced shelf-life, which is further aggravated by the fact that they are purchasing food closer to expiration (in-store promotions).

A similar result in expired discards is generated by Scenario #7, which produces 340.56 grams daily (SD 6.83). This scenario differs from Scenario #9 only in the storage conditions, in this case normal. This means that households do not purchase food closer to expiration, but on the other hand they also do not put in practice effective strategies to extend their shelf life. Consequently, they feel confident purchasing more perishables and fewer non-perishables, as they assume the perishables will not expire as quickly as those in Scenario #9.

A quick comparison between Scenario #9 and Scenario #3 reveals the significant impact of the consumption strategy. In Scenario #3, households follow a strict strategy and do not wait beyond the best-before date, which influences their consumption preferences. As a result, households consume and purchase fewer perishables, knowing they will discard them as soon as they reach their best-before date. This result in 24.22 grams (SD 0.94) of discard leftovers in Scenario #3, compared to 406.16 grams (SD 6.52) in Scenario #9.

# 5 CONCLUSIONS

## 5.1 Insights from scenarios

The findings from the what-if scenarios analysis for the two models demonstrate that there are crucial factors to take into consideration when designing and implementing FW reduction interventions at both the hospitality and household level. Using what-if scenarios to explore our research questions has enabled us to gain a deeper understanding of how various factors and interventions influence FW. This approach allows decision-makers to make more informed choices about which interventions to pursue and which population behaviours to target, effectively predicting FW outcomes and guiding strategic planning.

In this section, the main insights from both models are summarized:

**Establishment Diner model:**

- **Sustainability awareness is a core driver for FW generation and reduction**: sustainability awareness proved to be the most influential factor in FW reduction among the 36 what-if scenarios simulated. Scenarios featuring guests with a high sustainability awareness consistently generated less FW, highlighting that enhancing sustainability awareness alone can mitigate waste even in the presence of provocative messages, which have proven to produce the undesired effect of increasing FW. These findings suggest that awareness of the environmental and social impact of food waste is a crucial factor to effectively reduce FW. Guests who understand the consequences of food waste tend to act more consciously and generate less waste. In the contexts where sustainability awareness is low, other FW reduction interventions such as varying the plate size or showing FW reduction messages may not sufficiently trigger mindful consumption. Therefore, raising sustainability awareness at a higher and broader level should be seen as a key priority in any FW reduction strategy. Once this broader sustainability awareness is raised, specific settings interventions, as the ones within hotel or restaurant settings can be implemented to make this awareness salient.
- **Impact of communication strategies:** messaging strategies had a varied effect on FW generation. Provocative messages proved to consistently produce more leftovers when compared to scenarios differing only from communication strategy. Positive messages, on the other hand, had a more varied effect, resulting in slightly higher or slightly lower leftovers amounts from identical scenarios but with no messages implemented. These findings underscore the importance of carefully crafting messaging strategies to avoid overly direct or confrontational expressions.
- **Plate size interventions have a limited influence on FW**: reducing plates from large to normal showed mixed effectiveness in FW reduction. Smaller plates led to marginal FW reduction only in few cases, but in most of the scenarios, larger plates unexpectedly led to FW reductions. This counterintuitive outcome could be explained by guests serving themselves fewer times with larger plates, potentially leading to fewer servings overall. This indicates that plate size alone may not be an effective FW reduction strategy, as it can produce unintended results if guests respond by making multiple servings that result in serving more than needed. Instead, plate size adjustments may be most effective when combined with other interventions, such as sustainability messaging and campaigns.
- **Guest composition**: in our model, business guests show a higher level of conformism, meaning they are more influenced by social norms and the behaviour of other people present. This makes sense, as they often operate in a mindset where they represent their companies, which can override their personal habits or attitudes. By comparing scenarios with different ratios of business to non-business guests, we find that when business guests are predominant, there is less FW generated. This implies that FW reduction interventions should primarily target leisure travellers, who exhibit a more relaxed and individualistic behaviour when compared to business travellers. Leisure guests are

less likely to conform to social norms and are more inclined to indulge, making them a key group to focus on when designing FW reduction strategies.

- **Scenario combinations:** Some scenarios, combining intervention and population changes, provided valuable insights into the most effective combinations for FW reduction. In particular, the more effective combination resulted to be the one featuring normal plates, a prevalence of business guests with high sustainability awareness and the use of a positive message reminding guests not to waste food. On the other hand, the combination resulting in the highest amount of leftovers per individual resulted to be the one with normal plates, low share of business guests with low sustainability awareness and the use of a provocative message.

**Home Cook model:**

- **Consumption strategy:** the consumption strategy emerged as the most influential factor in FW generation in the Home Cook model, which focuses on expired discards. Scenarios where households adopted a relaxed consumption strategy, characterized by less attention to best-before dates, led to substantial increases in expired discards. In contrast, stricter consumption strategies – where households try to us products before the best-before date, produced lower amounts of expired discards. The relaxed consumption strategy led to households gaining confidence in purchasing more perishables, which they would overstock. This over-purchasing behaviour resulted in spoilage as food items surpassed their expiration dates, thus contributing to higher levels of waste.
- **Storage conditions and in-store promotions**: storage conditions proved to be the second crucial factor influencing FW generation. Scenarios in which households know how to effectively store their food items consistently generated less expired discards, because of prolonged products' shelf-life. Additionally, it was observed that reliance on in-store promotions for discounted perishable items close to their best-before date had a significant impact on FW generation, as a consequences of products' reduced shelf-life.
- **Eating preferences:** Scenarios employing a balanced approach on the use of perishables and non-perishables, as seen in Scenario #12, achieved reductions in expired discards compared to the same situation but with households prioritizing perishables for their meals. By alternating between perishables and non-perishables, households minimized expired items while ensuring purchasing balance.
- **Household composition comparison:** the comparison between the Spanish and Belgian simulations – used as proxy to compare different household composition situations – demonstrated some differences in FW generation, with Belgian households generally producing lower amounts of expired discards. This can be attributed to differences in household composition, with Belgian households having fewer adults and children, which affects both their purchasing and consumption behaviours. However, the overall patterns and trends remained consistent between the two situations.
- **Scenario combinations**: Some scenarios provided valuable insights into the most effective combinations of parameters for FW reduction. The least effective combination of parameters is represented in Scenario #9 (406.16 grams of expired discards daily), where households utilize in-store promotions, prioritize perishables in their meals and adopt a relaxed consumption strategy, letting the food spoil and not paying attention to best-before dates. On the other hand, Scenario #2 generated the least amount of expired discards, closely followed by Scenario #3. Scenario #2 is characterized by households that effectively put into practice storage techniques and that consistently consider best-before dates when deciding what to consume. The findings suggest that to effectively reduce FW, interventions should focus on promoting stricter consumption strategies that prioritize the consumption of foods closer to expire and encourage better food storage practices. Additionally, efforts to educate households about the implications of in-store promotions and the importance of adhering to best-before dates could further mitigate expired discards.

## 5.2 Potential areas for further work

Building on the activities and results discussed in this report, a potential area for further work could be represented by applying the two models in different settings. The following section briefly presents some initial ideas.

During the co-design sessions at the Oslo meeting, discussions about the Establishment Diner model led to the formation of a sub-group that focused on exploring what would be the modification needed to use the model for school canteens/cafeterias. In these settings, children's meal habits, time management, and decision-making differ significantly from those of adults. The group identified four main areas for model modification.

The first point is related to time constraints: in a school setting, the time dedicated to lunch is typically limited to around 30 minutes, during which children split their time between eating and engaging in other activities, such as playing. An important question raised was how children decide to transition from eating to playing, with the MOA framework proposed to understand relevant drivers. Reduced eating time could lead to higher food waste simply because children may be unable to finish their portions, directly impacting food waste outcomes within the model.

Another factor that prevents the current Establishment Diner model from being used to simulate school settings is related to food portions: children in school canteens usually receive fixed portions rather than selecting their own. The group discussed modelling considerations around whether portions should be consistent across all children, potentially affecting the rate of food consumption as children often eat while socializing. Adjustments to the portion size and eating rate would thus need to be made to reflect these behavioural differences.

Similarly, many schools have fixed menus, thus different food options are not offered. When children have two or three meal options, they sometimes include both healthy and less-healthy choices, the decision-making process around meal selection would also need to consider specific influencing factors, such as taste preferences, which may influence children's choices.

Lastly, the issue of social influences should be analysed. Children are often influenced by peers, and modelling peer influence could involve identifying characteristics of influential individuals and how they affect conformity. Self-identity, including factors like gender, may play a role in these dynamics. Additionally, the influence of teachers should be considered.

These points offer insights into adapting the Establishment Diner model for school settings and could enhance our understanding of how environmental, social, and individual factors shape FW behaviours among children in schools, limited to the cases in which schools have canteens serving food. A crucial point to consider is the wide variability of school systems across countries, reflected by the variability of canteens structures, which would necessarily have an impact on the model development. Just to present some examples, in some cases children can individually decide when to leave the cafeteria for play, while in other cases the teacher establishes when the eating time ends; in some countries, children can decide among different food options, while in others the menu is fixed. Alongside this inter-country variability, relevant peculiarities in school canteens systems and behaviours are present also within the same country, further complicating the goal of creating a generalized model.

# 6 REFERENCES


Abrahamse, W., & Steg, L. (2013). Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change*, *23*(6), 1773–1785. https://doi.org/10.1016/J.GLOENVCHA.2013.07.029

Amr Yassin, C., & Soares, A. M. (2021). Buy now before it expires: a study of expiration date-based pricing. *International Journal of Retail and Distribution Management*, *49*(4), 514–530. https://doi.org/10.1108/IJRDM-10-2019-0328

Ananda, J., Gayana Karunasena, G., & Pearson, D. (2022). Identifying interventions to reduce household food waste based on food categories. *Food Policy*, *111*, 102324. https://doi.org/10.1016/j.foodpol.2022.102324

Aoyagi-Usui, M., Vinken, H., & Kuribayashi, A. (2003). Pro-environmental attitudes and behaviours: An international comparison. *Human Ecology Review*, 23–31.

Aschemann-Witzel, J. (2018). Consumer perception and preference for suboptimal food under the emerging practice of expiration date based pricing in supermarkets. *Food Quality and Preference*, *63*, 119–128. https://doi.org/10.1016/J.FOODQUAL.2017.08.007

Aschemann-Witzel, J., de Hooge, I., Amani, P., Bech-Larsen, T., & Oostindjer, M. (2015). Consumer-Related Food Waste: Causes and Potential for Action. *Sustainability 2015, Vol. 7, Pages 6457-6477*, *7*(6), 6457–6477. https://doi.org/10.3390/SU7066457

Banerjee, S., Galizzi, M. M., John, P., & Mourato, S. (2023). Immediate backfire? Nudging sustainable food choices and psychological reactance. *Food Quality and Preference*, *109*, 104923. https://doi.org/10.1016/J.FOODQUAL.2023.104923

Bel, S., De Ridder, K. A. A., Lebacq, T., Ost, C., Teppers, E., Cuypers, K., & Tafforeau, J. (2019). Habitual food consumption of the Belgian population in 2014-2015 and adherence to food-based dietary guidelines. *Archives of Public Health*, *77*(1), 14. https://doi.org/10.1186/s13690-019-0343-3

Bowman, G., MacKay, R. B., Masrani, S., & McKiernan, P. (2013). Storytelling and the scenario process: Understanding success and failure. *Technological Forecasting and Social Change*, *80*(4), 735–748. https://doi.org/10.1016/J.TECHFORE.2012.04.009

Bradfield, R., Wright, G., Burt, G., Cairns, G., & Van Der Heijden, K. (2005). *The origins and evolution of scenario techniques in long range business planning*. https://doi.org/10.1016/j.futures.2005.01.003

Brehm, J. W. (1966). *A theory of psychological reactance*. AcademicPress.

Brehm, J. W., & Brehm, S. S. (1981). *Psychological reactance – a theory of freedom and control*. Academic Press.

Bruns, H., & Perino, G. (2023). The role of autonomy and reactance for nudging — Experimentally comparing defaults to recommendations and mandates. *Journal of Behavioral and Experimental Economics*, *106*, 102047. https://doi.org/10.1016/J.SOCEC.2023.102047

Cialdini, R. B. . (1985). *Influence : science and practice*. Scott, Foresman.

Cohen, J. F. W., Jahn, J. L., Richardson, S., Cluggish, S. A., Parker, E., & Rimm, E. B. (2016). Amount of Time to Eat Lunch Is Associated with Children's Selection and Consumption of School Meal Entrée, Fruits,




Horizon Europe

Vegetables, and Milk. *Journal of the Academy of Nutrition and Dietetics*, *116*(1), 123–128. https://doi.org/10.1016/J.JAND.2015.07.019

Conrad, Z., Niles, M. T., Neher, D. A., Roy, E. D., Tichenor, N. E., & Jahns, L. (2018). Relationship between food waste, diet quality, and environmental sustainability. *PLOS ONE*, *13*(4), e0195405. https://doi.org/10.1371/JOURNAL.PONE.0195405

Ellemers, N., De Gilder, D., & Haslam, S. A. (2004). Motivating Individuals and Groups at Work: A Social Identity Perspective on Leadership and Group Performance. *The Academy of Management Review*, *29*(3), 459. https://doi.org/10.2307/20159054

Fitzsimons, G. J., & Lehmann, D. R. (2004). Reactance to Recommendations: When Unsolicited Advice Yields Contrary Responses. *Marketing Science*, *23*(1). https://doi.org/10.1287/MKSC.1030.0033

Freedman, M. R., & Brochado, C. (2010). Reducing portion size reduces food intake and plate waste. *Obesity*, *18*(9), 1864–1866. https://doi.org/10.1038/OBY.2009.480

Hebrok, M., & Boks, C. (2017). Household food waste: Drivers and potential intervention points for design – An extensive review. *Journal of Cleaner Production*, *151*, 380–392. https://doi.org/10.1016/j.jclepro.2017.03.069

Hermanussen, H., Loy, J. P., & Egamberdiev, B. (2022). Determinants of Food Waste from Household Food Consumption: A Case Study from Field Survey in Germany. *International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 14253*, *19*(21), 14253. https://doi.org/10.3390/IJERPH192114253

Janssen, A. M., Nijenhuis-de Vries, M. A., Boer, E. P. J., & Kremer, S. (2017). Fresh, frozen, or ambient food equivalents and their impact on food waste generation in Dutch households. *Waste Management*, *67*, 298–307. https://doi.org/10.1016/J.WASMAN.2017.05.010

Juvan, E., Grün, B., Zabukovec Baruca, P., & Dolnicar, S. (2021). Drivers of plate waste at buffets: A comprehensive conceptual model based on observational data and staff insights. *Annals of Tourism Research Empirical Insights*, *2*(1), 100010. https://doi.org/10.1016/J.ANNALE.2021.100010

Kallbekken, S., & Sælen, H. (2013). 'Nudging' hotel guests to reduce food waste as a win–win environmental measure. *Economics Letters*, *119*(3), 325–327. https://doi.org/10.1016/J.ECONLET.2013.03.019

Koivupuro, H. K., Hartikainen, H., Silvennoinen, K., Katajajuuri, J. M., Heikintalo, N., Reinikainen, A., & Jalkanen, L. (2012). Influence of socio-demographical, behavioural and attitudinal factors on the amount of avoidable food waste generated in Finnish households. *International Journal of Consumer Studies*, *36*(2), 183–191. https://doi.org/10.1111/J.1470-6431.2011.01080.X

Langer, E. J., & Rodin, J. (1976). The effects of choice and enhanced personal responsibility for the aged: A field experiment in an institutional setting. *Journal of Personality and Social Psychology*, *34*(2), 191–198. https://doi.org/10.1037/0022-3514.34.2.191

Leiserowitz, A. A., Kates, R. W., & Parris, T. M. (2006). Sustainability values, attitudes, and behaviours: A review of multinational and global trends. *Annual Review of Environment and Resources*, *31*, 413–444. https://doi.org/10.1146/ANNUREV.ENERGY.31.102505.133552

Mertens, S., Herberz, M., Hahnel, U. J. J., & Brosch, T. (2022). The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioural domains. *Proceedings of the National Academy of Sciences of the United States of America*, *119*(1). https://doi.org/10.1073/PNAS.2107346118

Miller, C. H., Lane, L. T., Deatrick, L. M., Young, A. M., & Potts, K. A. (2007). Psychological reactance and promotional health messages: The effects of controlling language, lexical concreteness, and the restoration of freedom. *Human Communication Research*, *33*(2), 219–240. https://doi.org/10.1111/J.1468-2958.2007.00297.X

Miller, L. B., Rice, R. E., Gustafson, A., & Goldberg, M. H. (2022). Relationships Among Environmental Attitudes, Environmental Efficacy, and Pro-Environmental Behaviors Across and Within 11 Countries. *Environment and Behavior*, *54*(7–8), 1063–1096. https://doi.org/10.1177/00139165221131002

Nisa, C. F., Bélanger, J. J., & Scumpe, B. M. (2022). Assessing the effectiveness of food waste messaging. *Environmental Science and Policy*, *132*, 224–236. https://doi.org/10.1016/J.ENVSCI.2022.02.020

Osman, M. (2020). *Backfiring, reactance, boomerang, spillovers, and rebound effects: Can we learn anything from examples where nudges do the opposite of what they intended?* https://doi.org/10.31234/osf.io/ae756

Partearroyo, T., Samaniego-Vaesken, M. de L., Ruiz, E., Aranceta-Bartrina, J., Gil, Á., González-Gross, M., Ortega, R. M., Serra-Majem, L., & Varela-Moreiras, G. (2019). Current Food Consumption amongst the Spanish ANIBES Study Population. *Nutrients*, *11*(11), 2663. https://doi.org/10.3390/nu11112663

Partearroyo, T., Samaniego-Vaesken, M. de L., Ruiz, E., Aranceta-Bartrina, J., Gil, Á., González-Gross, M., Ortega, R. M., Serra-Majem, L., & Varela-Moreiras, G. (2020). Plate Waste Generated by Spanish Households and Out-of-Home Consumption: Results from the ANIBES Study. *Nutrients*, *12*(6), 1641. https://doi.org/10.3390/nu12061641

Peng, M. (2017). How does plate size affect estimated satiation and intake for individuals in normal-weight and overweight groups? *Obesity Science and Practice*, *3*(3), 282–288. https://doi.org/10.1002/OSP4.119

Porpino, G., Parente, J., & Wansink, B. (2015). Food waste paradox: antecedents of food disposal in low income households. *International Journal of Consumer Studies*, *39*(6), 619–629. https://doi.org/10.1111/ijcs.12207

Price, J., & Just, D. R. (2015). Lunch, recess and nutrition: Responding to time incentives in the cafeteria. *Preventive Medicine*, *71*, 27–30. https://doi.org/10.1016/J.YPMED.2014.11.016

Quick, B. L., & Stephenson, M. T. (2008). Examining the role of trait reactance and sensation seeking on perceived threat, state reactance, and reactance restoration. *Human Communication Research*, *34*(3), 448–476. https://doi.org/10.1111/J.1468-2958.2008.00328.X

Rasines, L., Castillejo, N., San Miguel, G., & Aguayo, E. (2023). Can household storage conditions reduce food waste and environmental impact? A broccoli case study. *Science of The Total Environment*, *892*, 164779. https://doi.org/10.1016/j.scitotenv.2023.164779

Reynolds, C., Goucher, L., Quested, T., Bromley, S., Gillick, S., Wells, V. K., Evans, D., Koh, L., Carlsson Kanyama, A., Katzeff, C., Svenfelt, Å., & Jackson, P. (2019). Review: Consumption-stage food waste reduction interventions – What works and how to design better interventions. *Food Policy*, *83*, 7–27. https://doi.org/10.1016/J.FOODPOL.2019.01.009

Richardson, R., Prescott, M. P., & Ellison, B. (2021). Impact of plate shape and size on individual food waste in a university dining hall. *Resources, Conservation and Recycling*, *168*. https://doi.org/10.1016/J.RESCONREC.2020.105293

Secondi, L., & Principato, L. (2020). Consumer Choice and Food Waste: A Demand-Side Perspective to Address the Challenge of Sustainable Consumption Models. In *Transitioning to Responsible Consumption and Production*. MDPI. https://doi.org/10.3390/books978-3-03897-873-2-5

Silvia, P. J. (2006). Reactance and the dynamics of disagreement: multiple paths from threatened freedom to resistance to persuasion. *European Journal of Social Psychology*, *36*(5), 673–685. https://doi.org/10.1002/EJSP.309

Stancu, V., Haugaard, P., & Lähteenmäki, L. (2016). Determinants of consumer food waste behaviour: Two routes to food waste. *Appetite*, *96*, 7–17. https://doi.org/10.1016/J.APPET.2015.08.025

Stefan, V., van Herpen, E., Tudoran, A. A., & Lähteenmäki, L. (2013). Avoiding food waste by Romanian consumers: The importance of planning and shopping routines. *Food Quality and Preference*, *28*(1), 375–381. https://doi.org/10.1016/J.FOODQUAL.2012.11.001

Tajfel, H., & Turner, J. (1979). An integrative theory of intergroup conflict. In W. G. Austin & S. Worchel (Eds.), *The Social Psychology of Intergroup Relations* (pp. 33–47). Brooks/Cole.

Toma, L., Costa Font, M., & Thompson, B. (2020). Impact of consumers' understanding of date labelling on food waste behaviour. *Operational Research*, *20*(2), 543–560. https://doi.org/10.1007/s12351-017-0352-3

Van Geffen, L. e. j., Van Herpen, E., & Van Trijp, J. C. M. (2016). *Causes & Determinants of Consumer Food Waste. A theoretical framework*. https://eu-refresh.org/sites/default/files/Causes%20&%20Determinants%20of%20Consumers%20Food%20Waste_0.pdf

Van, K., Wansink, I. B., Antic, B., Chang, L., He, S., Hsu, T., Lau, M., Posey, C., Queen, M., Shaw, B., Sheehan, D., Sukthankar, K., Miron, B., & Hale, C. (2011). Plate Size and Color Suggestibility: The Delboeuf Illusion's Bias on Serving and Eating Behavior. *JOURNAL OF CONSUMER RESEARCH, Inc. •*, *39*. https://doi.org/10.1086/662615

Vargha, A., & Delaney, H. D. (2000). *A Critique and Improvement of the " CL " Common Language Effect Size Statistics of McGraw and Wong Author ( s ): András Vargha and Harold D . Delaney Source : Journal of Educational and Behavioral Statistics , Vol . 25 , No . 2 ( Summer , 2000 ), pp . Pub*. *25*(2), 101–132.

Visschers, V. H. M., Wickli, N., & Siegrist, M. (2016). Sorting out food waste behaviour: A survey on the motivators and barriers of self-reported amounts of food waste in households. *Journal of Environmental Psychology*, *45*, 66–78. https://doi.org/10.1016/J.JENVP.2015.11.007

Vittuari, M., Garcia Herrero, L., Masotti, M., Iori, E., Caldeira, C., Qian, Z., Bruns, H., van Herpen, E., Obersteiner, G., Kaptan, G., Liu, G., Mikkelsen, B. E., Swannell, R., Kasza, G., Nohlen, H., & Sala, S. (2023). How to reduce consumer food waste at household level: A literature review on drivers and levers for behavioural change. *Sustainable Production and Consumption*, *38*, 104–114. https://doi.org/10.1016/j.spc.2023.03.023

Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers. *Annual Review of Nutrition*, *24*(Volume 24, 2004), 455–479. https://doi.org/10.1146/ANNUREV.NUTR.24.012003.132140/CITE/REFWORKS

Wansink, B., & van Ittersum, K. (2013). Portion size me: Plate-size induced consumption norms and win-win solutions for reducing food intake and waste. *Journal of Experimental Psychology: Applied*, *19*(4), 320–332. https://doi.org/10.1037/a0035053

Williams, H., Wikström, F., Otterbring, T., Löfgren, M., & Gustafsson, A. (2012a). Reasons for household food waste with special attention to packaging. *Journal of Cleaner Production*, *24*, 141–148. https://doi.org/10.1016/J.JCLEPRO.2011.11.044

Williams, H., Wikström, F., Otterbring, T., Löfgren, M., & Gustafsson, A. (2012b). Reasons for household food waste with special attention to packaging. *Journal of Cleaner Production*, *24*, 141–148. https://doi.org/10.1016/J.JCLEPRO.2011.11.044

Yuan, S., & Kuehl, C. (2023). Exploring the Influence of Aggressive and Target-Framing Messages on Proenvironmental Behaviors. *Https://Doi.Org/10.1177/10755470231153634*, *45*(2), 225–251. https://doi.org/10.1177/10755470231153634

Zhang, L., Ye, L., Qian, L., & Zuo, X. (2024). The impact of dietary preference on household food waste: evidence from China. *Frontiers in Nutrition*, *11*, 1415734. https://doi.org/10.3389/FNUT.2024.1415734/BIBTEX

Zhao, X., & Manning, L. (2019). Food plate waste: factors influencing insinuated intention in a university food service setting. *British Food Hournal*, *121*(7), 1536–1549. https://doi.org/10.1108/BFJ-07-2018-0481

Zheng, H., Chen, K., & Ma, Z. (2023). Interactive effects of social norms and information framing on consumers' willingness of food waste reduction behaviour. *Journal of Retailing and Consumer Services*, *75*. https://doi.org/10.1016/J.JRETCONSER.2023.103525

# 7 APPENDIX

Table A1. Establishment Diner model 36 what-if scenarios and results.

*Baseline scenario
[a]Selected scenarios

| *Scenario ID* | *Plate Size* | *Guest Composition* | *Sustainability Awareness* | *Communication* | Average Leftovers per guest and standard deviation (g) |
|---|---|---|---|---|---|
| *1** | large | low business guest | medium | no communication | 30.20 ± 14.68 |
| *2* | normal | high business guest | high | no communication | 11.46 ± 5.67 |
| *3* | normal | high business guest | high | provocative message | 17.41 ± 6.37 |
| *4* | normal | high business guest | high | positive message | 9.73 ± 5.76 |
| *5* | normal | high business guest | low | no communication | 109.95 ± 18.96 |
| *6* | normal | high business guest | low | provocative message | 130.01 ± 18.46 |
| ***7[a]*** | **normal** | **high business guest** | **low** | **positive message** | **108.53 ± 19.75** |
| *8* | normal | equal | high | no communication | 12.26 ± 7.39 |
| *9* | normal | equal | high | provocative message | 29.7 ± 8.44 |
| *10* | normal | equal | high | positive message | 13.43 ± 7.25 |
| *11* | normal | equal | low | no communication | 182.8 ± 25.64 |
| *12* | normal | equal | low | provocative message | 184.01 ± 25.41 |
| *13* | normal | equal | low | positive message | 191 ± 23.01 |
| *14* | normal | low business guests | high | no communication | 15.44 ± 8.39 |
| *15* | normal | low business guests | high | provocative message | 20.73 ± 8.71 |
| *16* | normal | low business guests | high | positive message | 16.97 ± 7.43 |
| *17* | normal | low business guests | low | no communication | 256.89 ± 29.03 |
| ***18[a]*** | **normal** | **low business guests** | **low** | **provocative message** | **277.41 ± 28.41** |
| *19* | normal | low business guests | low | positive message | 255.63 ± 27.85 |
| *20* | large | high business guest | high | no communication | 10.61 ± 5.92 |
| *21* | large | high business guest | high | provocative message | 17.56 ± 6.3 |
| *22* | large | high business guest | high | positive message | 11.91 ± 6.29 |
| *23* | large | high business guest | low | no communication | 107.49 ± 17.27 |
| *24* | large | high business guest | low | provocative message | 117.82 ± 19.1 |
| *25* | large | high business guest | low | positive message | 111.08 ± 17.49 |
| *26* | large | equal | high | no communication | 13.48 ± 8.05 |
| ***27[a]*** | **large** | **equal** | **high** | **provocative message** | **15.2 ± 7.25** |
| *28* | large | equal | high | positive message | 11.02 ± 5.58 |
| *29* | large | equal | low | no communication | 174.89 ± 25.85 |
| *30* | large | equal | low | provocative message | 185.73 ± 24.46 |
| *31* | large | equal | low | positive message | 184.93 ± 29.2 |
| *32* | large | low business guests | high | no communication | 14.77 ± 8.74 |
| *33* | large | low business guests | high | provocative message | 24.61 ± 11.98 |
| *34* | large | low business guests | high | positive message | 14.85 ± 7.59 |
| ***35[a]*** | **large** | **low business guests** | **low** | **no communication** | **248.8 ± 29.03** |
| *36* | large | low business guests | low | provocative message | 260.25 ± 29.98 |
| *37* | large | low business guests | low | positive message | 262.36 ± 29.69 |

Table A2: Results of Tukey's HSD test comparing scenarios presented in Section 3.5

The table shows the mean differences (*meandiff*), adjusted p-values (*p-adj*), confidence intervals (lower, upper), and whether the null hypothesis (no significant difference between groups) is rejected (*reject*) with a p-adj<0.05. If True, the null hypothesis is rejected.

*Baseline scenario

| Scenario1 | Scenario2 | meandiff | p-adj | lower | upper | reject |
|---|---|---|---|---|---|---|
| #1* | #7 | 76.8792 | 0.0 | 68.7612 | 84.9972 | True |
| #1* | #18 | 245.7565 | 0.0 | 237.6385 | 253.8746 | True |
| #1* | #27 | -16.4531 | 0.0 | -24.5711 | -8.335 | True |
| #1* | #35 | 217.1507 | 0.0 | 209.0326 | 225.2687 | True |
| #4 | #7 | 98.7984 | 0.0 | 90.6804 | 106.9164 | True |
| #5 | #7 | -1.4176 | 1.0 | -9.5356 | 6.7004 | False |
| #7 | #19 | 147.0997 | 0.0 | 138.9817 | 155.2178 | True |
| #7 | #25 | 2.5456 | 1.0 | -5.5724 | 10.6636 | False |
| #17 | #18 | 20.5253 | 0.0 | 12.4073 | 28.6434 | True |
| #18 | #36 | -17.1579 | 0.0 | -25.2759 | -9.0398 | True |



Horizon Europe

Table A3: Home Cook model 24 scenarios with Expired discards results

| Scenario | Country | Storage conditions | Eating preferences | Consumption strategy | Expired discards (g, daily) |
|---|---|---|---|---|---|
| 1 | Spain | Normal | Perishables first | Strict strategy | 6.1 ± 0.28 |
| **2** | **Spain** | **Much better** | **Perishables first** | **Strict strategy** | **5.62 ± 0.23** |
| 3 | Spain | Worse | Perishables first | Strict strategy | 24.22 ± 0.94 |
| 4 | Spain | Normal | Proportional consumption (50%) | Strict strategy | 6.03 ± 0.26 |
| 5 | Spain | Much better | Proportional consumption (50%) | Strict strategy | 5.63 ± 0.19 |
| 6 | Spain | Worse | Proportional consumption (50%) | Strict strategy | 23.26 ± 0.71 |
| 7 | Spain | Normal | Perishables first | Relaxed strategy | 340.56 ± 6.83 |
| 8 | Spain | Much better | Perishables first | Relaxed strategy | 229.21 ± 5.95 |
| **9** | **Spain** | **Worse** | **Perishables first** | **Relaxed strategy** | **406.16 ± 6.52** |
| 10 | Spain | Normal | Proportional consumption (50%) | Relaxed strategy | 310.09 ± 5.8 |
| 11 | Spain | Much better | Proportional consumption (50%) | Relaxed strategy | 110.24 ± 2.16 |
| 12 | Spain | Worse | Proportional consumption (50%) | Relaxed strategy | 342.16 ± 6.37 |
| 13 | Belgium | Normal | Perishables first | Strict strategy | 3.69 ± 0.19 |
| 14 | Belgium | Much better | Perishables first | Strict strategy | 3.3 ± 0.14 |
| 15 | Belgium | Worse | Perishables first | Strict strategy | 18.05 ± 0.77 |
| 16 | Belgium | Normal | Proportional consumption (50%) | Strict strategy | 3.6 ± 0.18 |
| 17 | Belgium | Much better | Proportional consumption (50%) | Strict strategy | 3.3 ± 0.14 |
| 18 | Belgium | Worse | Proportional consumption (50%) | Strict strategy | 17.68 ± 0.66 |
| 19 | Belgium | Normal | Perishables first | Relaxed strategy | 266.71 ± 6.14 |
| 20 | Belgium | Much better | Perishables first | Relaxed strategy | 171.86 ± 5.15 |
| 21 | Belgium | Worse | Perishables first | Relaxed strategy | 324.75 ± 7.54 |
| 22 | Belgium | Normal | Proportional consumption (50%) | Relaxed strategy | 199.72 ± 5 |
| 23 | Belgium | Much better | Proportional consumption (50%) | Relaxed strategy | 80.04 ± 2.21 |
| 24 | Belgium | Worse | Proportional consumption (50%) | Relaxed strategy | 231.41 ± 6.06 |

Table A4: Home Cook model scenarios results on: Daily consumption of leftovers, Daily consumption of perishables, Daily consumption of non-perishables, Total perishables bought, Total non perishables bought, Total food stored, Leftovers stored, Daily plate waste, Daily leftovers generated

| Scenario | Daily consumption leftover (g) | Daily consumption perishables (g) | Daily consumption non-perishables (g) | Total perishables bought (g) | Total non-perishables bought (g) | Total food stored (g) | Leftovers stored (g) | Daily plate waste (g) | Daily leftovers generated (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 733.93 ± 12.17 | 883.63 ± 15.38 | 1330.58 ± 22.88 | 1259.34 ± 21.41 | 1331.88 ± 23.18 | 11927.41 ± 197.99 | 358.86 ± 5.86 | 55.96 ± 0.93 | 739.54 ± 12.29 |
| **2** | **734.91 ± 11.68** | **1487.68 ± 23.11** | **729.5 ± 13.41** | **1871.22 ± 29.19** | **731.51 ± 13.36** | **12763.84 ± 208.98** | **359.38 ± 5.71** | **56.04 ± 0.89** | **740.53 ± 11.78** |
| 3 | 735.25 ± 11.37 | 420.16 ± 7.47 | 1797.97 ± 27.7 | 696.81 ± 11.94 | 1815.21 ± 27.9 | 11215.49 ± 174.71 | 359.46 ± 5.51 | 56.06 ± 0.86 | 740.86 ± 11.43 |
| 4 | 734.31 ± 12.16 | 670.75 ± 11.57 | 1544.68 ± 26.13 | 941.74 ± 15.93 | 1557.66 ± 26.26 | 11147.66 ± 187.74 | 359.01 ± 5.94 | 55.99 ± 0.93 | 739.94 ± 12.26 |
| 5 | 736.77 ± 12.75 | 1127.26 ± 20.54 | 1095.49 ± 18.72 | 1393.35 ± 25.03 | 1107.37 ± 19.1 | 11406.42 ± 194.48 | 360.2 ± 6.25 | 56.18 ± 0.97 | 742.4 ± 12.82 |
| 6 | 733.63 ± 10.67 | 332.66 ± 5.45 | 1880.67 ± 27.76 | 539.91 ± 8.52 | 1903.9 ± 28.19 | 10741.03 ± 157.89 | 358.85 ± 5.21 | 55.94 ± 0.81 | 739.25 ± 10.74 |
| 7 | 733.51 ± 13.26 | 1837.82 ± 32.81 | 375.2 ± 8.83 | 2154.2 ± 38.64 | 362.3 ± 8.97 | 12959.84 ± 233.66 | 358.68 ± 6.48 | 55.93 ± 1.01 | 739.14 ± 13.32 |
| 8 | 735.45 ± 13.85 | 2143.02 ± 40.44 | 75.65 ± 2.97 | 2250.84 ± 42.24 | 60.9 ± 2.81 | 13975.28 ± 273.09 | 359.58 ± 6.77 | 56.07 ± 1.06 | 741.04 ± 13.96 |
| **9** | **731.77 ± 11.12** | **1197.78 ± 18.17** | **1009.84 ± 16.94** | **1581.46 ± 23.76** | **1009.91 ± 17.1** | **12089.91 ± 185.85** | **357.82 ± 5.44** | **55.79 ± 0.85** | **737.35 ± 11.22** |
| 10 | 735.72 ± 12.94 | 1415.49 ± 25.02 | 804.17 ± 14.76 | 1615.36 ± 28.39 | 814.03 ± 15 | 10790.75 ± 190.46 | 359.82 ± 6.28 | 56.1 ± 0.98 | 741.36 ± 13.01 |
| 11 | 732.62 ± 10.12 | 1567.41 ± 21.61 | 642.87 ± 8.97 | 1611 ± 22.14 | 654.41 ± 9.12 | 10537.9 ± 144.41 | 358.25 ± 4.9 | 55.86 ± 0.77 | 738.23 ± 10.19 |
| 12 | 734.27 ± 13.24 | 910.2 ± 15.98 | 1305.05 ± 25.37 | 1184.19 ± 20.86 | 1317.11 ± 25.74 | 11088.32 ± 200.87 | 359.1 ± 6.37 | 55.99 ± 1.01 | 739.89 ± 13.34 |
| 13 | 434.02 ± 9.46 | 708.09 ± 16.06 | 1066.29 ± 23.47 | 1008.88 ± 22.68 | 1067.27 ± 23.67 | 9479.23 ± 206.94 | 212.14 ± 4.61 | 40.01 ± 0.87 | 437.33 ± 9.54 |
| 14 | 431.74 ± 9.08 | 1183.35 ± 24.79 | 581.75 ± 13.23 | 1488.21 ± 31.18 | 582.97 ± 13.31 | 10087.26 ± 216.31 | 211.04 ± 4.45 | 39.8 ± 0.84 | 435.04 ± 9.15 |
| 15 | 431.14 ± 8.7 | 334.78 ± 7.57 | 1427.87 ± 28.67 | 554.84 ± 12.33 | 1441.52 ± 29.02 | 8831.01 ± 178.88 | 210.78 ± 4.3 | 39.74 ± 0.8 | 434.43 ± 8.75 |
| 16 | 433.76 ± 7.13 | 418.72 ± 7.48 | 1354.69 ± 22.41 | 582.8 ± 10.26 | 1371 ± 22.67 | 8523.33 ± 141.57 | 211.99 ± 3.52 | 39.98 ± 0.66 | 437.09 ± 7.19 |
| 17 | 432.65 ± 9.75 | 676.89 ± 15.18 | 1091.89 ± 25.01 | 834.01 ± 18.66 | 1107.98 ± 25.42 | 8639.28 ± 193.89 | 211.51 ± 4.77 | 39.88 ± 0.9 | 435.95 ± 9.82 |
| 18 | 431.82 ± 9.14 | 218.32 ± 4.89 | 1547.15 ± 33.08 | 349.17 ± 7.67 | 1569.71 ± 33.5 | 8290.01 ± 177.78 | 211.12 ± 4.47 | 39.8 ± 0.84 | 435.13 ± 9.21 |
| 19 | 433.04 ± 9.59 | 1469.59 ± 32.49 | 300.85 ± 8.11 | 1722.3 ± 38.02 | 292.88 ± 8.01 | 10249.1 ± 231.9 | 211.7 ± 4.67 | 39.92 ± 0.88 | 436.35 ± 9.67 |
| 20 | 433.3 ± 8.22 | 1709.25 ± 32.28 | 62.24 ± 2.81 | 1795.65 ± 34.16 | 50.83 ± 2.59 | 10922.08 ± 218.32 | 211.83 ± 4.02 | 39.94 ± 0.76 | 436.61 ± 8.26 |
| 21 | 433.35 ± 10.15 | 960.94 ± 21.72 | 810.83 ± 20.72 | 1268.56 ± 28.72 | 810.8 ± 20.68 | 9625.58 ± 227.54 | 211.85 ± 4.95 | 39.95 ± 0.93 | 436.68 ± 10.22 |
| 22 | 432.68 ± 10.24 | 821.02 ± 19.48 | 947.88 ± 22.6 | 942.82 ± 22.28 | 963.76 ± 23.05 | 8456.45 ± 200.79 | 211.54 ± 5.02 | 39.88 ± 0.94 | 435.98 ± 10.31 |
| 23 | 431.93 ± 9.74 | 913.76 ± 20.56 | 852.07 ± 19.29 | 935.67 ± 20.95 | 868.08 ± 19.64 | 8424.52 ± 189.6 | 211.17 ± 4.74 | 39.81 ± 0.9 | 435.22 ± 9.81 |
| 24 | 433.57 ± 10.08 | 556.27 ± 13.2 | 1216.31 ± 28.81 | 720.88 ± 16.85 | 1232.4 ± 29.32 | 8467.68 ± 198.09 | 211.96 ± 4.93 | 39.97 ± 0.93 | 436.88 ± 10.18 |

Table A5: Results of Tukey's HSD test comparing scenarios presented in Section 3.5

The table shows the mean differences (*meandiff*), adjusted p-values (*p-adj*), confidence intervals (lower, upper), and whether the null hypothesis (no significant difference between groups) is rejected (*reject*) with a p-adj<0.05. If True, the null hypothesis is rejected.

| Scenario1 | Scenario2 | meandiff | p-adj | lower | upper | reject |
|---|---|---|---|---|---|---|
| #2 | #3 | 18.5994 | 0.0 | 16.6852 | 20.5136 | True |
| #2 | #8 | 223.5948 | 0.0 | 221.6806 | 225.5089 | True |
| #7 | #9 | 65.6006 | 0.0 | 63.6864 | 67.5148 | True |
| #3 | #9 | 381.9419 | 0.0 | 380.0278 | 383.8561 | True |
| #9 | #12 | -64.0041 | 0.0 | -65.9183 | -62.09 | True |

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