Flexible cooking

Master thesis

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Master thesis
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Flexible cooking

Store it in a Backie!

Preface

This MSc graduation thesis is the result of the design process of “Backie”, which took place from February till August 2024. The project is the final assignment of the Master Integrated Product Design at the faculty of Industrial Design Engineering at Delft University of Technology. This master thesis project is part of the interdisciplinary project “Food Waste: Transition from Excess to Enough” from the universities of Delft, Wageningen and Groningen, together with a large consortium of partners from practice.

This project was conducted in four phases: literature research, target group interviews, conceptualization and prototyping. The result of this design journey is the development of the product ‘Backie’, a product that changes the way leftover meals are used and aims to reduce food waste in Dutch households.

Special thanks to my supervisor Rick Schifferstein and my coach Martijn Haans for their expertise and help during the times I needed it most. Your professional and critical insights have elevated the quality of this project to a higher level. To the PMB and Applied labs staff, thanks for all the support during the prototyping of this project, I could not have done it without your knowledge and experience working with these materials.

I would like to thank my parents and sister for their enthusiasm concerning the topic of the project, and their unwavering support during these last months, I could not have done it without their love and care for me. Special thanks to my dear friend Wouter, who helped me to grow as a person and was always there for me when I needed him most. Thanks to him, Moos, Stan, Berend, Sep & Jip, for being my friends and making these two last years of my studies such a good time. These guys were always up for doing something fun and made sure that there was always a social life next to graduating, which kept these last 6 months bearable. They truly are friends for life.
I am deeply grateful to Maartje for her unconditional support during this past year. I cherish our special bond and the deep understanding we have for each other. Thank you for being there, not only as a friend but also as a great example of strength and compassion.
Finally I would like to thank Anne, as our meet-ups were the highlights of my week filled with relaxing and the much needed distraction from all the serious stuff.

My time as a student at TU Delft has been an unforgettable experience. All the people that I’ve met and all the things I’ve learned will forever be cherished. The past two years I have learned a lot about the whole design journey from an initial idea to a final product, and all the methods and aspects that have to do with that. I have been able to push my own capabilities and knowledge to the next level and have been able to develop myself as a real design engineer. The prototyping and physical model making that I’ve been able to train and develop these years and during this project is amazing. There is nothing like seeing the product you’ve imagined come to life. There is no doubt that I will keep on finding little pieces of white PLA from the prototyping up until the day that I will move out of my student room, and I will love every single piece of it.

Tom van Veldhuisen

Delft, August 2024

Executive summary

Food waste is one of the biggest and fastest growing problem in todays' society. There is a huge contrast between people that suffer from hunger and parts of the world that are prone to an abundance of food resulting in obesity and food waste. Food waste has a great social influence and influence on the environment. In Europe, over 40% of all food waste takes place in the consumer and retail stages of the food supply chain. In the Netherlands this results to 33,4 kg of food wasted per person per year (Van Lieshout & Knüppe, 2022). The most problematic consumers that contribute to food waste in the Netherlands are people in the age groups of 18-40 years of age (Voedingscentrum, n.d.). Especially single person households, smaller households and households with younger children show more food waste compared to other demographical groups. Therefore these people were the target group during this project.

This graduation project is part of the bigger interdisciplinary project "Food Waste: Transition from Excess to Enough". The goal of this project is to change the behaviour of consumers relating to food waste, in an effort to reduce the amount of food wasted in the Netherlands. As the scope of the project is specifically Dutch households, households of other nationalities than Dutch are not taken into account.

Literature research shows that food gets wasted because of various reasons and types of behaviour. To get deeper insights into the behaviour leading to this phenomenon, three user researches were carried out to find why this happens in Dutch households. The first research was an online questionnaire to find out the general opinion on food waste and get an understanding of the reasoning behind the behaviour. Secondly a food diary research was performed with a smaller group, to find out more detailed information about what and why food was wasted. Finally due to the findings in the previous researches, a last research interviewing the target group was carried out with their specific opinion on leftover consumption.

The findings from these researches can be summarized as following:

- Leftovers from meals contribute most to food waste in Dutch households.
- Leftovers are being saved up due to guilt of throwing food away. Consumers fail to identify when to consume saved leftovers or forget about their existence until it is too late.
- Leftover meals are often consumed as lunch instead of dinnertime meals, but are deemed inconvenient to bring elsewhere and thus are consumed at home primarily.

The first finding was one of the most important findings in the project, as the original scope was to incorporate half ingredients in other meals. However, more food waste can be prevented by focussing on leftover meals instead of (specific) half ingredients. Secondly the reason why the leftovers get thrown away most often results in a clear goal: increasing leftover consumption. The third and final finding is the current situation and provides the opportunity to intervene and change the behaviour of the consumer. This all led to the diversion of the original goal of flexible cooking towards stimulating flexible consumption. It resulted in the following design statement: "I want to reduce food waste by giving consumers the tools and opportunity to make leftover meals more valuable and versatile to use on a daily basis, by making it more user-friendly and convenient to take leftovers with them to consume in more scenarios and environments."

Multiple concepts were generated, after which they were evaluated on their potential to effectively change the behaviour and finally one was chosen for further development: Backie. The idea of Backie was to create the ultimate on-the-go food storage container, with many features to boost and encourage the usage of leftovers during lunch. For example by including a date tracker, offering more reheating opportunities, a cooling element and insulating effect. The concept evolved during the prototyping through many iterations towards a final design which was used to evaluate the product with the target group.

The prototype was evaluated with five persons from the intended user group. During the evaluation they were asked to perform a series of tasks, which simulated the usage and interactions that they would have whilst using the product. Finally they were asked questions about their experience and their opinion about the Backie. The result of the evaluation was that the product and its features was perceived positively and showed potential to change the behaviour of the target group, hopefully reducing the food waste generated in Dutch households.

In summary, the prototype and its features were perceived to be useful artefacts in reducing food waste through stimulating leftover consumption. However, the product could use some further development on the details to make the experience more easy. A final test should be conducted to show the products' long term impact on the user behaviour, hopefully showing a sustained behavioural change.

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Introduction

Context

Food waste is a big and fast growing societal problem in the world. The existing food system is grounded in assumptions of the need for excess and elaborate choice to account for consumers' everchanging preferences and demands for food anywhere, anytime. While this can boost consumer satisfaction, it leads to significant societal costs due to inefficient resource utilization. This unsustainable behaviour results in an abundance of food bought by consumers and part of this food expires or does not get used, and as a result huge amounts of food gets thrown away without consumption.

The worlds' population is growing whilst there are already millions of people that do not have access to sufficient amounts of food. On the contrary of hunger worldwide there is also the problem of obesity and food waste in other parts of the globe. The food supply chain knows numerous points where food gets lost and households are one of the biggest contributors to food waste of them all.

Problem definition

The focus of this project is aimed on the food waste in Dutch households and how the behaviour of the consumers contributes to this phenomenon. This is merely a small part of the food supply chain in which food gets produced and eventually ends up with the consumer for consumption.

Due to the unpredictable schedule of consumers, whether people do or don't eat at home, a lot of food is wasted as it is not consumed within the expiring date. Consumers struggle to adapt to sudden changes in their planning and as a result food is either not consumed or the consumer ends up with unexpected leftovers after cooking. These small portions are easily forgotten and as a result get thrown away as they have gone bad after some days. Besides this the consumers are not able to use the leftover ingredients in other meals.

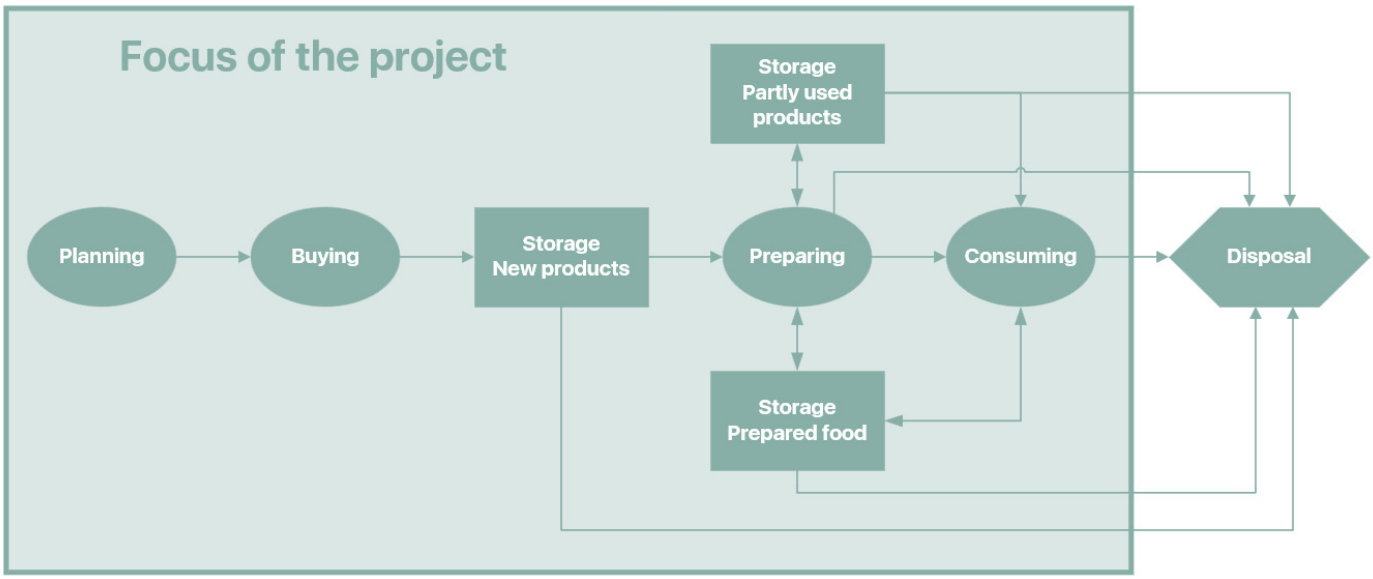


Figure a: Focus of the project

This project will focus on preventing that leftover food or ingredients end up as waste after the consumer has (partly) consumed his/her meal. The outcome of the project should result in prevention of unnecessary (food)waste produced by Dutch households, by making the consumer conscious about the lifespan of the product and more creative to use these ingredients in other meals.

Assignment

The aim of the project is described as following:

"Stimulate more flexible and adaptive behaviour when cooking and consuming (leftover) meals and ingredients, to prevent and reduce food waste in Dutch households."

The assignment includes the following parts:

- Investigate and get insight into the reasoning behind the consumers' behaviour and how to change this
- Find out where opportunities arise to reduce food waste
- Develop a prototype which can be used for further research

Chapter 1
Literature research

This chapter dives deeper into the phenomenon of food waste by addressing the worldwide and local statistics, demographical influence, the behavioural actions, values, motives, the knowledge of changing behaviour and the current efforts in preventing food waste in general. This gives a clear overview of what is happening in the wastage of food and gives insight in where possible opportunities arise.

Food waste in the world

Food is an essential part of our everyday life. The FAO describes it as the following: "Food means any substance, whether processed, semi-processed or raw, which is intended for human consumption.." (FAO, n.d.) Getting the right nutrition and sufficient amounts of this enables us humans to function properly on a day to day basis. Nowadays it is very easy to get your hands on food. The availability and variety of food in supermarkets is greater than ever. This results in a new problem, a large part of the food gets wasted. In European countries more than 40% of food is wasted in the consumer and retail stages of the food supply chain (Barker et al, 2021). Big organisations such as the United Nations and the European Union want to reduce this food waste problem in current society.

The impact that food has on the world

The United Nations state that roughly 30 percent of all food that is produced every single year goes uneaten due to food loss and food waste in the food supply chain. As visible in figure 1, in Europe over 30% of all this food waste is happening in the consumption phase (FAO et al., 2013). The consumption phase is when consumers have bought the food but ultimately discard the food without consumption due to their behaviour and poor decision-making. This could severely be reduced.

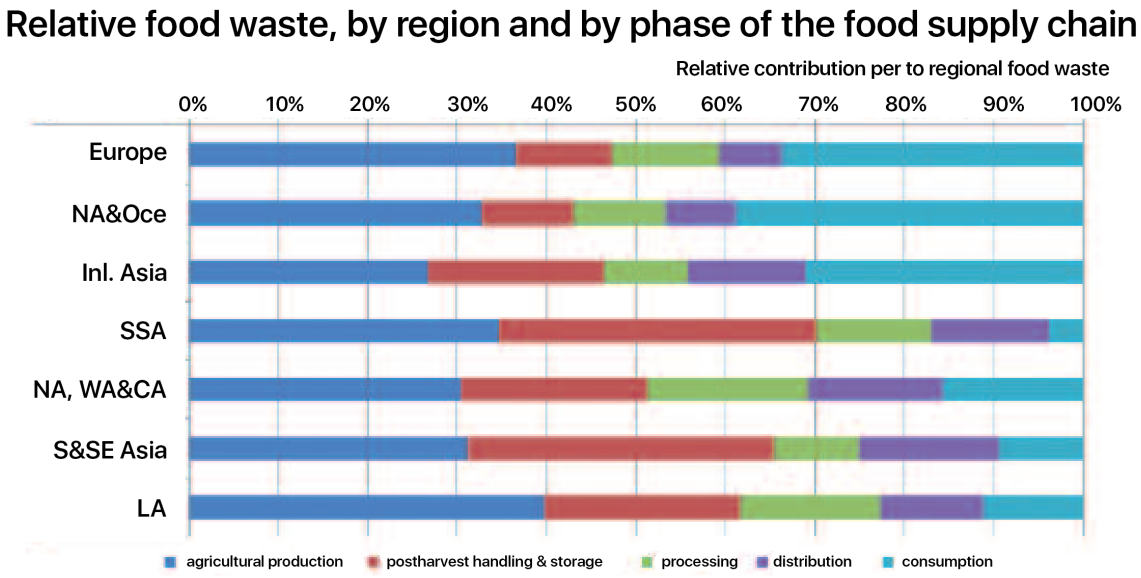


Figure 1: relative food waste

Impact on the environment

The total wastage of food has an enormous impact on the environment, worldwide contributing to over 3 gigatonnes of CO2 equivalent. Which would make food waste be on place three of most CO2 emitting countries in the world (FAO et al., 2013), as visible in figure 2. Food waste is therefore a huge problem for not only humanity but also for climate change in general. In addition to the emission due to the actual food waste, there is also a lot of emissions linked to the production of the food as well. The actions and processes needed to produce the food such as raising cattle and farming in general are very harmful to the environment too. The emission of greenhouse gasses such as CO2, N2O and CH4 related to the whole food supply chain contributes greatly to global warming. The yearly food-system emissions back in 2015 contributed 18 gigatonnes CO2 equivalent in total, which is 34% of all greenhouse gas emissions worldwide (Crippa et al., 2021). Most notable is the fact that the agricultural sector is responsible for half of the total methane (CH4), two-third of nitrous oxide (N2O) and 3% of CO2 (Ivanovich et al., 2023).

Food inequality

The wastage of all this food is happening whilst 12.9% of all the people in the world suffer from chronic hunger (UNEP, n.d.). The sustainable development goal (SDG) 2 of the UN is the 'zero hunger' goal, striving to end world hunger, achieve food safety and promotes sustainable agriculture. (Hasegawa et al., 2019)Meanwhile the worlds' population is still growing with an expected grow from 7.2 billion to 9 billion people in 2050 (UNEP, n.d.).

The contrast seen with the availability of food is enormous. Whereas there are parts of the world with limited availability to food there is also a part of the world where people suffer from obesity due to too much food. The UN estimates that over 30% of all adults worldwide suffers from obesity (UNEP, n.d.). These statistics are visible in figure 3.

According to Hasegawa et al. (2019) there are two possible ways of tackling this problem. Either increasing food production worldwide or pursuing a more equitable food distribution by redistributing the available food worldwide. The first would mean an increase in greenhouse gas emissions and is therefore the non-favourable solution to the problem. To achieve the second scenario, a change in the consumer behaviour must be established and food waste must be reduced globally. Only then it is possible to create a sustainable difference in how food is used worldwide and opens up possibilities to help other nations combat hunger by political interventions. A combination of targeting undernourishment and reducing over-consumption can result in a reduction of 9% in food demand while reducing hunger and improving sustainability in the food supply chain (Hasegawa et al., 2019).

Figure 3: World hunger statistics (Hasegawa et al., 2019)

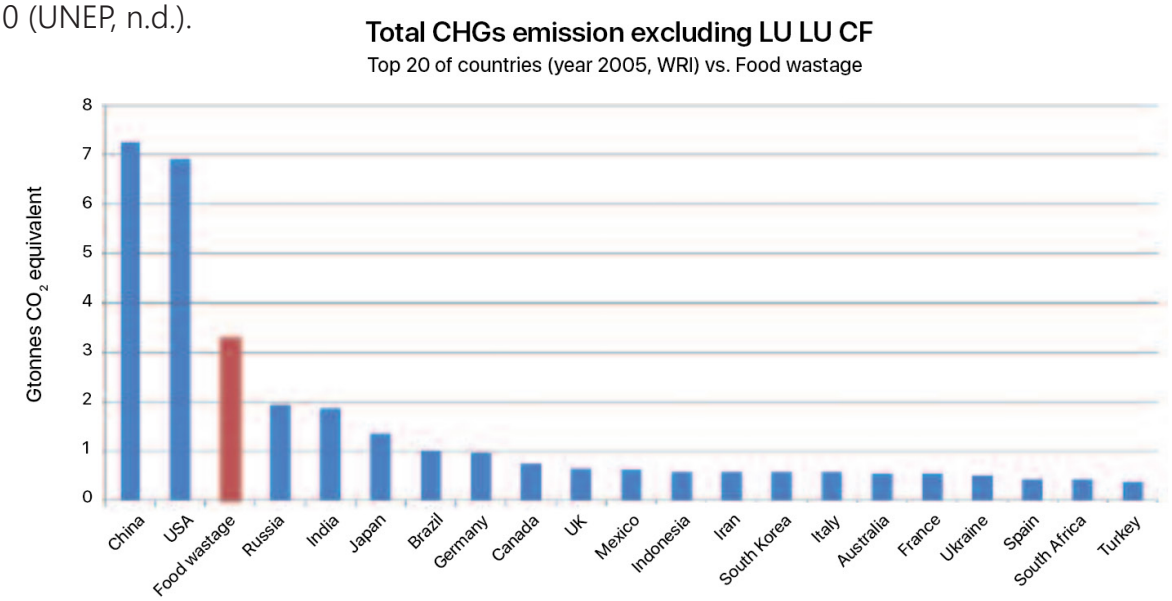


Figure 2: Emission of greenhouse gasses (FAO et al., 2013)

The food supply chain

Every piece of food, being fruits, vegetables, dairy products, meat, fish or whatever is destined for human consumption is part of the food supply chain. The food supply chain (figure 4) is the process from primary production to consumption by consumers and every step in between (Luo et al, 2022). The food supply chain knows five main stages in all of which food gets lost in some way or another. It is important to understand this process to identify where the biggest problem of food waste is located.

Figure 4: Food supply chain

Production

The production stage is where food starts its life. It is grown, harvested and getting ready for transport. Any losses in this stage might be caused by management issues, namely overproduction or inadequate demand forecasting. Technical problems in the actual collecting of the produce due to damaging, harvesting errors or faulty machinery. It can also be due to human error or neglect during this stage. Crops left out on the field, not having the right quality, shape, size or colour can result in the crop being unharvested and lost. Finally factors that cannot be controlled like environmental damage to the crops (Magalhães et al., 2019)

Post-harvest storage, handling and transport

Lack of adequate storage facilities, spillage of produce, poor storage conditions or wrong temperatures can deteriorate the quality of the produce and results in loss of produce. Vegetables and fruits can get squished and are not sellable anymore. Over time, products can get mouldy or start rotting in which case they are filtered out. Livestock can die during transport or due to illness and are not suitable for slaughter anymore.

Processing and packaging

Inadequate packaging, improper handling and storage or inefficient processing techniques can result in loss of produce (Magalhães et al., 2019). Half-fabricates like minced meat are created by trimming from 'full' products, which results in other parts getting lost. Inefficient processing of fruits and vegetables result in edible parts getting discarded after poor separation from inedible parts. Quality control filters out lower quality produce.

Distribution and retail

Products near their expiry date or not living up to expected quality or weight are rejected by the retailers. Stores have limited time to sell the produce before it cannot be sold anymore and gets thrown away. Technical problems can lead to loads of food being thrown out at once. (Magalhães et al., 2019)

Public and household consumption

Food service locations and private homes are the final destination of the food in the food supply chain. The reasons for food waste at this stage is very different to the other stages as it is no longer due to management or technical inefficiency but made by poor consumer behaviour and decision-making (Magalhães et al., 2019). **This is the most relevant aspect of the food supply chain for this thesis.**

Food waste and food loss

Generally speaking, there are two clear main categories of wasted food in the food supply chain: Food loss and Food waste (figure 5).

Food loss

Food loss is edible food that goes uneaten at any stage in the food supply chain from the crop field to the supermarket. This covers the first three stages of the food supply chain. The official definition for this is "The decrease in quantity or quality of food resulting from decisions and actions by food supliers in the chain, excluding retailers, food service providers and consumers." (ISFT, 2021) This is for example the case when a crop is left/forgotten on the field or when environmental issues destroy part of the crops before yielding them. Or when it does not make it to the store for other reasons. (FoodPrint, 2024).

Food waste

Food waste on the other hand is defined as the following: "The decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers." (ISFT, 2021). Food waste can be a partly eaten product, something that has expired or a leftover meal that ends up in the garbage. The definition implies that food waste is a choice, made by consumers not to consume a product in time. The decrease in quality ultimately results in the product being thrown away without consumption, wasting the food that once was in a state of consumable quality. (ISFT, 2021). In this project the focus will be on food waste as this phenomenon can be reduced in the Dutch households.

Figure 5: Examples of food loss and waste

There are three main types of food waste distinguishable (figure 6):

Avoidable; foods and drinks that were edible at some point before disposal. These are the foods that have expired or that are not consumed. This is about 60% of the total waste (WRAP et al., 2013).

Possibly avoidable; these are foods that get discarded because of dietary reasons. Some people like it, other people don't. They do not have to be wasted. This can both be due to allergies or simply not liking something. Possibly avoidable food waste contributes to 17% of the total waste (WRAP et al., 2013).

Unavoidable; waste originating from food preparation, which was not considered to be edible in the first place. Examples of this food waste are egg shells, bones, skins of certain products (orange peel). 23% of the total food waste belongs to this category (WRAP et al., 2013).

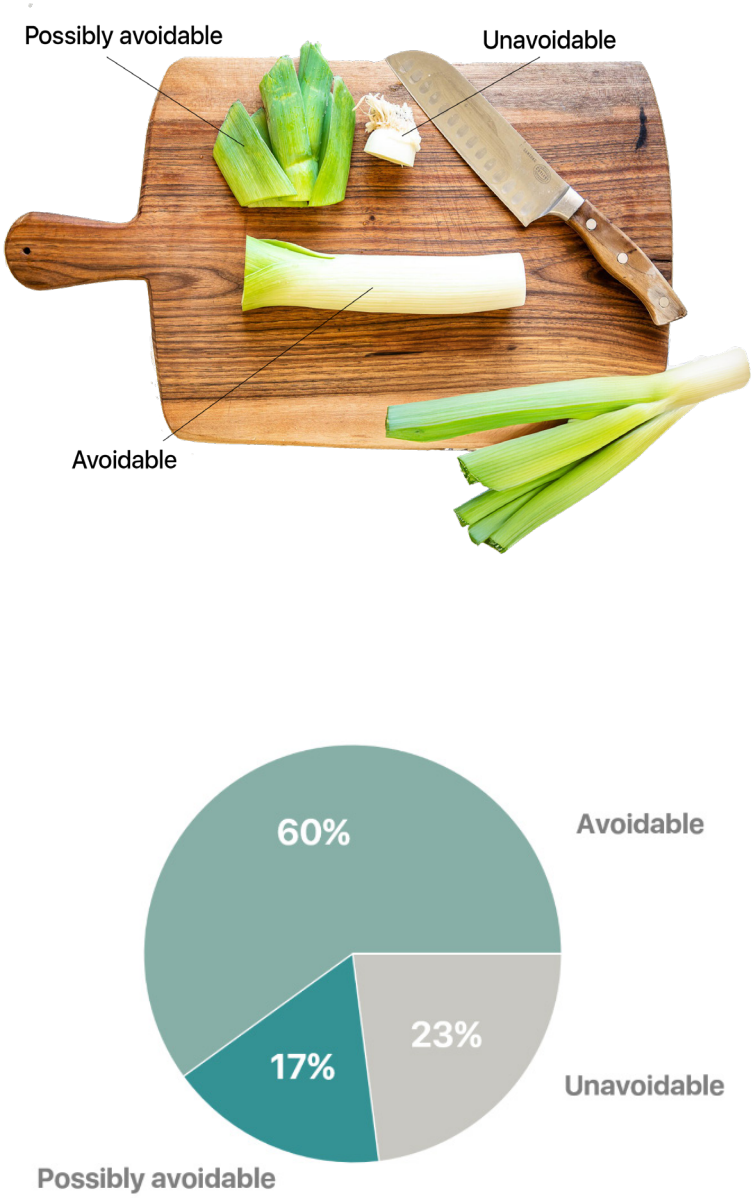


Figure 6: Types of food waste

Almost 80% of the total food waste can be categorized as 'avoidable' meaning that they have been disposed because of not using it before the expiration date or too much was prepared/cooked/served and thrown away as a result (WRAP et al., 2013). Avoidable is therefore not just food that is lost, but lost due to human actions and inadequate behaviour by which the food is lost.

Households contribute the most to the total amount of (avoidable) food waste. Every person in the Netherlands contributes to 33,4kg of food waste every year. This is 8,9% of the total amount of food bought each year. Even though the amount of food waste has reduced from 43,3 kg since 2015, there is still some way to go to reach the 21,6 kg goal of 2030. (Van Lieshout & Knüppe, 2022).

Why does food waste occur?

Food waste occurs when too much food is bought than can be consumed before the expiring date and/or when it is improperly stored before consumption (Koivupuro et al., 2012). Besides this, improper portion size can lead to serving too much food, and can result in leftovers portions. These is an extensive list of the factors that play a role in food waste. These factors give insight in why food might end up in the garbage instead of being eaten by the consumer.

Improper portion size / not saving / not eating leftovers

Some groups of products are more likely to be thrown away than others. Pasta and rice account for 5,0 kg of food waste combined every year (Van Dooren et al., 2020). From all bought produce of these two types of food, respectively 34% of rice and 23% of pasta gets thrown away. The reason this happens is because it is difficult to guess the amount needed for the meal. These products for example, absorb water whilst being cooked, changing their volume and also the precepted amount that is being cooked. Besides this, appetite can vary from moment to moment. Furthermore when these oversized portion do not get saved or eaten as a leftover, more food waste is generated (Stöckli et al., 2018).

Mouldy/Rotten

Inappropriate storage of leftovers and partly used ingredients can result in faster decay of quality. When the products decay to a state in which they are regarded as not usable for consumption anymore, they get thrown away as eating the food might result in a food safety hazard. This is not only the case with ingredients but also with leftover meals.

Use-by-date / best before date confusion

Confusion about the use-by-date results in products being thrown away while they are still edible for normal consumption (Stöckli et al., 2018). This is even more significant when the date is not easily findable on the packaging. Besides this, being too sensitive to these date labels make that people throw out food that is still edible because the package says it is overdue. (Stöckli et al., 2018).

Improper storage / poor storage management

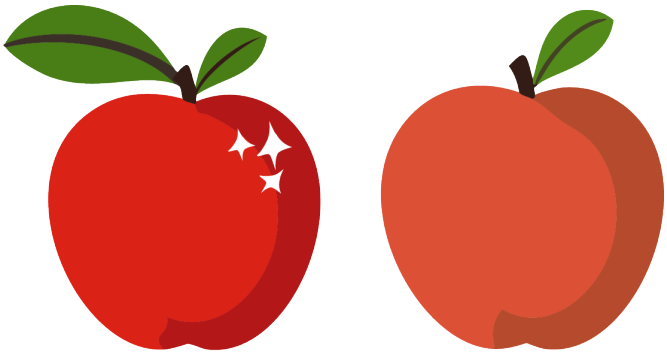
Not all products need to be stored in the same way. Lack of knowledge about the correct way of keeping different products in storage accelerates the decay of quality of the food unnecessarily. Products reach their maximum usage date earlier. Next to this if some products gets stored together they might accelerate the process of ripening, for example bananas produce gas that ripens avocados much faster. (Stöckli et al., 2018)

Uncertainty about product shelf life / estimating food edibility

Consumers struggle to identify when a product has gone bad. When odours start forming or discoloration happens, consumers throw the food away in anxiousness about the food safety. When there is doubt if the food is still edible, people tend to play it safe and not eat it. It often happens that consumers leave these products in their storage or fridge until it is certain that they have gone bad, which is usually the point at which mould starts forming (Van Geffen et al., 2019).

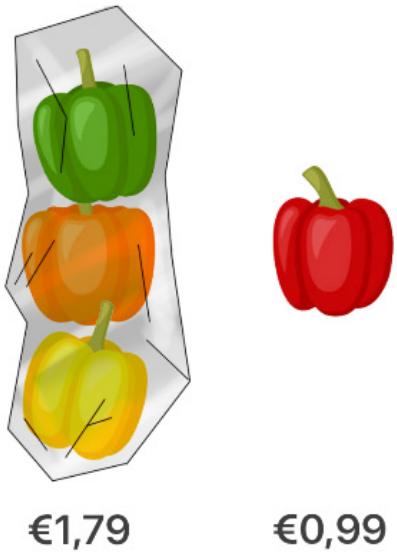
Forgotten ingredients / preference for freshness

Consumers often forget what they have in stock. This is because there is often no dedicated spot In the fridge to store specific items. Consumers organise their fridges so that it accommodates for the size of specific objects (Waitt & Phillips, 2015). That makes them buy more of what is already in their fridges, ultimately resulting in overstocking and not being used within the eat by date. Besides this, consumers prefer fresher ingredients over older ones. The freshwe ingredient will be favoured above the lower quality older product which results in the old one being disposed (Stöckli et al., 2018).



Buying food packages that are too large

Package size plays a very important role in food waste. Consumers tend to buy larger volumes of ingredients as a bigger package size is often relatively cheaper compared to smaller sized portions ('volume pack, family pack etc.'). This makes that the price of a multipack of 3 bell peppers is often only 80ct more expensive than a single bell pepper, whilst getting triple the amount. Even though a recipe asks for one single bell pepper, it is financially smarter to buy a 3-pack and try to use the other bell peppers in another dish (Koivupuro et al., 2012). These special offers result in overstocking and can lead to food waste if it concerns perishable foods that have a limited freshness. (Stöckli et al., 2018).



Inaccurate planning and shopping

Consumers tend to shop for groceries once or twice per week, depending on household size and available room for storage of products. The accessibility to supermarkets plays a big role in this problem. The further away the supermarket is, the more shopping will be done in one visit to the stores (Van Geffen et al., 2019). This also increases the inaccuracy of the shopping with a higher amount of waste as a result. By doing groceries far before the intended use day, plans can change a lot. In addition to this, the amount of appetite can vary easily. Besides that, produce can vary in quality which could result in the ingredients being fine when they are being bought, but when it's time to use them they can have gone bad. Another big problem is that life is very dynamic and plans can change suddenly. After a long day of work someone might not be in the mood to be cooking and decides to eat something easy or order food instead of cooking a meal. As a result ingredients that have been bought earlier will not be consumed on the intended day.

Availability and size of storage equipment

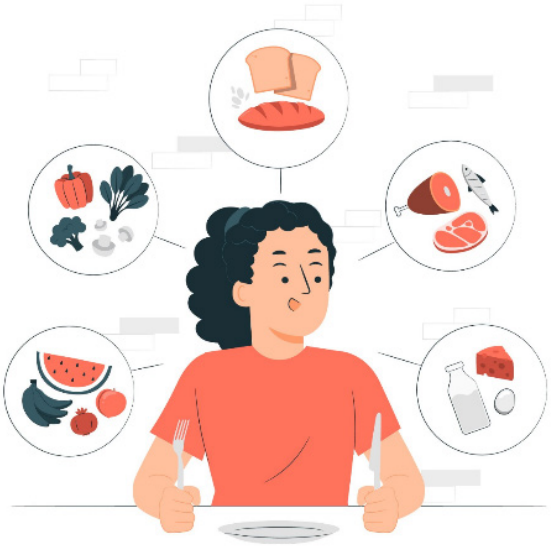
Having properly sized containers to save leftovers and other small ingredients increases the probability of saving the leftovers for a later moment (Van Geffen et al., 2019). Next to this, there must be available space in the fridge/ freezer to be able to store it for a longer amount of time before the food expires.

Cooking skills / equipment

Next to the normal waste of food, there is also a chance that inability to cook can result in food waste. For example when food burns during cooking, it will result in more waste. Consumers need to have some skills in the kitchen to prevent this from happening. Besides this occurrence, increased skills might also help to prevent food waste due to more creativity during cooking. With an appropriate amount of knowledge, it is possible to do more with food. More skills make it easier to make the food tastier and increases the chance of still being eaten. Having the right tools increases the probability of eating leftovers. Consumers who can be more versatile in the way they prepare their food tend to waste less. (Van Geffen et al., 2019).

Preference for variety

Research shows that consumers prefer to have variety in their diet. It is not preferred to eat the same meal on multiple consecutive days in a row. This reflects why leftover foods are thrown away when they are stored for too long. To try to mitigate the variety of consuming various foods, consumers store the leftovers for multiple days (Stöckli et al., 2018).



Malfunctioning equipment

This phenomenon does not happen often, but for example when the power goes out or when the fridge simply breaks down, large quantities of food become unsafe to eat and as a result get thrown out.

Food waste in the Netherlands

As said before, the average Dutch person is responsible for 33,4kg of food waste on a yearly basis. Four types of food make up for more than half of the total amount of produce being thrown away: Bread, pasta and rice (6.2kg); Vegetables (4.4kg), Fruit (4.3kg), Potatoes (2.8kg). The specifics about this can be found in figure 7. (Van Lieshout & Knüppe, 2022).

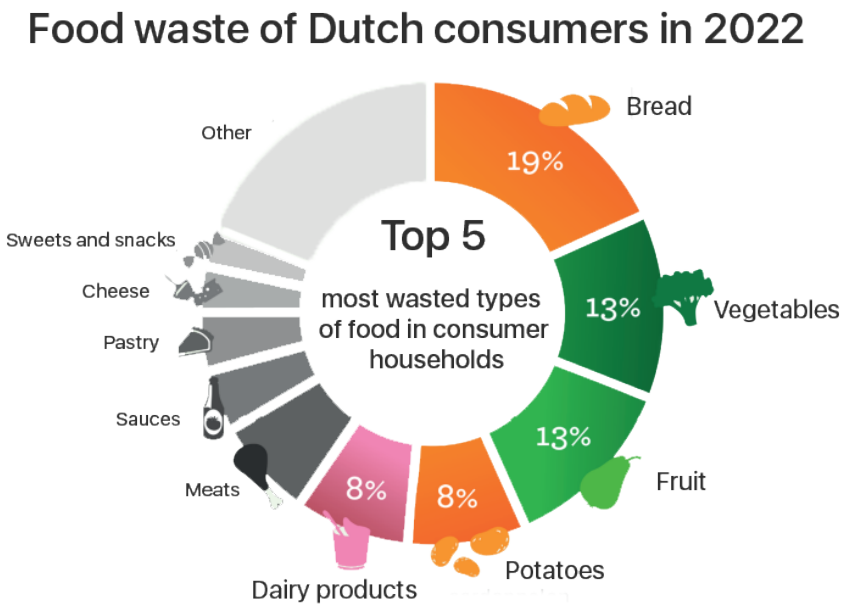


Figure 7: Food waste of Dutch consumers (Van Lieshout & Knüppe, 2022)

Next to the specific produce/ingredient, the amount of food that gets wasted is also highly influenced by the way it is kept in storage. Products that are frozen tend to be thrown out less regularly. These products get checked upon yearly or not at all, in high contrast to products that are stored refrigerated. Refrigerated products can be thrown out weekly or monthly, depending on the type of product (Janssen et al., 2017). Products from ambient storage (not cooled) are somewhere in between these numbers.

There are differences in the reasons why certain products are being disposed as waste, depending on their storage type. Products in the freezer get disposed because their expiry date has passed or the product was forgotten. The main reasons for getting rid of products in the fridge were indicated as the product actually having gone off and having prepared too much (Janssen et al., 2017).
Products that have a frozen version of their ambient or refrigerated counterparts tend to be thrown out less frequently. (Janssen et al., 2017) This suggests that frozen ingredients might play a big role in preventing food waste. Especially in the Netherlands, where most fresh ingredients are bought in a non-frozen variant. Encouraging consumers to opt for frozen versions of fresh/ perishable produce can play a big role in reducing food waste (Janssen et al., 2017).

Figure 8 shows all the routes that food can follow from being bought at the store till the disposal of the bought goods. This is the part of the food supply chain that has to do with consumers and their behaviour. This more zoomed-in part of the food supply chain will be focussed on during this project.

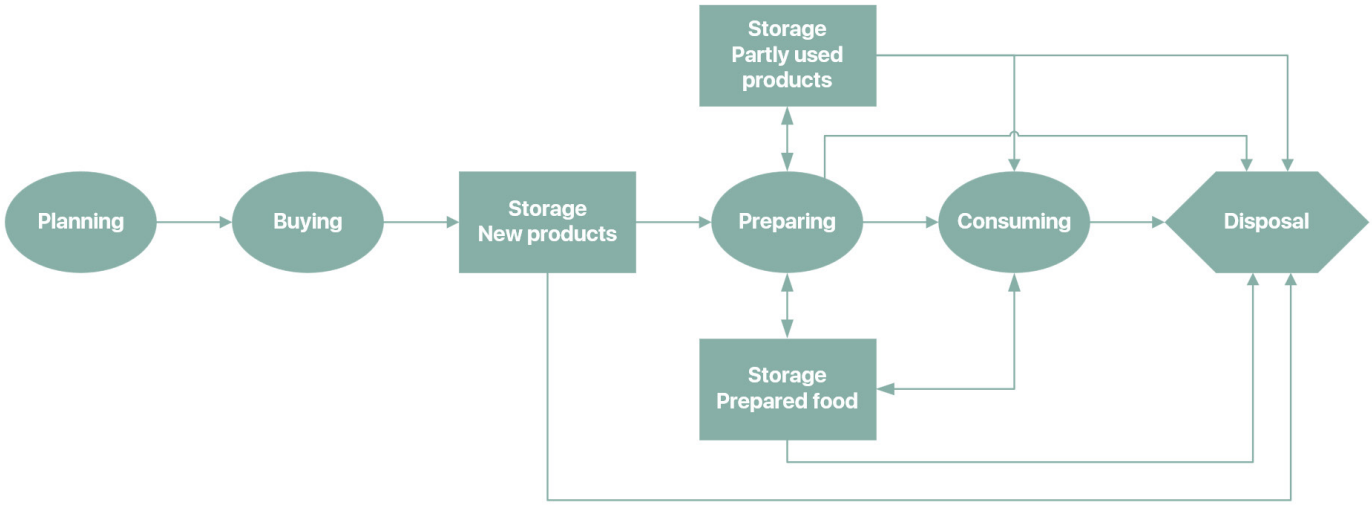


Figure 8: Food routes from buying to disposal

Demographics and behavioural influence

Everybody is responsible for food waste in some way. A study performed by Koivupuro about factors influencing household food waste in Finland showed that food waste decreases with age (Koivupuro et al., 2012). Higher age groups have significantly less food waste compared to younger age groups (Janssens et al., 2019).

In the Netherlands the most amount of food gets wasted by people in the age of 18-34, living alone or with one other person (Voedingscentrum, n.d.). In addition, families with children under the age of 4 are also wasting food more than other groups (Koivupuro et al., 2012). These groups waste between 16 and 30% of all food that is bought. The higher the age group, the less food is wasted. Besides this, females and elderly appear to be more conscious and aware about food waste, which results in them producing less food waste compared to males.

Finally, research shows that there is a relationship between the level of income and food waste generated in households. Higher incomes produce less food waste compared to lower incomes. This however contradicts different research by Koivupuro stating that lower incomes generate less waste as they are more conscious about their budget (Koivupuro et al., 2012).
The amount of food waste increases linearly with the number of people living in the household. So to say, a household of 4 people will waste more avoidable food waste compared to a single-person household. However, the waste per capita decreases with the amount of people living in the house, as visible in figure 9. This is due to the fact that less food spoils as an unit/package of an ingredient is consumed quicker by more people, so there is less chance that food will go bad (Koivupuro et al., 2012).

People that buy discount products or special offers (1+1 free), tend to waste less food compared to people that do not. An explanation for this is that these consumers often are more limited in their budget and do not want to waste money on food that will be thrown away. Who is responsible for grocery shopping is also important in understanding food waste. A study in Finland showed there is significantly more food waste when a female is responsible for the groceries (Koivupuro et al., 2012), even though they are more conscious about food waste in the first place.

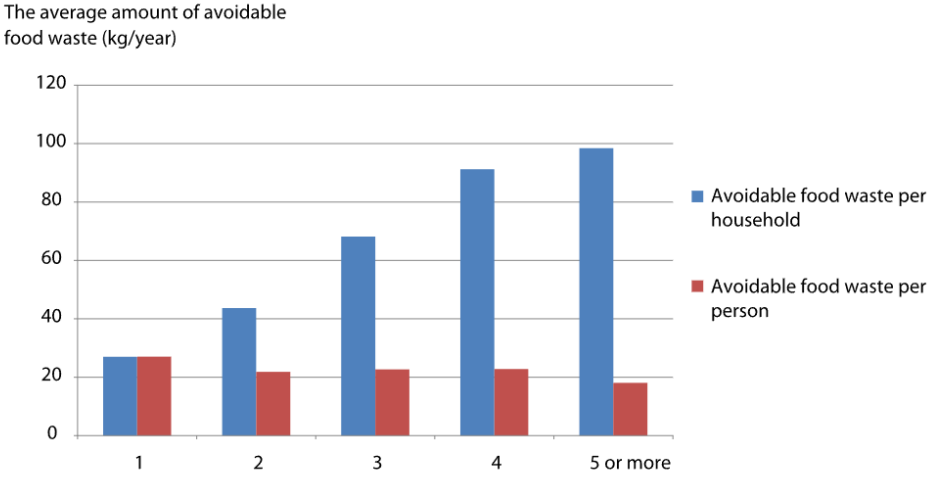


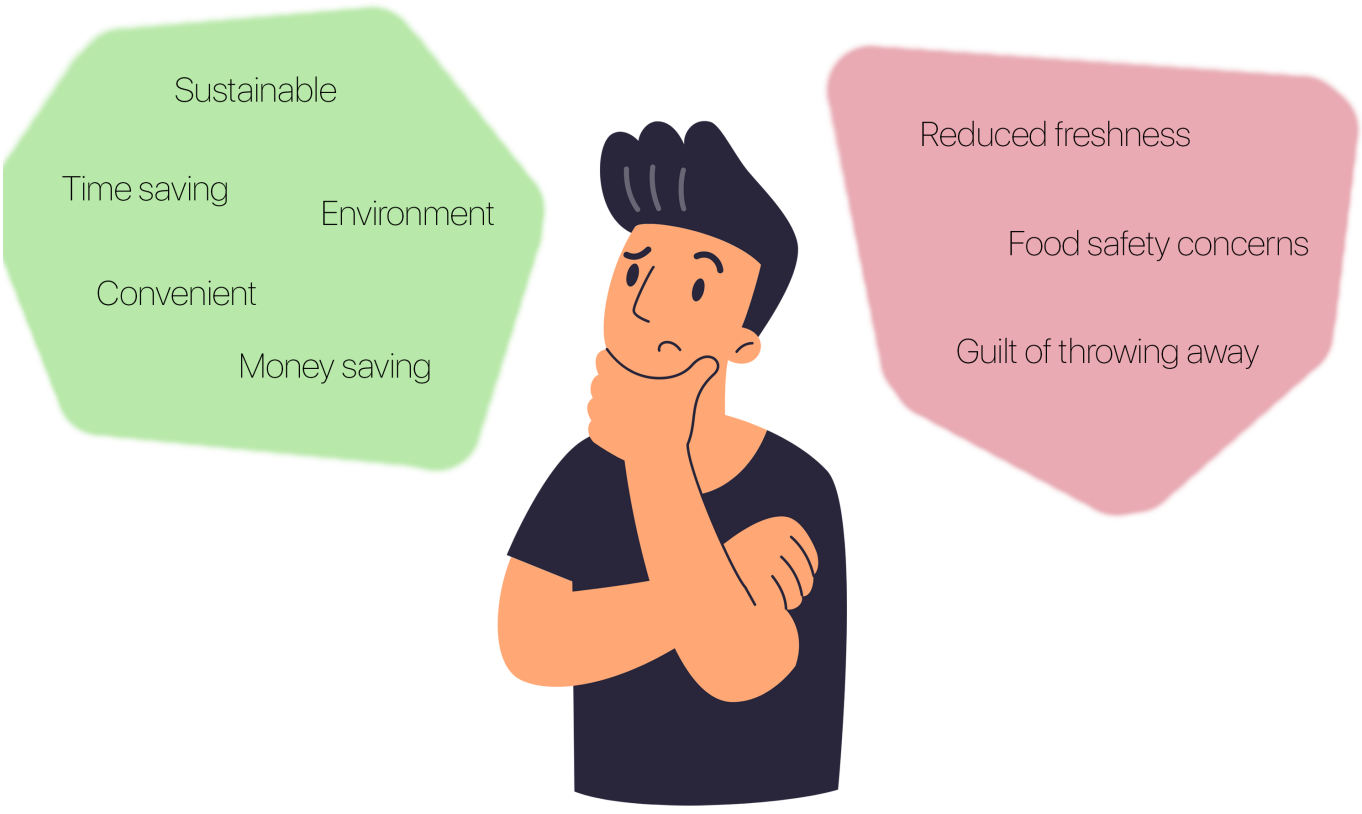
Figure 9: Food waste per household composition (Koivupuro et al., 2012)

Motivations, attitudes and values

Even tough food is wasted a lot in Dutch households, consumers tend to have a positive attitude towards leftover food and ingredients. Leftovers are often valued because of them being convenient in both money- and timesaving. These positive attributes make it worthwhile to save these leftovers and consume them even if they are perceived to be less fresh and vulnerable to contamination (Waitt & Phillips, 2015).

The social beliefs make it hard to throw away food, so people often re-refrigerate leftovers to use them in a later stadium. However, it happens that we find excuses to throw away food once we forget about them. Consumers sometimes know that they will not be using the food in the future but save it for later anyways, often resulting in it going bad and being thrown out with the garbage. They prevent throwing out the food because of the guilt of doing so (Quested et al., 2013).

Food waste is also considered as an unnecessary waste of money. In research of WRAP, 75% of all respondents indicated that the possibility of saving money influenced them somewhat or a lot in the reasons to prevent food waste (Quested et al., 2013). This could mean they can spend money elsewhere in their budget instead of spending it on food.
Besides the reasons named above, the environmental impact and sustainability is also influencing the way people try to avoid food waste.



Changing behaviour of consumers

To effectively tackle the problem of food waste in Dutch households, it is important to know how to influence the individual. Simply designing a product will not be sufficient, as the product needs to change the behaviour or accommodate to the behaviour of consumers too. Behavioural change is achieved when the consumer is taken out of their standard behaviour and can actively decide to do something. Behavioural change occurs when people are pulled out of their autopilot decision-making.
By changing the behaviour of consumers, either by preventing or stimulating specific behaviour, it is possible to change the way in which consumers tackle food waste.

COM-B theory

Behaviour is determined by three main components. Capability, Opportunity and motivation (figure 10) can be used to plan interventions in behavioural habits. It uses components of behaviour that have to do with the nonconscious decisions made based on impulsivity, habit, self-control, learning and emotional processing (Pinder et al., 2018). Capability includes all internal factors that contribute to an individuals' ability to perform a specific behaviour. Opportunity addresses all external factors that make the behaviour possible or help to prompt the behaviour on the spot (Pinder et al., 2018). Motivation focusses on having individuals motivated to express the behaviour that is wanted. Together they make a behavioural change possible.

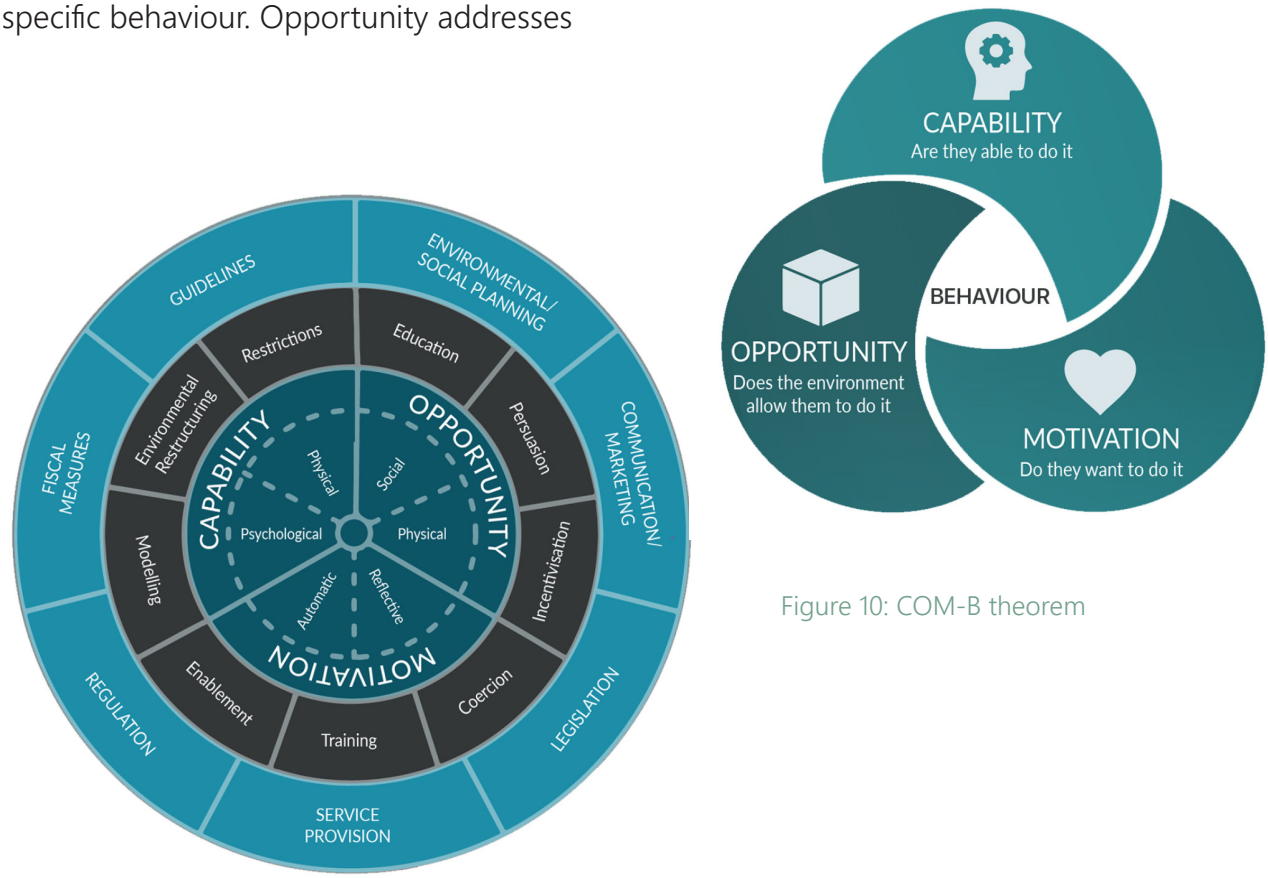


Figure 10: COM-B theorem

Behavioural interventions

The COM-B theory of behavioural change can be achieved by making use of behavioural interventions. These are interventions that are addressing either one or more of the 4 pilars of the COM-B model. Many interventions are possible to create a behavioural change (figure 11) in the mass. The nature of the various interventions are differentiated in two main groups: Antecedents and Consequences (Stöckli et al., 2018). Antecedents set the tone, suggest a specific behaviour and give an example without any further involvement, whilst the consequences generally strive for behaviour change which can result in a negative or positive reaction after a certain behaviour is performed. These interventions with rewards and penalties are currently very rare in the food sector.

Antecedents have four subgroups. They can be informational, prompts, modelling or commitment related. Informational antecedents aim to increase skills and knowledge with the user. This is often done through education or training of a certain desired behaviour. Prompts are verbal or written messages, which stimulate and remind people to do specific behaviours. This can for example be a sticker or sign near a garbage bin to recycle properly. With modelling the desired behaviour is demonstrated and people should copy said behaviour. These can be infomercials or other types of video instructions. Commitment focusses on the promise that people can make and agree to specific rules. (Stöckli et al., 2018).

There are 3 different possibilities in which a consequence can be an intervention. Feedback is a way in which information about the performed behaviour is shown to the user. It shows the consequences which this behaviour might introduce. Rewards can work as an intervention by being a positive consequence to stimulate specific behaviour. Users will want to perform the desired behaviour to gain this reward. Finally, there is the penalty intervention. Penalties are negative consequences that a user will face when displaying certain undesired behaviour. (Stöckli et al., 2018).

Behavioural change is currently most often achieved by making use of informational interventions in settings where the behaviour must be changed. These informational interventions are most used to make the targeted group aware of a certain topic by educating and training them. Even though this is the dominant way of intervention, it is also the one with the least effect. According to Stöckli; prompts, modelling, rewards and penalties will have the most substantial effect on changing behaviour in consumers.

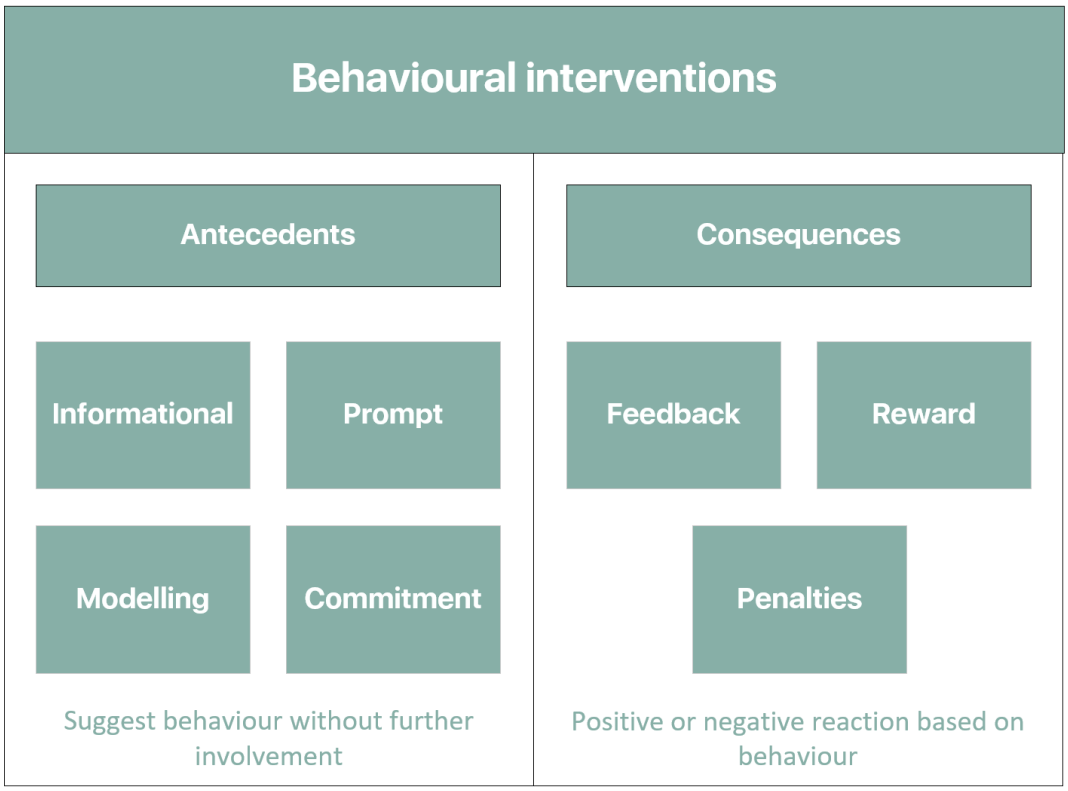


Figure 11: Behavioural interventions (Stöckli et al., 2018)

Nudging

Behavioural change models and frameworks suggest that using nudges that are tangible, relevant and beneficial have the most probability to be a successful initiative to prevent food waste. Nudging alters the environment to steer people in the desired behavioural direction. It involves subtly influencing individuals' behaviour to align with societal beliefs. The subtleness of nudging can change behaviour of individuals without restricting their own choice making or prohibiting certain behaviour (Vandenbroele et al., 2019). Because nudges target the individual self, there might be effects possible like the way pictures on cigarettes make people more aware of the risks of smoking. They are unobtrusive and trigger responses without much cognitive effort (Vandenbroele et al., 2019). Nudging differs from traditional informational campaigns or education which try to convince changing their attitudes by stating rational arguments. Nudging is more subtle and requires less cognitive effort by targeting the fast and automatic response system.

Nudging is already used in food-related situations. For example the way products are positioned in the supermarket, their visibility or what the packaging looks like highly influences the customers' decision-making in buying a specific product (Vandenbroele et al., 2019). Food consumption is a highly habitual and unreflective process, which makes nudging a good way to achieve change in behaviour. However, this is mostly achieved in public environments and targeting nudging in private homes is very challenging (Lehner et al., 2016). Therefore nudging is used in supermarkets instead of homes where the effect will be greater and increase effectiveness.

Nudges are a relatively easy and inexpensive way to establish behavioural change in consumers. The downside of nudges is that once the intervention is removed, the behaviour will go back to the pre-intervention state (Hertwig & Grüne-Yanoff, 2017).

Boosting

In contrast to nudges, boosting focusses on improving competence of people in making their own choices. Boosting provides people with tools resources and knowledge to make their own decisions. Boosting is targeted to change individuals psychological processes or behaviours, facilitated by enhancing their skills, capabilities or motivations to change their behaviour (Hertwig & Grüne-Yanoff, 2017). An example of this could be a financial incentive to quit smoking or to take the bike to work instead of commuting by car.

There are two main categories of boosts. The first one is a short-term boost, fostering a competence that is limited to a specific context or situation. The second category is long-term boosts, these permanently change the cognitive and behavioural acts of a person that can be engaged across multiple situations (Hertwig & Grüne-Yanoff, 2017).

The nature of the boosts can range from interventions that require little cognitive effort and time to boosts that require training, effort and motivation to perform certain behaviour (Hertwig, 2017).

Boosting requires more effort than nudging and tries to reflect on the consumers' depicted behaviour. Whereas nudging targets the subconscious and automatic behavioural choices passively, boosting tries to actively change the decision making by letting consumers overthink the situation and gives them the capabilities and incentives to do so.

These two types of intervening in the decision making process are very different but one is not better than the other per definition. It will depend on the specific application and conditions which strategy will perform better (Hertwig, 2017).

Existing efforts to prevent food waste

Artificial intelligence

In recent years Artificial Intelligence (AI) has gotten more and more advanced and used in everyday activities. The recent surge in AI applications throughout everyday life, results in more and more tools being developed that mitigate the problem of food waste amongst consumers. Conimex for example has built an AI camera tool which identifies the ingredients in a picture made by the phone's camera, and consequently gives recipes that includes these ingredients as a suggestion to cook. Other examples are 'DishGen', 'Meal Practice', Meal Genie, ChefGPT and Let's Foodie (specific for integrating leftovers in dishes). This new technology helps partly used ingredients to get a second dish to be featured in, and get wasted less often.

The food industry has taken interest in food waste in households too. Hellman's, known for its mayonnaise, came up with the idea of so-called Flexipes, which should make consumers more flexible in their way of cooking.

Intelligent packaging techniques

Suppliers in the food chain make use of 'Freshness indicators'. These are markings on product packaging which tell whether the product has been handled like it should be with the correct temperatures. It is a simple process of colour change to show when a product has been outside of refrigeration for too long or any other product-specific storage conditions. There are multiple variants of these indicators. There are indicators that monitor time-temperature (TTI), freshness (FI), leaks (LI) or pH-value (PHI) (Ma et al., 2022). The colour changes once this threshold is surpassed and visually notifies that the product might not be safe for consumption any longer. These indicators give a quick overview of the quality and safety of the product.

Intelligent fridges

Intelligent fridges are kitchen appliances that make use of IoT-technology to extend their functionality beyond solely refrigerating products. These fridges include functions to monitor and extend the shelf-life of products inside, but also functions to help consumers in food-related tasks like a real-time data of the stock during grocery shopping and cooking. (Liegeard & Manning, 2019)

The system can make use of RFID technology or barcodes to retrieve information about the product that is being stored inside. The fridge can notify the user when a product is about to expire but can also optimize the fridge environment/ climate to prolong the shelf-life of the product. Cameras and sensors inside can monitor the food packages and the state of their content. (Liegeard & Manning, 2019). Implementation of touch screens enabled these systems to have an intuitive interface for the user to interact with. Additional features like keeping track of shopping list and recipes for cooking can be displayed. However, these fridges are not for everyone. The technology used in the intelligent fridges makes that they have a higher price compared to 'conventional' fridges without IoT applications. Manufacturers like LG and Samsung offer variants to the mass market. Other problems with these products are that the applications used are manufacturer specific and often outdated (Wu & Chuang, 2017).

Physical tools

The Dutch voedingscentrum has multiple tools on offer that help consumers with making more effective choices during the preparation of meals. They provide tools for measuring how much pasta and rice should be cooked "Eetmaatje", recipe applications or tools that help to identify where to store certain products (Voedingscentrum, n.d.). These are just a few examples in a series of tools available to the market.

Smartphone / online applications

Smartphones are extremely versatile devices that we carry around every day. The amount of information we receive through the small display on a daily basis is enormous. Smartphone applications are therefore a very easy-to-implement way to make people conscious about the food waste problem. Supermarkets like Albert Heijn have tools built into their Apps which help consumers identify what to cook based on their own input of ingredients, other similar tools are 'Flexipes' by Hellmanns, 'SuperCook' and 'Slim koken'.

The big problem of smartphone tools is that they are easily forgotten, which makes their effectivity lower compared to physical tools.

Campaigns

Campaigns like 'samen tegen voedselverspilling' are initiated to connect various stakeholders in an effort to reduce food waste. These can be NGO's, Governmental departments and businesses. Their combined knowledge and efforts try to inform and change the behaviour of consumers and make them more aware of what they can contribute to the problem.

Conclusion literature research

The food supply chain knows a lot of loss and waste of food. The last stage of the food supply chain are the private households where food is lost due to consumers' behaviour and poor decision-making skills. Food waste in Dutch households is a big problem which needs to be reduced in the near future. There are numerous reasons why foods get wasted in the current system and addressing these problems will help reduce the food waste in the Netherlands.

Changing the behaviour of consumers has the most impact on resolving the food waste problem in the Dutch households. By addressing the COM-B model we can change the way consumers act to establish a change in their behaviour. The consumers must be capable, have the opportunity and motivation to change their behaviour. Designing a product that allows them to have the capability and opportunity to change their behaviour will make a big difference as the motivation is already present due to the social values present in the society. This behavioural change can be stimulated and supported in multiple ways: Behavioural interventions with antecedents or consequences, nudging or boosting. These actions will help to make people even more aware of the problem and subconsciously help them change their behaviour.

Current efforts in the battle against food waste are not enough to combat the severity of the problem and more is needed to make a change.

Chapter 2
Target group interviews

This chapter dives deeper into the interaction between the target group and the food they buy. The insights and knowledge of the target group are extremely important in designing a solution to the problem. What is their experience and why is that so? Their habits and consumption patterns influence the amount of food waste generated greatly. Interviewing these groups gives new insights in the problem and takes into account what they would like to see. Three interviews are conducted to generate more specific findings and deeper knowledge about their behaviour. The first interview focusses on their own food behaviour. Secondly, food diary research will give more specific insights into what food is wasted and why this happened. Finally a third and final interview is conducted, focussing on the usage of leftovers, the values and opinions on this topic.

User research 1: Food behaviour

The previous chapter shows all the reasons why consumers tend to throw out their purchased goods. This chapter will focus on the reasoning behind certain behavioural actions by consumers and what we can learn from some examples.
For this study, a questionnaire was sent to the focus group in bulk for as many responses as possible. By doing this, the goal is to rectify some contradicting sources and get a better view upon the behavioural problem itself. Later on a food-diary survey will be conducted with a smaller sample size to get more insights into the specific actions and decisions that might lead to food waste or the creativity that can prevent this from happening.

Focus group / Participants

As described in the study performed by the Voedingscentrum, there are clear demographical groups (figure 12) that have a greater contribution to food waste in general. These groups are the single-person households, couples and young families with children under the age of 4, have significantly more food waste compared to other groups in Dutch households. Because of this, the target audience is set to be between 18 and 40 years of age, living on their own or in smaller sized households.
Besides this, the interviewed participants had to have a Dutch nationality. Reason for this is that other nationalities have different (food) cultures and can have different behaviour, making it difficult to distinguish a pattern.

Focus area

The study will focus on the totality of behaviour concerning food consumption. This has mostly to do with the fact that being flexible in cooking starts by making plans for doing groceries. The realisation that some foods need to be consumed before they expire make that it is also needed to look for reasons for them do be disposed, if the reason why it is not consumed is visible, there might be room to address this specific waste scenario. Finally, even though the behaviour of the consumer in the supermarket is not the focus of this assignment, it is very valuable to know the different behavioural acts that lead to decision making in food consumption.

Household composition
Single person
Couples
Young adults
Young families with children

Age
18-40

Nationality
Dutch

Figure 12: Target group

Research questions

1. Do perceived cooking skills influence the amount of food that gets wasted?
2. What is the shopping behaviour of the target group?
3. How do consumers use leftovers and how do they improvise while cooking?
4. What are their current efforts to prevent food waste?

Methodology

This research was performed by means of an online survey in google forms. This was done for the collection of bulk data within a relatively small timeframe. All participants had the Dutch nationality and were part of the targeted age group of 18-40 years old. They had various household compositions, being single-household, couples, small households and young families with children. By having this split gives a broader a more complete perspective on the phenomenon.

During the survey, the participants had to answer questions about their shopping behaviour, general food waste behaviour, their storage behaviour and some general questions. These were not only closed answer questions but also left the opportunity to add more possible answers and follow-up questions were used to get their reasoning behind some of the shown behaviour.
Following the initial survey, the participants were offered the opportunity to participate in a so-called food diary research. Participating in this research was voluntary and was performed some days after the initial survey was launched. About 1 out of 3 participants of the initial research agreed upon participating in this follow-up research. During this food-diary research, participants were asked to keep track of their stock, groceries and what they were disposing for a week. Besides this quantifiable data, also reasoning is asked to get insight in the reasoning for their choices.
This food-diary was sent to the participants via an online form which the researcher sent messages for to the mobile phones of the participants at +/- 20.00 every evening for a week.

A full list of the questions used during the research can be found in Appendix A.

Results user research 1

General demographics

The questionnaire was completed by 26 participants. A little over half of these participants were in the age 18-24. 13 of the participants were living in a single-person household. 1/5th of all the participants had one or multiple children. There was a wide variety in the (combined) incomes of the households, they ranged from less than €2000,- a month to more than €7000,- a month. 34,6% of all participants had an income of less than €2000,-. This was likely due to the fact that they were students and have limited time to work next to their education.

Doing groceries

Over 80% of all participants were responsible for groceries in their household. This is partly explainable by the composition of their households, with a lot of single-person households among the interviewees. This will likely increase their accuracy with specific behaviours in the following questions. Groceries are done multiple times a week in general. 2-3 times a week was the most common frequency of grocery shopping being done as visible in figure 13.

46% of all respondents check their stock before going to the supermarket sometimes, but in general they always check. 34,6% always check their stock and 19,2% did it sometimes, but not in general.
The most reoccurring reason for checking stock was so that the participant knew what to buy (14x), to not unnecessary double up on stock (5x), reduce waste by cooking with what is about to expire (3x) and to save money (2x).
People that did not check up on their stock gave the following explanation for this. "Because I am the one responsible for both groceries and cooking, I just know what I have in stock so there is no need to check it again.". Another respondent remarked that schedules change all the time and that it is difficult to know when they'll be eating home.

About ¾ of the participants said to always make a shopping list before going to the supermarket. The other quarter did it sometimes and one person did not make shopping lists at all. The motivation to do so can differ greatly. Most participants did not want to forget anything (9x), did it because of increased efficiency in the supermarket (8x), buy the right amounts (5x) and not wanting to buy unnecessary things (3x). Reasons not to make a list included looking specifically for discounts, being flexible in what they were going to cook (inspiration (4x)) or it was too little to make a list.

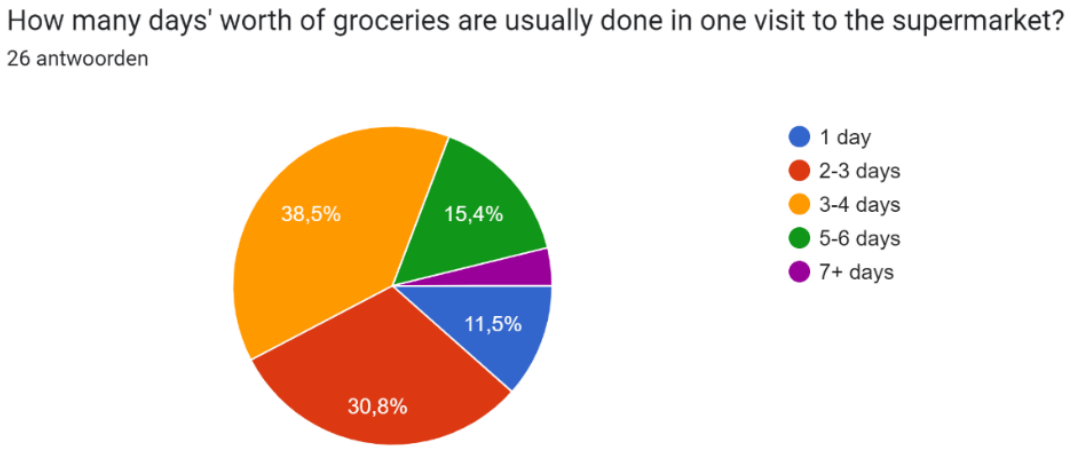


Figure 13: grocery shopping behaviour

When a specific ingredient is out of stock in the supermarket, 50% of the participants would use another ingredient to replace the original ingredient with. 5 respondents said they would leave out the ingredient, 3 would go to another supermarket and 2 would eat something completely different.

When ordering food at an online supermarket, for example Picnic or Flink, they buy product with long shelf-life to reach the minimum order value for delivery. Pasta, rice, toilet paper and snacks were mentioned as products that would be added to the order to reach the value.

General food waste

None of the participants would throw away open products without checking for edibility first. The "best before" date is checked and they look at the products first; 88,5% of all participants will do this. Smell is mentioned often too (73,1%). Besides this the product information is also checked regularly. Less than half of the respondents said to check by tasting or checking the texture of the food. Leftover meals are thrown out most often (53.8%) from all food that gets thrown away. Bread, fruit, vegetables and dairy products completed the top 5.

There is a very distinct split opinion about leftovers. Most people love them but others are more neutral in the opinion. Most times people try to eat small leftovers as lunch. Bigger full portions are saved as a meal for one person. Even though they get saved, they get thrown out a lot after some days due to decreased quality and freshness. Besides this there are multiple mentions about meal prepping in which people consciously cook more than one serving to have multiple cooked meals in their fridge. It saves them time and is really convenient when living in a single person household.

More than 65% of the participants said to save leftovers no matter how small the portion would be. Almost 20% would try to eat it anyways if it was too small of a portion. 15% would throw it out if the portion was not sufficient for a meal. Concerning leftover ingredients the following was learned from the questionnaire. If there is half an ingredient left after cooking dinner, the majority of people save it up for another dish later in the week. However, there is also a group that always uses the whole ingredient in the dish. Only 2 participants acknowledged that they would throw it out in the garbage. One person used the ingredient as snacks during the week.

Hotspots of food waste

The 3 pain points of food waste are mostly the fridge, fruit basket and normal cabinet. Most interesting are the findings about the fridge (mentioned 16 times) and the fruit basket (mentioned 8 times) . The fridge is the place where sensitive foods get stored or the place where consumers try to prolong the edibility of the products inside. However, due to the design of a fridge, food gets wasted here most often. Because the produce is inside the fridge, the visibility of the product decreases. Once the fridge is shut there is no visual control possible and stock is easily forgotten. Products tend to get on a second row behind other products and are easily missed at a quick glance, or when not actively looking for the product.
The location of the products in the fridge also results in more food waste. Products in the line of sight are easily visible whilst produce in the vegetable drawer (most often in the bottom of the fridge) are easily looked over.
Fruit baskets contribute to food waste as well. As the fruit basket is usually not in sight due to placement elsewhere in the kitchen (e.g. dinner table, countertop, on top of other appliances) the visibility of the produce decreases. The consumers actively have to take a look at the fruit basket to notice that fruits have gone bad. Another reason for this is that fruit baskets often have fruits lying on top of each other. The lower fruits therefore get pressed down which can decrease their quality. One of the participants mentioned that some fruits influence how fast other fruits decay, for example bananas give off a specific gas which ripens other fruits more quickly.

Skills in cooking

One of the research questions was to find out if (lack of) cooking skills could influence the amount of food that gets wasted in the households.
The average score that the participants gave themselves for cooking skills was 3.7 out of 5.
Opinions about if this could influence the amount of food that gets thrown away varied somewhat.
On the one hand people were confident that their perceived (good) cooking skills allows them to be more creative and incorporate other ingredients. Their knowledge about food in general gives them ideas about what is possibly tasteful when combined. Good cooking skills also allows them to make the food taste better and this makes them want to save leftovers more often. It also results in them being able to estimate right portions compared to lesser cooks, which result in less overcooking in general.
On the other hand, less skilled cooks mention to be cooking within their level of skill, which prevents them from making difficult dishes and there will be less chance of ruining the food. If the food tastes bad it increases the probability that the food will be thrown out as garbage.
Higher rated cooking skills generally gave a more positive view on how that could prevent food waste. Lower own perceived cooking skills are more negative towards how this influences the amount of food that gets wasted.
Besides this, lower cooking skills result in more usage of recipes. Higher scores tend to use them less frequently.

Current efforts in limiting food waste

The battle against food waste food waste starts by knowing what the current efforts are that consumers already make in everyday life. According to the questionnaire, the most reoccurring effort is simply not buying too much and using what is already in stock.
Freezing food to extend the lifespan of the product is mentioned too. This mostly happens to products like bread. After a follow-up question it became apparent that this behaviour is mostly due to discounts in which it is favourable to buy multiple loafs of bread at once. To keep the bread fresh and mould-free it gets frozen.
Portion size is something that is being used as a strength against food waste as well. This does not only apply whilst cooking, but also during grocery shopping.
One of the questions was about getting insight in why certain products are bought frozen instead of fresh. Frozen products are bought because they are generally cheaper compared to their fresh counterparts. Their prolonged shelf life makes it easier to keep it in stock and/or use smaller portions. Besides this the frozen goods are often pre-cut so it makes it easier for the consumer to use them. The quality and freshness is generally perceived as the same or sometimes even better. A small portion of the respondents said not to use frozen ingredients in general.

Using the fridge

Consumers tend to have a somewhat specific way of organising the fridge. Not everybody keeps a high structure in the fridge though. This is in this sample group also due to the fact that most students share a fridge and it simply has to fit all the products. Products or also double as students do not always share their groceries, resulting in multiple packages of various products in the fridge simultaneously.
Others have specific placements for some products based on the space required. Sauces are often on top as they have a small footprint, vegetables and meat in the bottom in the drawers. The organising of the fridge helps to identify when certain products are near their best before date.
The placement of products is therefore highly depending on the size of the product and the space that is available in the fridge.

Fresh packages

Fresh packages are bought because they are considered to be easy, convenient and a great way to discover new recipes or get ideas what to cook. One of the key aspects that consumers like is that the content of the package is tailored to the amount that is used in the recipe. For example, it will have half a cabbage instead of a whole one which might not be used.
Problems however are that it depends on the dish whether the portion is correctly sized, which results in more ingredients being bought. They are also considered to be expensive and sometimes it is questionable how 'fresh' these packages really are. Besides this, the packages often require you to buy other ingredients separately, which makes it an incomplete meal. When living in an one person household the packages can be too large, as they are mostly sized for 4 persons. Depending on the size of the household and the appetite of the consumers it might not even be enough for 4 persons but rather 3.

Premade dinner

Premade dinners are bought when there is a lack of time to cook. They are considered a convenient alternative to cooking, but it is not preferred as it often is unhealthy and lacks taste. They are also expensive in relation to the nutritional value they provide. There is however a difference in frozen premade dinners and semi-fresh premade dinners (like steam meals). These semi-fresh meals are perceived as the fresher and healthier option.

Creativity in the kitchen

To accommodate creative cooking it is valuable to know how people are currently using their imagination to come up with ways to use leftover produce. Besides the step of identification what should be used, it is critical to know in which cuisines the ingredients are common and thus usable.
Italian dishes like pastas are commonly used to incorporate different ingredients and experiment with flavours. 17 out of 26 candidates specifically said pastas are easy to be creative with, whilst 21 out of 26 people mentioned Italian cuisine in general.
In addition to this, soup is also considered to be category of food which allows some creativity. This is also due to the mindset that blended food offers the possibility to include lower quality ingredients, as they get pureed anyways. Finally a lot of ingredients are able to be used in Asian food. The Asian cuisine has a wide variety of possible dishes in which the ingredients can be used. As long as there is a base with good spices and ingredients like coconut milk, a lot of ingredients will find their way into Asian food.

Figure 14: Creativity in the kitchen

Conclusion user research 1

How do consumers use leftovers and how do they improvise while cooking?

Leftovers are seen as welcome and efficient time-saving meals when consumers do not fancy to cook for an evening. Especially in single-person households this saves a lot of time, not having to cook every day. When portions are too small for consumption as a dinner, they get eaten as lunch, or they will get additional ingredients to make it a sufficient meal.
One of the identified downsides of leftover meals is that the quality might be lower than the consumer would like when eating a meal, due to it being less fresh. Because of uncertainty of the quality, these leftover foods often get discarded due to food-safety concerns. Even though the food safety is checked by smelling, looking and other sensory tests, the gamble is not taken.
Specific cuisines are often used to incorporate leftover ingredients and leftovers in general. Mainly Italian cuisine and Asian cuisine offer high potential due to the variety and diversity of tastes and ingredients. Soups are used to use lower quality foods as they get blended anyways, so texture is less important.

Do perceived cooking skills influence the amount of food that gets wasted?

Perceived cooking skills do influence how much food is getting wasted. When people are more sure of their own skills, they tend to be more positive that this can prevent food waste in general. This is due to the fact that they can be more creative with what they have in stock and know how to incorporate it in dishes. Besides this, they tend to be better at estimating portions which result in less leftovers.
When people are less sure about their skills they make use of recipes more. Higher skilled cooks make less use of recipes and use them less often, or only as an inspiration source in deciding what to cook.

What are their current efforts to prevent food waste?

The consumers try not to build up too much stock of inventory that has a limited shelf life. The general thought is, what is not in stock cannot expire. Besides not buying too much, they try to use what is already present in their kitchen. Consumers actively use their cooled appliances to extend shelf life of products that tend to go bad quickly. Bread for example gets frozen when multiple breads are bought at once, just like leftover meals that will not be eaten in the near future. That said, consumers struggle to identify when the leftovers will be eaten exactly, making that part of it gets discarded anyways because of simply forgetting that they exist. The result of this ignorance is that the food goes bad by the time it is remembered to consume it.

What is the shopping behaviour of the target group?

Shopping is done on a regular basis with most people going to the supermarket 2-3 times a week, making it possible to be flexible during cooking by getting additional ingredients from a store. The high amount of shop visits also influences the amount of stock that the consumers have in their homes at all time.

User research 2: Food diary

Following up to the first user research, a food diary research was performed to get more detailed information about the 'actual' behaviour of the participants compared to the questionnaire. During this research, the focus will be on the behaviour during dinner primarily and secondarily on lunchtime activities. Breakfast is excluded from the scope as it is unlikely that leftover meals will be used in the morning. The objective was to get insights for a whole week in what was eaten during dinner, what was bought and what was discarded in a household. Participants of the first research had the opportunity to leave behind their contact details to participate in this research. As the initial response was not as high as expected, more people were asked to participate in the research. The target group audience was enlarged to 18-40 year old participants to increase the sample group. Additional participants were found by asking friends, family and other connections.
Every day around 20.00 a text message with the link to the online form was sent via WhatsApp Messenger to all participants. This time was chosen to accommodate for different dinnertimes that the participants might have, too early and it will be ignored/forgotten, too late and they might forget some specific information.

The online form was structured in 4 parts, where the participant could indicate what their dinner activity had been. They could have cooked themselves, eaten leftovers, had take-out/premade dinner/store-bought food or they could not have eaten at home. Based on their answer the online form would direct them to another part of the form.
After their dinner-specific answers they all were redirected to the same parts again. Questions about their groceries, how they used leftover foods and what they threw away were asked accordingly. Finally they had to upload a picture (figure 15) of what their fridge looked like. This was mainly done to be able to identify specific products and possibly see a structure arise from the pictures.

An empty version of the form can be found in Appendix B.

Figure 15: Participant fridge pictures

Results user research 2

General

In total, 13 people participated in the research, but only 10 participants fully completed the week. Even though 3 of the participants did not complete the full week, their data was used anyways as a more elaborate dataset always gives more insights. In total the data of 79 days was collected amongst the 12 participants. From all respondents, only 3 participants had one or multiple children, making the percentage of households with young children about 20%.

Cooking and consumption behaviour

The responses indicate that half of the dinner meals in a week is cooked on the day itself. 25% is consumption of leftovers of earlier made meals and the other 25% is eating somewhere else or eating a convenience meal either bought premade at the store or take-out.

When the respondents were cooking they would most often cook multiple portions at once. This is remarkable as most of the participants were a single-person household. Only 13% of all times that was cooked was for a single person/portion. As a result in 75% of the cases leftovers were produced after dinner was finished. Some of the portions were too small to be considered as a viable meal or worth saving, and were therefore thrown out with the garbage.
The participants were also trying to accommodate incorporation of the leftover ingredients they had in stock. In a little over a third of all recipes a leftover ingredient from another meal was used. Reasons to use these ingredients were that people knew from previous recipes that they'd work in the dish that they were cooking. Some participants stated that they'd check their fridge for leftover ingredients and look for recipes to use these in and go to the supermarket with a plan with what to make.

A little under 10% of the dinners were convenience meals bought premade from the store. This is an important part of getting to know why these meals are bought in the first place. The decision to buy a premade meal, mostly is influenced by factors like being exhausted of a busy day of work or having limited time to cook. These meals are therefore bought because of their convenience.

Only 7 times leftovers were eaten during lunch. This was mainly because lunch was consumed at home, making it possible to prepare the food before eating it. Over half of the days food was bought at the store, accommodating for the nutritional needs of the participants. This is in line with the results found in research 1 about the general behaviour with food.

The overall discarding of food was lower than expected. This could be a result of smaller amounts of groceries being done at once, or due to changed buying behaviour of the target group. The green section on the next page dives deeper into this assumption. All the food that was discarded was either unsafe for consumption or too small to save for later. The things that were thrown away were mostly vegetables that had gone bad, (small) leftover meals and fruits. This data is in line with the findings of the Voedingscentrum. Some were specific foods that had no use in other dishes, for example salmon eggs or half a lime. These are examples of

ingredients that are bought for one specific dish but are hard to combine in other meals.

Fridge data

The fridge pictures gave insight into the fact that everyone has a different way of organizing the fridge. There was a high variance between the different participants, starting off by just mentioning the difference in size of all the fridges. There were full-household sized fridges but also small square fridges looking similar to minibar-sized fridges in hotel rooms. The (lack of) volume which people could use therefore influenced the structure in the fridge massively. This is also due to some people having to share their fridge with roommates.
Some people had their sauces in the top, others in the door. Drinks in the door or on the bottom shelves. Dedicated spots made by the manufacturers intended for, for example eggs, are used differently with everyone some put butter in there, others sauces or other small packages. One of the things that stood out most was that people tend to place full cooking ware with leftovers in the fridge, while others use containers consistently. The containers varied a lot in size and shape, some were more efficient than others, resulting in a lot of lost volume in the fridge. Containers with leftovers were placed in random places and were there for multiple days in a row. Some of the participants indicated that they would actively start meal prepping and use these containers as a portion size of a specific meal.

What is the influence of inflation on buying behaviour?

According to research performed by Deloitte in 2023, 75% of the consumers actively change their buying behaviour due to inflation. This value was 67% back in 2022 and thus has increased almost 10 percent in a year (Deloitte, 2023). The increased prices result in the consumer buying more consciously by choosing cheaper products and discounts (Business Insider Nederland, 2022). Besides this they buy generally less and visit multiple supermarkets to lower the expenses in grocery shopping. About 89% of the consumers are conscious about the price increases of consumables (Deloitte, 2023).
Ever since COVID-19 occurred, the prices of consumer goods have been rising. In addition to this, back in February 2022 the Russian invasion in Ukraine began and caused prices of food and energy to increase drastically, as these countries are major suppliers of oil, gas, energy and agricultural food in Europe (Economic Governance and EMU Scrutiny Unit (EGOV) et al., 2023). The increase in costs due to scarcity of the products and their increased costs for transportation found their way to the consumers and led to high inflation in the European economy.
These events might explain the relatively low food waste found amongst the participants of the food diary research. Lower amounts of food bought will result in less food waste, as there is simply less food present in the households that could get wasted (Janssens et al., 2019).

Conclusion user research 2

The research gave a good insight in the actual behaviour and decision-making of the participants. Information found in the general research from papers and statements made in User Research 1 were confirmed and elaborated by this follow-up research.

There are two main activities on which can be focussed during this project, namely the consumption of leftovers and stimulating the creativity and knowledge of novice cooks.
The data indicates that leftovers get consumed during dinners primarily, however not so much during lunchtime. In addition to this, the data showed that consumption of leftovers during lunch only really occurred when the participant was at home during lunchtime. Finding this, in combination with the previous research in which participants acknowledged to throw away leftovers regularly indicates that there might be a big opportunity for leftover consumption during lunchtime. If this behaviour can be stimulated, less amounts of food waste might be possible as smaller leftovers are considered to be sufficiently sized as a lunch. Coincidentally, smaller portion leftovers are often regarded as impractical or too small to be saved from throwing out. Addressing this specific scenario might result in less discarding of small leftovers.

Most food is discarded because there is a concern about the food safety as the products have expiring shelf-lives or the quality is lowered significantly. When the food is saved it gets forgotten or it is uncertain when they will be eaten, resulting in them going bad.

Meal prepping seems to be very useful for small households to consume all bought food. The bigger portions and amounts needed during preparation result in less leftover ingredients, as bigger packaging volumes get consumed in one cooking session. Next to less waste of food, the time saved by cooking a bigger batch at once for multiple days is preferred compared to cooking every day. This indicates that if the convenience of meal prepping, or consciously cooking with leftover meals in mind, is more widely known and stimulated, can result in lower amounts of food wasted.

There was less food waste than expected amongst the participants, this might be due to the inflation that is going on and the limited budget the part of target group knows. This will be researched in the next section.

Limitations to the study

Because of the low response rate to the research, the findings have a high chance of inaccuracy because of the small sample size. Besides this, a week is a good start but can give an inaccurate view on long term behaviour. The more days this study would take, the more accurate the behaviour would be recognizable and patterns would become more obvious. As the study took place without supervision of the researcher the entered data is fully depending on the integrity and honesty of the participants' responses. The initial idea of findings patterns through the fridge pictures was not deemed as valuable.

User research 3: Consumption of leftover

As the first two studies indicated that there was an opportunity within stimulating the consumption of leftovers, a third study was executed to explore this matter more deeply. This third research was conducted as a small interview. A copy of the questions can be found in Appendix C.
The goal of the interviews was to find out how consumers handle the leftovers on a day-to-day basis and what their concerns were in relation to the leftovers. The specific area that was looked into was using the leftovers during lunch, especially in work/education related environments and understanding what the limiting factors are in using leftovers in these scenarios.
The interview was conducted with 12 participants, age ranging 20 to 36 with different occupations (students, teachers, corporate) and various lifestyles. These participants were friends and family of the researcher, as there was limited time to find participants and complete the study.

Results

Leftovers are saved when it is sufficiently sized for being used as a meal, either dinner or lunch. When the portion size is too small it gets thrown out. This is highly in line with the results of research 1. It depends on the planning and whether the leftover is foreseen what the immediate action will be. If it is quickly established that the leftover will not be consumed within 2-3 days people will try to freeze it. If there is the opportunity in the near future they will just save it in a container in the fridge for consumption within a few days of creating the leftover.

Most participants did not have a real system of storing the leftovers. They just put it in a container and try to eat it at the first suitable moment. The date on which the leftover was created is not being tracked as the idea is that it gets consumed quickly. However, they often forget about the leftover and get concerned with the freshness and food safety. As a result the leftover gets discarded once there is doubt about the quality of the food. Some explained that they started with marking the foods to identify what is in the frozen bag/container more easily. When it is put in the freezer, the need for a production date seems unnecessary as it gets frozen.

The biggest concerns with leftovers are the freshness, tastiness and food safety of the product after a few days. They trust their basic senses to assess the quality of the food in the containers. If there are ingredients that are more prone or believed to be more prone to go off quickly, like dairy products and meats, the safety is questioned sooner and assessed more carefully.

Leftovers are not only used during dinner, but also during lunch. They are considered as more nutritious and more filling compared to 'typical' Dutch lunches like sandwiches with toppings. The problem however is to be reminded to use these ready-to-go leftover meals and to actually eat them during the day.

To consume the leftovers at another place than just at home multiple things are being considered. First of all, it fully depends on what the leftover is. Some are not considered to be convenient or even safe to bring to another place. Leftovers with a lot of liquid content are avoided to bring anywhere else than home because of the fear of spilling it. Prevention of spillage during transportation is therefore something that needs to be guaranteed for people to consider bringing leftovers.

Besides this, the logistical difficulties with keeping the leftover fresh is a struggle. Not every place has a fridge which results in the leftover sitting in an unrefrigerated environment, becoming less tasty, losing freshness and potentially increasing food safety risks.

Next to this, some types of leftovers need to be reheated or prepared before consumption. When the leftover becomes less tasty due to preparation far before consumption, for example wraps, the ingredients can become soggy and thus less tasteful when consumed. The texture decays and therefore it is preferred to prepare the leftover just before consuming it. The mixing of ingredients can also become a problem, with the overall experience of eating the leftover decreasing.

Furthermore, some places just don't have the required or optimal appliances to prepare the food in general. A lack of for example and oven instead of a microwave can be a hurdle in maximizing the willingness to eat specific leftovers as the food experience is not as what's preferred. At home it is easier to adjust the leftover if needed, by adding some spices or heating it in a pan instead of a microwave. This is less likely on the go.

Simple things like bringing cutlery and storing this after usage when it's dirty also influences the chance of consuming leftovers at another location.

Finally, if the leftover is not consumed on the workday or at location and there were no amenities to store the leftover in the fridge, it has been outside of refrigeration for approx. 8 hours. After this time the leftover is considered to be compromised in freshness which results in it being thrown away.

Another unexpected finding is that people feel like bringing leftovers to another is socially not very well accepted. They feel conscious and judged when eating their leftovers instead of buying something fresh. This is magnified when the leftover is very smelly.

By analysing the answers from the interview, it was possible to create a new chart specifically about the usage of leftover meals. All the routes are visible in figure 16 below.

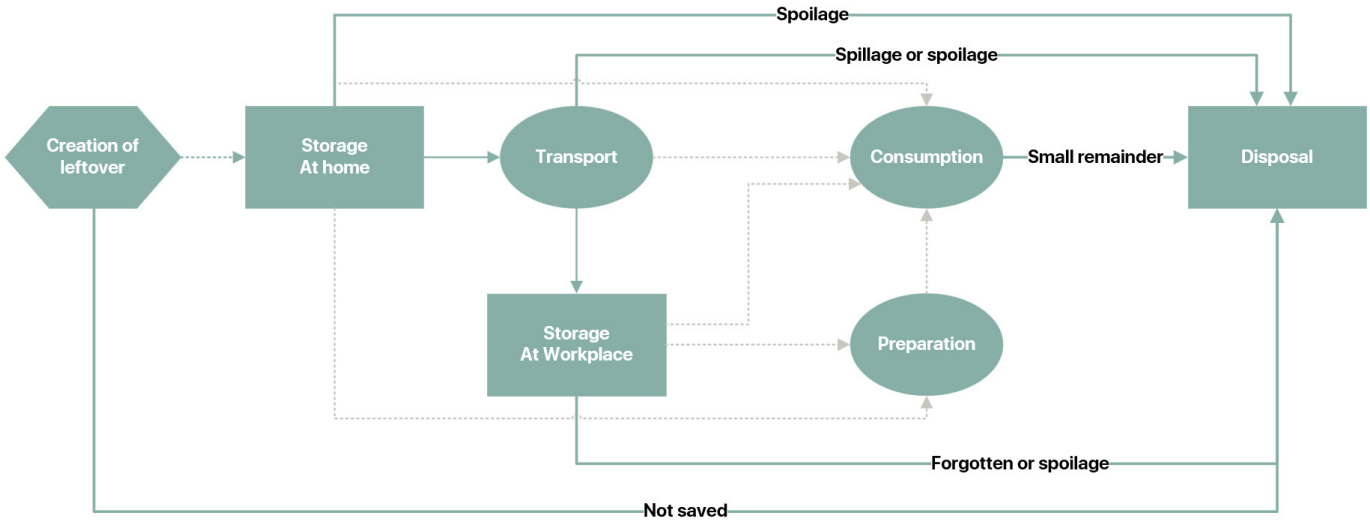


Figure 16: Leftover usage and disposal

Conclusion user research 3

This interview showed the problems with consumption of leftovers anywhere else than home. The current problems and hurdles that consumers have with bringing leftovers to their daily activities limits the possibility to consume leftovers on the go. If these problems can be addressed by a new product, there might be an increase in leftover consumption as there will be more possibilities to consume them during the week. As a result, leftovers might be thrown out less frequently, resulting in less food waste in Dutch households.

To make bringing leftovers as meals to other places more attractive it is important to address the current obstacles (figure 17).

Figure 17: Conclusion user research 3

Conclusion target group interviews

General skills in cooking are a leading factor in the creativity and opportunity to reduce food waste. When a consumer is more capable in the kitchen they have more trust in their own ability to incorporate other ingredients in a dish. Their knowledge about how to use specific ingredients and their general sense of what is a good combination makes that higher skilled cooks tend to throw away less. If these skills would be present in less skilled cooks less food waste might be achievable. Educating and guiding these novice cooks can positively affect the way they approach cooking and using their leftover ingredients in a more creative and flexible manner. However, even though the perceived cooking skills influence the general beliefs of food waste prevention by more creativity and knowledge, most of the participants stated that leftover ingredients could easily be used in certain types of food such as pastas, curry's and soups. The ingredients that get thrown away are mostly very specific ingredients and if the participant identifies this during shopping they try to prevent having leftover ingredients or substitute the ingredient for another one.

According to research 1, **leftover meals contribute the most to the foods that get thrown out in a household.** Leftover meals are saved even though the portion might be too small for a dinner meal, however if the size is considered too small even for a lunch it gets discarded. The date on which the leftover was produced gets forgotten easily and concerns about food safety plays a big role in deciding when the food gets thrown out. The basic human senses are used to assess the foods' quality before consumption. The uncertainty about the food quality or freshness, especially presence of mould is the deciding factor to throw the leftover in the garbage bin. The consumers struggle to identify when the food is still edible, and take caution when there is doubt. The result is that leftovers are kept until there is no denying in the fact that it is not edible anymore and is gotten rid of.

Consumers **fail to identify when leftovers will be consumed,** as leftovers are often unforeseen and not counted on when doing groceries, as they are a byproduct of another meal. As a result the leftovers stack up in the fridge for an unknown amount of days, decreasing in quality over time. Addressing the problem to identify when to consume might bring new value to the system. If the leftovers are more convenient and versatile to use they might be easier to be used on a daily basis.

Leftover meals are not only used for dinner but also as lunchtime meals. However, **the leftovers are used most often at home as it seems inconvenient to bring them to work**. Hurdles as (safe and secure) transportation, adequate storage in a fridge and the correct appliances in the kitchen to prepare the leftovers are some of the struggles that limit consumers to bring leftovers to work. Especially in places such as school/university lack the correct appliances and ammenities to stimulate this behaviour as there are often no fridges to store the leftovers during the day. As a result they are kept in the bag where there is a chance of spillage and spoilage of the leftover. When the leftover is brought for lunch but is not consumed that day, the food has been unrefrigerated for 8+ hours and is deemed unsafe to eat and gets thrown out. This is because not every workplace or location has the proper amount of fridges or has other reasons why it can not be stored in a fridge. Products that need to be refrigerated and are prone to spoilage are unsafe to eat after 2+ hours out of refrigeration (Voedingscentrum, 2016).

Chapter 3
Conceptualization

Conceptualization combines all the gathered information, insights and knowledge from the target group interviews and the literature research to identify a focussed direction for the project. It creates the framework for the development of a product to be more effective during the creative process and product development phase of the project.

Design directions

Based on the findings in chapter 2, possible opportunities arise in preventing food waste in Dutch households. To streamline the process, design directions are generated which subdivides multiple opportunities with the same basic ideas and group them.

Enhancing cooking skills by guiding less skilled cooks – making cooking fun

Making users more capable in the kitchen by helping them manage their behaviour in the kitchen Better cooks tend to waste less due to better decision making skills and management in the kitchen. If these skills were present in less experienced cooks a lot of food waste could be saved. A design which helps novice cooks to maintain more control in the kitchen could contribute to less food waste. Implementation of features like suggestions, cooking instructions and alerts could make them more capable in the kitchen.

Providing skills and basic knowledge to novice cooks

By showing that something can be done and giving them the experience how to do so can influence the amount of food waste generated in Dutch households. Giving them the feeling that they actually can do something with the leftover ingredients/meals and empower them with the knowledge needed to do so.

Making cooking more fun and rewarding

Next to making them more capable it should motivate them to have more fun during cooking, for example by allowing them to have music on demand. Interactions.

Enhancing creativity by making meal suggestions based on currently available products

Help consumers discover more possible combinations of ingredients. Making them more creative and knowledgeable about the various ingredients and their possible usage in different dishes. This should boost the possibilities during cooking. Recipes could be tailored to for example budget or cooking skills present in the consumer.

Focus on more accurate recipes compared to current recipe suggestion tools.

Current recipe tools allow you to enter the ingredients that you have, but do not account for the amount of ingredient that you have. A tool like the AH "Recipe tool" will allow you to enter tomatoes as an ingredient (even though it might be just 2 small tomatoes) and it will suggest to make tomato soup. A tool which takes the amount into consideration whilst suggesting recipes might be more enabled to give accurate suggestions that will actually be used by consumers.

Making the possibilities of leftovers more pronounced

Not knowing how to integrate various ingredients (leftovers) in an unfamiliar dish can result in the ingredients being thrown out. By highlighting use cases of the various ingredients, cooks can be reminded of the possible integrations with the available produce. Tool for combining the various ingredients and give it a match score. Instead of very specific recipes, leave some room for own creativity.

Optimization of leftover portion size

Help consumers to cook better sized portions during cooking, either precisely one portion or deliberately make bigger portions for so-called meal prepping. The goal should be to prevent half portion sized leftovers which tend to be thrown away more often.

Increasing visibility of expiring products

Making expiring products stand out more in the kitchen so that the users notice that ingredients are about to go off in time. Research shows that most products go bad because of simply forgetting about them. By highlighting the expiring products the attention of the consumer will be attracted/directed to the ingredient, reminding them to use them before they go off.

Keeping track of produce date and expiring date of leftover (meals)

When making leftovers, they disappear in the fridge and are forgotten about. Due to this the consumer is uncertain about the food safety of the leftover and gets thrown out in the garbage. By easier ways of checking when food is about to expire, the amount of food waste can be lowered.

Tailoring meals/shopping lists based on current inventory (e.g. HelloFresh)

Using currently available ingredients in dishes from online supermarkets to reduce the amount of perishable ingredients in a household at the same time. Partners like HelloFresh already have somewhat of an insight in what consumers have in their homes, and could easily adapt their deliveries to that. Besides this, consumers tend to do groceries multiple times a week so this might be a viable option for adaptability in cooking.

Enhancing storage environment

Focussing on keeping leftover meals as fresh and attractive as possible during storage. Dividing meals instead of one large container with everything mixed up. Different meals need different storing conditions and vegetables and fruit have the same problem. Besides this a highly structured fridge can help to minimize food being overlooked or being forgotten due to low visibility.

On-the-go storage optimization (longevity of the leftover)

If leftovers are transported during the day, but not consumed they are thrown away because the food has been out of refrigeration for too long. As a result it gets thrown away because of food safety. Making it more convenient to bring leftovers as lunch.

Narrowing down concept directions

As the title of this project is “flexible cooking” the vision of the solution should be within the actual preparation of food and the behaviour of consumers in the kitchen. However, the convenience of leftovers and the current ignorance of these leftovers makes that this is a very promising target as well. Flexible cooking might as well become flexible consumption. During this journey it is important to consider how the behavioural change can be accomplished by using nudging, boosting or enabling the COM-B model as described in the literature research.

Enhancing skills & knowledge

Enhancing skills & knowledge focusses on empowering the consumer with the required experience and tools to combat food waste. By stimulating them in more sustainable behaviour a lot of food waste could be reduced. When it becomes easier to perform certain practices the self-confidence and belief will increase and show that it is actually possible to decrease the amount of food waste produced. These can both be in the form of nudging and boosting the consumer to change their behaviour around food preparation.
Giving (less skilled) cooks the tools and knowledge to counter the food waste. By giving them more hands-on experience and guidance a sustainable change in their practices and behaviour can be achieved.

Key aspects

Autonomy

The consumer should keep a sense of autonomy in the kitchen. By stimulating their own confidence in the kitchen a sustainable change in behaviour is possible. The choice must be theirs to make instead of being forced to show a specific behaviour.

Informative & educative

By enhancing skills a cook can become more capable in the kitchen, learning them insights and new things can drastically change the amount of food wasted.

Stimulating creativity

The way in which they should do things should leave room for experimenting and creativity in the cooks themselves. A recipe should not be set in stone but be a guideline and stimulate using similar ingredients if the specific one is not available. Instead of having a fully defined shopping list of ingredients for the dish give multiple options to achieve somewhat of the same flavours.

Rewarding

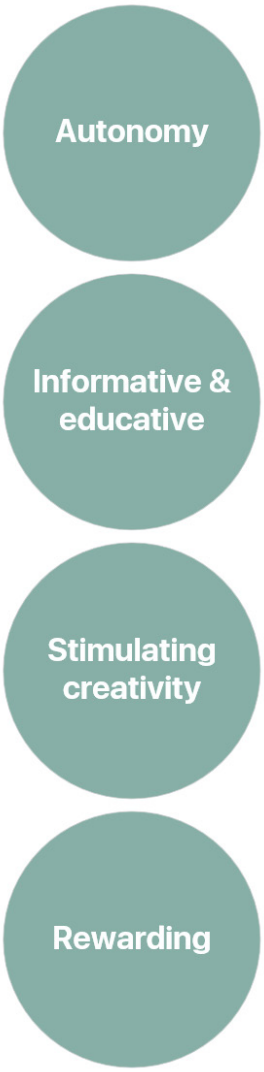
Using the product should appeal because there is a sense of reward after it has been used. By a reward system the interaction is highly intrinsically motivated and will result in more usage. The goal is to make the intervention feel natural and it should motivate the user to keep on using the product.

Figure 18: Key aspects enhancing skills and knowledge

Stimulating leftover consumption

Making it more convenient to eat leftovers will reduce the amount that gets thrown out. Implementing leftovers in dishes or being able to bring them with you to work can be very effective to increase consumption of these leftovers. Besides this, simply keeping track of the different leftovers and knowing the date before which they should be consumed.
This design direction allows people to be more flexible in their consumption behaviour, making it easier to guarantee and indicate the food safety / freshness and stimulating the actual consumption of the leftover on other moments than just consuming the leftovers during dinner. Smaller portions might not be sufficient as a meal during dinner, but might be perfectly sized for lunchtime.

Key aspects



The convenience of having leftovers should be stressed and if possible making them even more convenient in other scenarios. Being able to use the leftovers in more possible scenarios will influence the perceived convenience positively and result in the leftovers being consumed in other scenarios. This might make them more favourable over store-bought meals during working days for example.

Leftovers are widely forgotten because of unstructured fridges and as they are something that 'was not counted on'. It is a surplus which otherwise will be wasted. By being reminded of the leftovers and attracting attention to these products, less food waste will occur and likely improve the consumption ratio.

One of the main concerns with leftovers is that it is uncertain what the quality of the leftover is like. Prolonging the foods quality is essential to increase the chance that the leftover will be consumed. Next to this, simply tracking when the food was made can be a good indication for the safety in general. Assuring the food safety can help to minimize food waste as the food will be consumable for an extended period of time. This could be done by making sure the food is kept at a low temperature so the growth of bacteria and fungi is limited.

Figure 19: Key aspects stimulating leftover consumption

Choice of concept direction

Stimulating leftover consumption was chosen as the concept direction for the final product of this project. The amount of food that can be saved with this concept direction will really be noticeable. Designing a product which tackles leftovers in general will be way more effective compared to a product which focusses on a much smaller detail of a bigger problem. Besides this, the amount of developments comparable to what would be classified under the "skills and knowledge" direction is huge due to the surge in AI technology.

Design vision

Even though the title of this thesis is “Flexible Cooking” this will no longer be fitting as the working title. Research showed opportunities beyond the actual preparation of the food and it seems more interesting to be focussing on that part: **Flexible Consumption**

Design statement:

“I want to reduce food waste by giving consumers the tools and opportunity to make leftover meals more valuable and versatile to use on a daily basis, by making it more user-friendly and convenient to take leftovers with them to consume in more scenarios and environments.”

The goal of the project is to reduce food waste produced by Dutch households. Initially the intention of the project was to make the households more flexible in their way of using leftover ingredients and meals. After research it turned out that the cooking part was actually less interesting to focus on, as there are a lot of developments in this market as the project is taking place. This demonstrates once again that this problem is very important to address and that the topic is booming. Bigger companies like Hellmans and Conimex (recipe tools) are providing tools to the mass market to focus on more flexible behaviour during the meal preparation/cooking.
Because of these developments it is more valuable and rewarding to focus on the other part, namely the prevention of leftovers being thrown out in the garbage. However, this is also currently under high development and interest of other companies like Albert Heijn. Currently there is a promotional collaboration with royalvkb for food storage containers. However, these are limited to purely the storage and do not focus on scenarios outside of the household.

Analogy

Using an analogy gives a relatable experience or feeling to what the outcome of the product should express while being used by the consumer.

Like having a Swiss army knife

A Swiss army knife is a versatile and powerful tool to bring to any situation. It is multifunctional and can be used in a wide array of scenarios and environments. It is something to rely on and can help you out by having loads of tools in one. The basic function is a knife, yet all the additional tools create a highly versatile product which can be used for many different user scenarios.

Market research - currently available solutions

To know where the gap in the current offerings in the market is, market research must be performed on what is currently available and this should be analysed. In addition to this, the target group can be approached once more to find out their specific requirements for the product.
The market is defined by tools and products that enable people to eat food at other places than home. This can range from very simple food containers to more engineered products that have multiple functions and usage possibilities, see figure 20.
The food container market is very elaborate and quite saturated with a lot of diversity in the products that are currently for sale. There are products with thermos insulation, foldable food containers, icepack included, glass, plastic, stainless steel, cheap, expensive, small and big, suitable for oven, with cutlery, with divisions. You name it and there might be a product on offer that has this feature. Some people even said to use takeout food containers. Big names in the business include IKEA, RoyalVKB, Tupperware and Mepal.

Figure 20: competing products

Sizing and shape

The size and shape of the food containers is very diverse with none being exactly the same. However, the shapes are most often rectangular or square with some exceptions of round shapes for liquids. These basic shapes are most efficient to use in small spaces without unnecessary loss of space. The volume varies from basically 400ml till 2.5L, with 750ml - 1000ml being the most common size. These containers have sufficient volume for a sizable leftover without using up too much space.

Functionality

Most food containers are suitable to use in the microwave, fridge and freezer. This is mostly because most of these containers are made of Polypropylene (PP) plastic. A few containers are made from other plastics or even glass and stainless steel. These containers are suitable to be used in the oven as well.

Functions of the product

There are numerous combinations of additional features that can be implemented in the container. Interview 3 showed some of the pain points in the system and gave insight in the desired functions a product should have to tackle these pain points. This should however still contribute to an improved experience for the user and offer additional value over a 'standard' food container. To prevent the development of functions that are abundant to the overall use, a choice and priorities should be made to guarantee an easy to use product while reducing food waste.

Three main categories of functions can be identified (figure 21). "Core functions" which the product has to have to fulfill its intended main task, these functions have to do with the basic functions like enclosing the food. These are the functions that have to be met in any case. "Food safety functions" that influence the longevity of the food quality or enable the user to monitor the quality of the food. And finally, "Ease-of-use functions" which focus on making the product more convenient for the user and hopefully stimulate usage of the product in general.

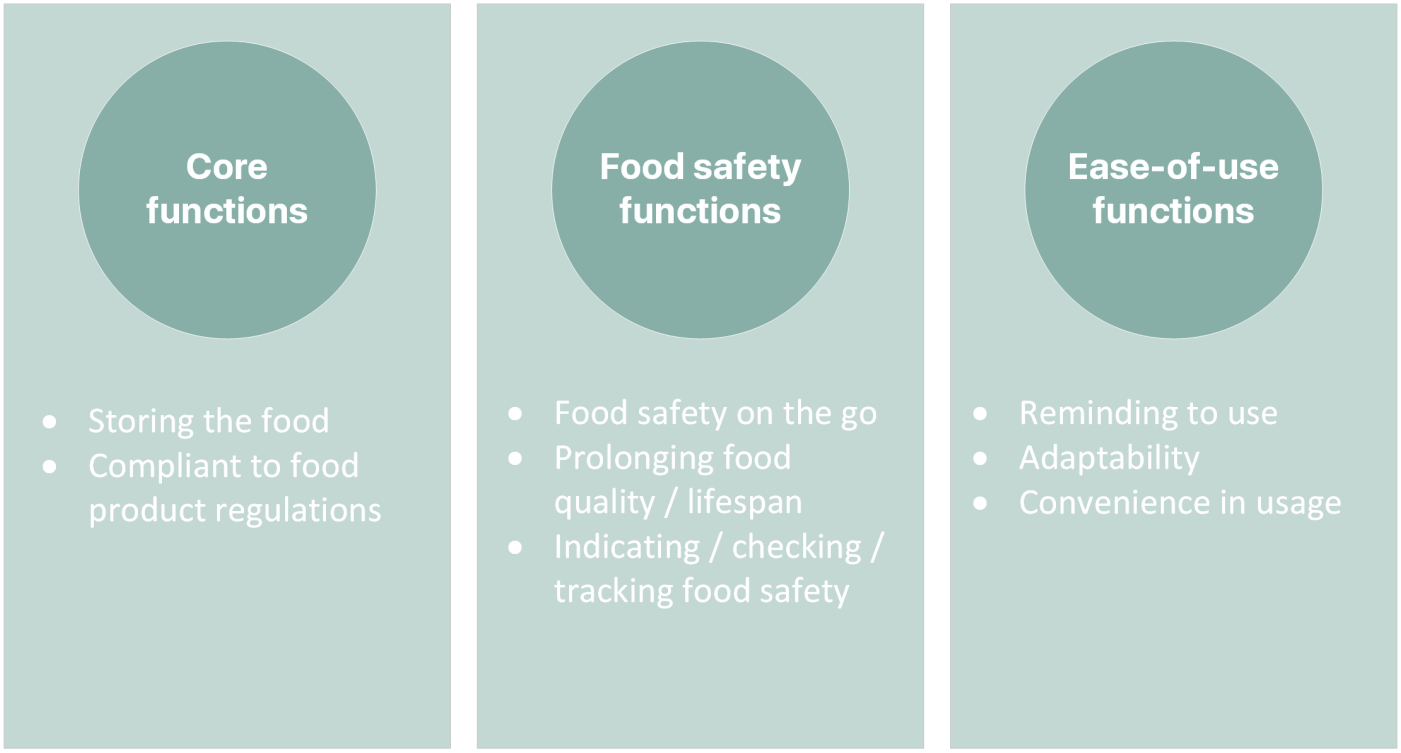


Figure 21: Functions of the product

List of requirements

Performance
- The product should be durable.
- The product should enable users to take leftovers more easily to other places.
- The product should ideally be safe to both use in a microwave and oven.
- The product should be able to seal its containments airtight for transportation.
- The product should minimize a decrease in food quality during transportation.
- The product should help identify the food quality/safety for the user.
- The product should have an internal volume of at least 750ml, based on competition.

Environment
- The product should be usable in temperatures ranging from -30 to 220 degrees. Fridge, freezer, microwave and oven.

Life in service
- The product should be usable every day of the week, for a period of at least 2 years.

Maintenance
- Parts that are prone to damaging and decay should be accessible for changing parts.

Target product cost
- The product should cost no more than 30 euros, aiming to be as cheap as possible.

Transport
- The product should be compact and fit in a backpack.
- The product should be easily transportable.

Size and weight
- The product should be as light as possible.

Materials
- The product should be made of food-safe materials.
- The product should be made of dishwasher proof materials.
- The product should be made of microwave-safe materials.
- The product should be able to withstand temperatures between -30 to +220 degrees.

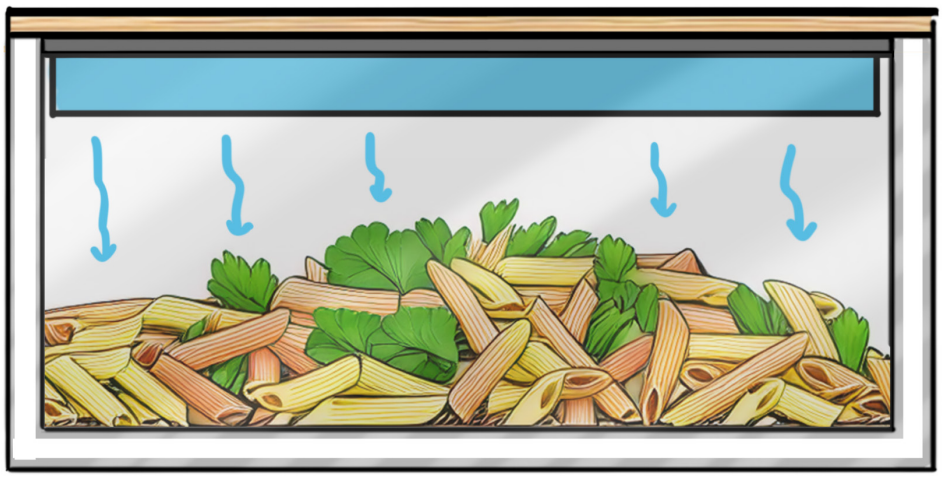
Wishes
- The product should have as few parts as possible.
- The product is manufacturable with conventional production techniques.
- The product is aesthetically pleasing.

Concept 1: Thermos container with (passive/active) cooling

The first product is based on the fact that the users would like to have their leftovers as fresh as possible and safe to eat on the go. Naturally this involves keeping the leftovers refrigerated while on the go. The interviews of research 3 showed that one of the main obstacles in taking leftovers to another place is the absence of the logistical things needed to maintain food safety. Not every place has a fridge that they can use to store their food until consumption.

Because of these reasons the first product idea has a thermos effect to minimize the amount of heat exchanged between the (refrigerated) leftover and the ambient environment. By integrating a thermos effect in the product the food will maintain a lower temperature for an extended period of time, ensuring lower chance of decreasing the quality and freshness of the food. This thermos effect is created by using a two-part structure of the container.
In addition to the thermos effect, the product offers the opportunity to place a frozen cooling element in the lid to have active cooling on the go in a passive way. For a more consistent cooling experience a heat exchanging element can be integrated to have active cooling like a refrigerator. This however will use electricity.

To minimize the volume of the product there will be several modular add-ons to make the product more suiting for the desired use. Possible add-ons include a place to store cutlery and other related products.



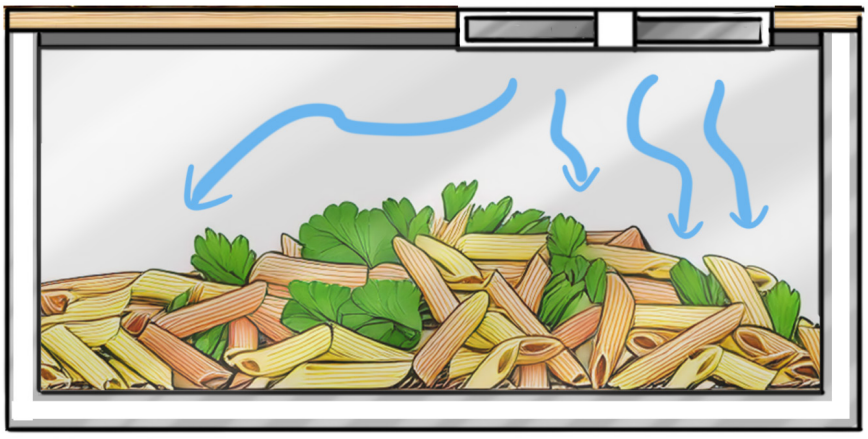


Figure 23: Concept 1: active cooling

Concept 2: Thermos with reminder to use

The second product is somewhat of a variation on product one with including the same thermos effect in the container by using different layers to build the final container. However, this container is also designed to remind the user to consume the leftovers.
One of the main reasons that leftovers get thrown away is that they disappear in the back of the fridge or that the consumer simply forgets to use the leftover in time. Another reason was that they fail to indicate food freshness / struggle with food safety as they forget when the leftover was created. For this reason there are 2 possible solutions to the problem.

Digital reminder system

A digital component is used to track when the food was put into the container and display the day and time since. In addition to this, the digital component can be used to increase visibility, if the digital display is used to attract attention. A small speaker can be installed to sound a chime once the fridge is opened. This can be tracked by implementing a light sensor which registers when the fridge is opened (light) or closed (dark) to minimize energy consumption.
The downside of this digital reminder is that there are more elements that can break and the user friendliness is lowered as the digital components are not suitable for microwave usage.

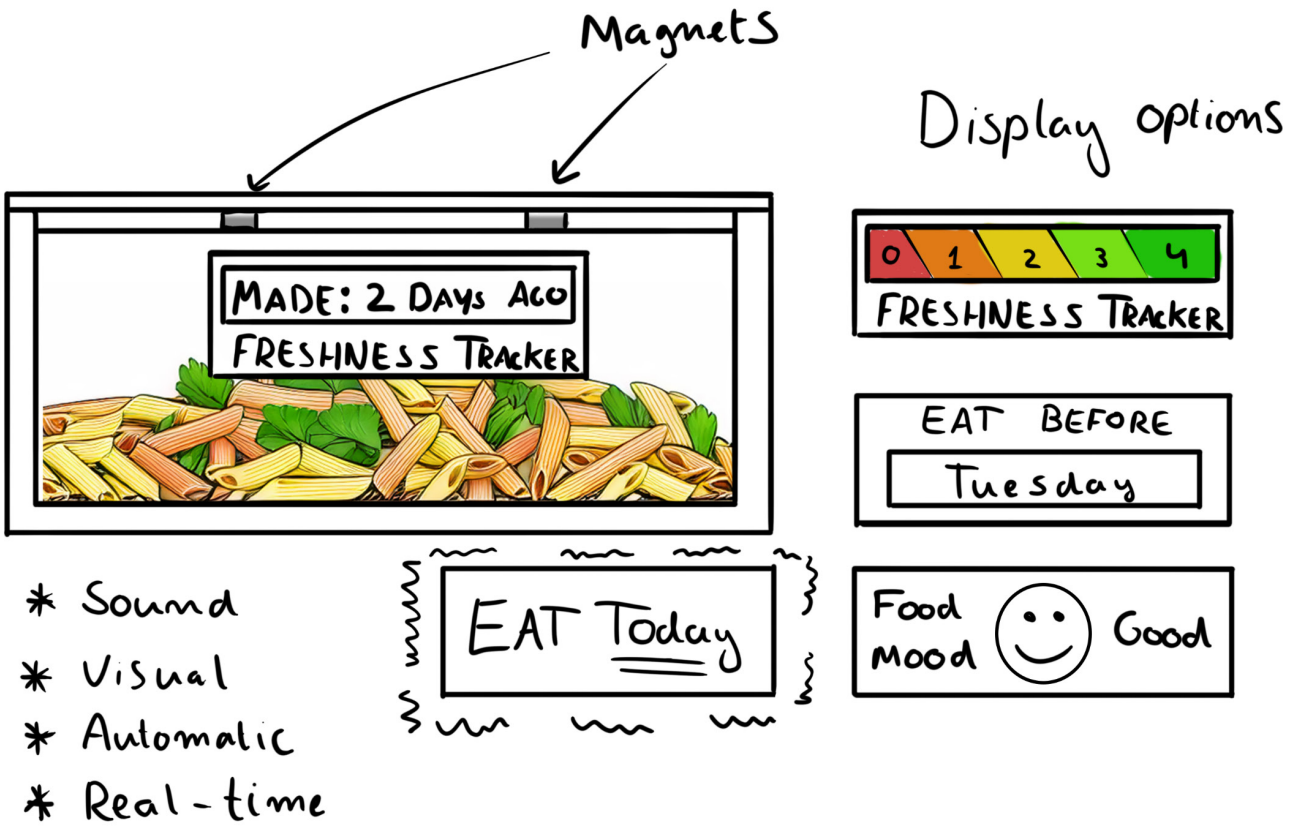


Figure 24: Concept 2

Analogue reminder

The same tracking information can be achieved by using an analogue version of the same system. Simply by putting a sticker or similar on the container it can be tracked when something was produced. The downside of the analogue version is that the possibility to use photosensitive and auditive cues to attract attention gets lost.

Figure 25: Concept 3

Concept 3: Portable fridge

This concept focusses on making the leftovers more visible by making a separate fridge to store the leftovers in. This fridge can be strategically placed to make it more likely that the people will remember to use their leftovers. The fridge comes with good insulation and a battery to power the cooling element when not connected to the grid for power.
The front of this fridge is transparent so that the food is not hidden away, as which is the case in 'conventional' household fridges. This is done to increase the visibility of the product inside the fridge, making it harder for the products to get lost in the back of the conventional fridge.

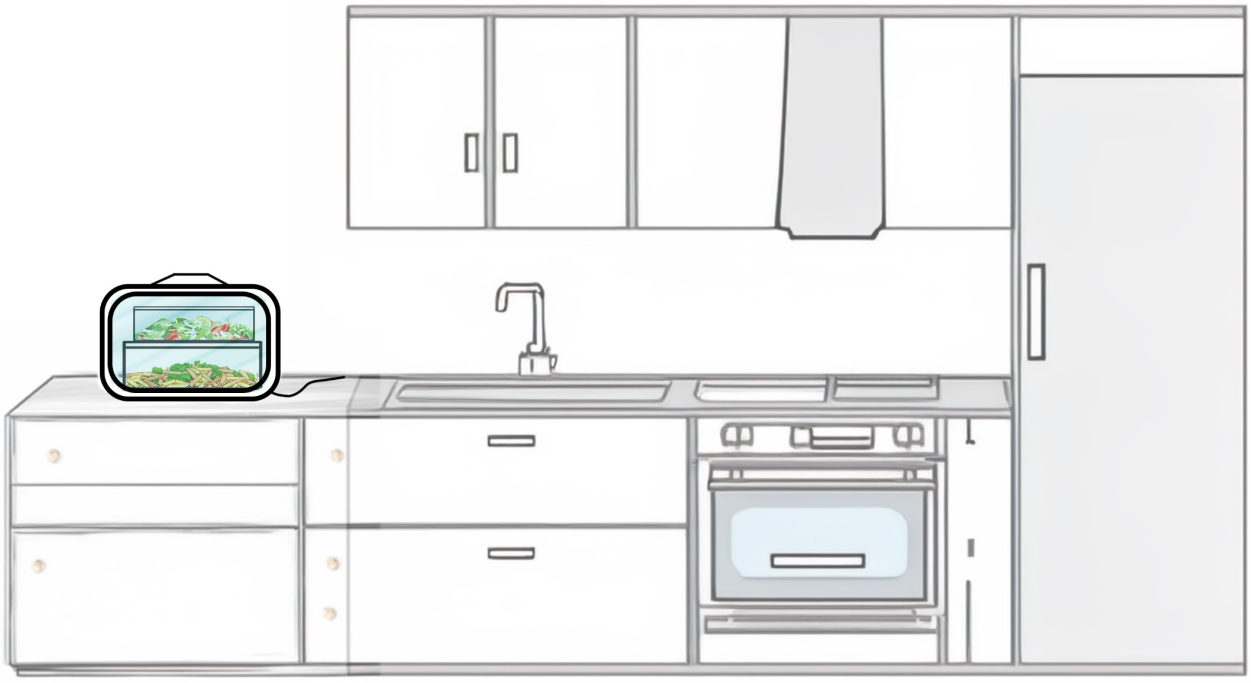


Figure 26: Concept 3 portable fridge

Concept 4: Ultimate on-the-go food container

The final concept focusses on making it as easy as possible to take the leftovers to another place than home. It is basically a combination of the 1st and 2nd concept, making it the ultimate all-inclusive design for a food container.
The container comes with a thermos insulating layer and cooling element to prolong the foods' quality on the go out of refrigeration. There is place to store cutlery and it closes securely so it will not spill food on the go in a bag.
Furthermore, this concept can be used to not only preserve the food on the go, but also making it easier to prepare the food at the destination. By making it easier and more convenient for the user to prepare the food in the desired way, it might take away one of the hurdles of bringing leftovers.
The freshness tracker will also be included so it is an all-including concept with all aspects addressed.

Figure 27: Concept 4 ultimate on-the-go food container

Conclusion

The four concepts as depicted in the paragraph before show the opportunities within the frame of the desired solution. To make a decision in which one is most viable to continue with, the concepts will be evaluated on their possible influence and likelihood of succeeding.

1. Concept 1 shows potential to battle the amount of food wasted compared to 'standard' food containers. However, after some research it seemed like products like these already exist on the market and therefore will not be interesting to continue with.

2. Concept 2 addresses the problem of forgetting that leftovers are present in the fridge and need to be consumed. It attracts the users attention and stimulates the consumption of the leftover in the fridge. However, the potential impact the product will have is diminished by the limitations of including the electronical parts which reduce the usability. The analogue version might not attract attention to the desired extend.

3. Concept 3 is a far too technical and illogical solution to the problem. Carrying around a fridge makes it less likely to use the product as it is inconvenient.

4. Concept 4 shows most possibilities and is a relatively simple solution to the problem as described in this project. It is versatile, convenient and has simple features that combine to make a big impact on the general problem of food waste. It does not only help in the household itself, but also enables the user to prepare the food on the go more conveniently.

Harris profile

A Harris profile (figure 28) was made to make an objective and well-reasoned choice for deciding which concept will be developed in the following phase of the project. The criteria were chosen based on the general idea of this project namely; preventing food waste, but also attributes that came forward through the target group interviews. The concepts were given scores on each aspect to decide which one would be most promising.

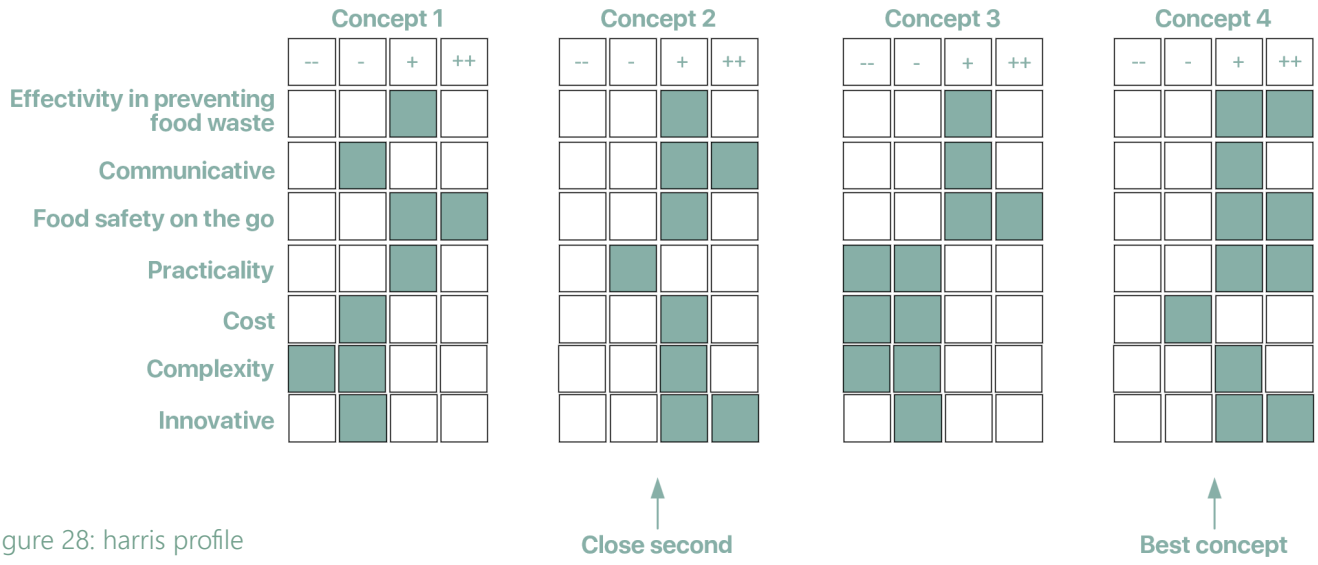


Figure 28: harris profile

Based on the results of the Harris profile, concept 4, the ultimate on-the-go food container will be further developed from concept to product.

Concept development

In this part of the report the whole process of developing the concept towards the final product, including materializing and prototyping will be explained. Concept 4 was chosen due to its versatility, convenience and its expected qualities in addressing the pain points of using leftovers in time.

The final concept idea: Backie

The concept which will be developed has the following four main functions. It reminds the user of when the leftover was produced, and thus helps indicating freshness and food safety, it prolongs the lifespan of the product inside, it enables the user to bring the leftovers to other places with increased freshness and makes it more convenient to consume and prepare the leftovers away from home.

Starting with one of the main problems. Consumers forget when leftovers are made and as a result they are more careful and hazard avoidant concerning the food safety of the leftover. With the smallest doubt about the freshness of the food, especially when they can't remember the day on which it was produced, it will get discarded in fear of food poisoning. This is often the case whilst the food is still safe for consumption.
Secondly, consumers fail to indicate when to eat the leftover within the timespan that the food is still safe for consumption. They either don't have the chance or simply forget about the existence of the leftover.
Furthermore, consumers don't like their food out of refrigeration for too long. Not every place has the right amenities to store food until it is consumed. Once again the fear of food safety plays a big role in this. According to the voedingscentrum, food is only safe for consumption if it has been out of refrigeration for less than 2 hours (voedingscentrum, 2016). However, besides the food safety, the food experience suffers from being out of refrigeration for too long.
Finally, not every place is as suitable to bring leftover foods, therefore it must be as easy as possible to enable the consumers to bring their leftovers elsewhere to consume them. Taking in mind that eating food requires additional products like cutlery and extra activities like preparing or heating the food before consumption. These matters need to be addressed and it should be as easy as possible to meet the customers' needs to make it more likely to bring leftovers elsewhere.

The product should be giving a solution to the following problems:

1. Forgetting about the leftover and when it was produced.
2. Limited time to use the leftover before it goes bad.
3. Inadequate amenities to refrigerate food elsewhere.
4. Lack of convenience in bringing leftovers.

Morphological chart

The different solutions can be achieved in a combination of different attributes. To explore all the possible combinations a morphological chart (figure 29) was created to get an overview of the possibilities.

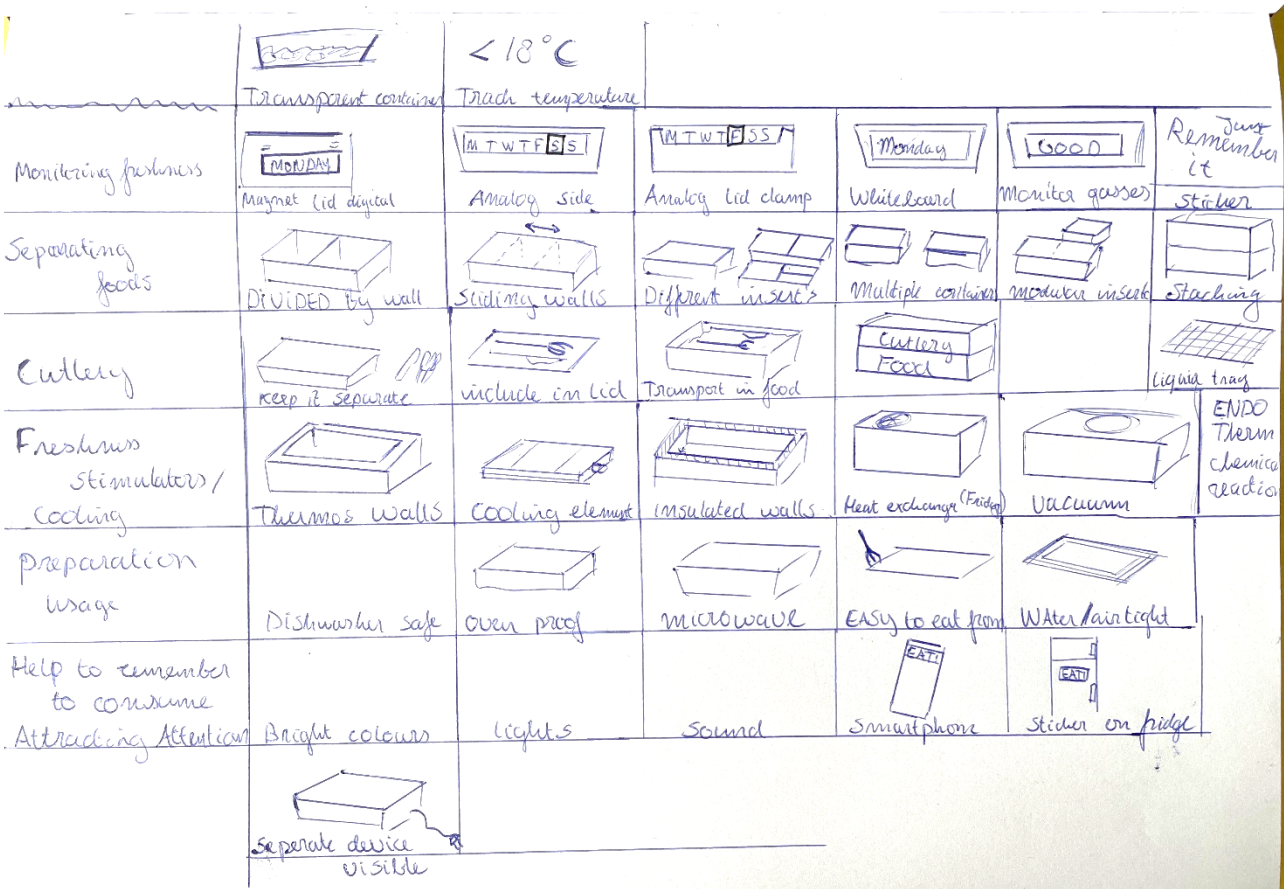


Figure 29: Morphological chart

Preliminary concept

The first visualisation of Backie was to get an idea for the size and dimensions needed in the container. The physical 3d printed model gave great insights in the dimensions and possible packaging options. Most of the features and attributes were present in this model, yet not really fully thought through yet. An example of this is the date tracker, which was included in the clamps for the lid, however, this would have been a problem with securing the lid as it would be easier to accidentally get stuck behind something and open.

This full scale model (200x150x93mm) showed that the dimensions were comparable to a large ordinary food container which somewhat compromised the portability and convenience of the container compared to other lunchboxes containers. The solution to this could be to offer various sizing options to accommodate to the users' needs. The concept model was mainly used as a prop during coach sessions and to brainstorm about possible packaging options.

Figure 30: Preliminary concept

The preliminary concept (figure 30) had all the different parts that the final design should include, based on the combinations made with the morphological chart. The results from the morphological chart were used to find useful combinations of attributions in the food container. The proposed design was based on making it as worry-free and low-tech as possible for the users' experience while using the container. The container is designed without any electronical components which could fail or needed additional actions for the intended usage. Backie is designed so it works just like a regular food container, and can be used in a wide variety of scenarios.
The next part will discuss the various features and attributes of the concept, what their additional value is and how they are present in the concept as shown.

Concept attributes

The following figure 31 shows an overview of the functions in the concept. The numbers in the illustration correspond to the features named in the text below.

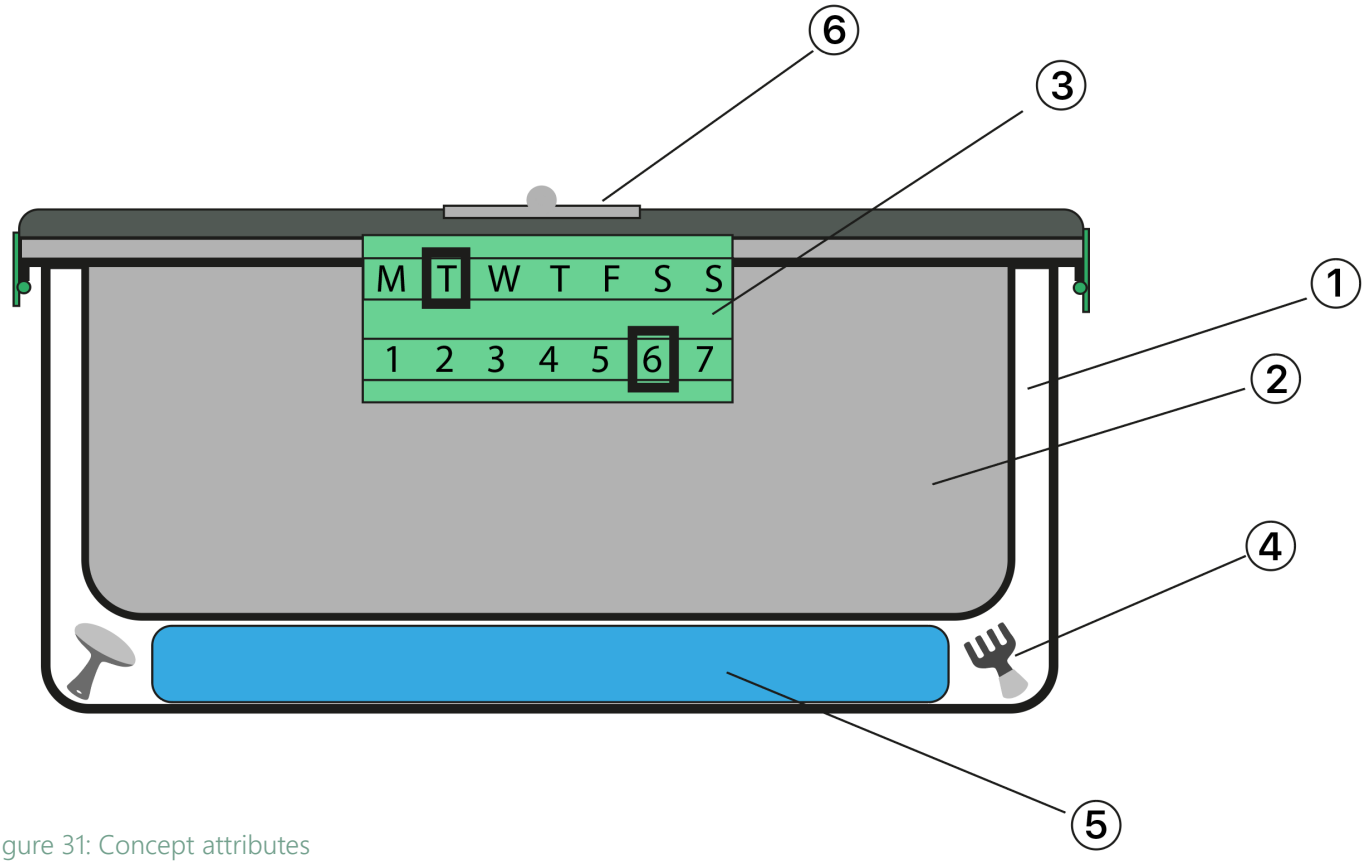


Figure 31: Concept attributes

Thermos insulation (1)

The design incorporates multiple parts that are used together to create a multiple layered product. By creating multiple layers it is possible to create a volume of air in between of the different layers which act as an insulating, thermos-like feature to the container. The pocket of air acts as a insulation layer which limits heat transfer between the food and the outside environment. This ultimately results in the leftover being cooler for an extended period of time, which improves the food safety.

Silicone inside layer (2)

Silicone is used as the material for the inside layer of the container. This material has some special attributes which make it perfect for easy preparation of the leftover inside. Silicone is not only safe for the microwave, but also safe for usage in temperatures up to 300°C, which makes it possible to use the material in the oven as well. Besides this, the silicone inside bowl can be used to act as the gasket to prevent leaks as a one-part solution, reducing the amount of moulds needed to produce the product.

Date/freshness tracker (3)

The container has a feature installed to keep track of the date on which the food was produced. The placement of this date tracker is on the front of the container, for easy visibility in the fridge. The production date can be registered and an assumed amount of days for which the food will be edible can be highlighted on a sliding rails. The addition of this feature is based on the fact that people lose track of when something was made and struggle indicating food safety of the containments.

Cutlery (4)
Addressing the practical considerations with taking lunch on the go includes the problem of bringing cutlery. However, as the internal usable volume of the container is already smaller because of the insulated wall structure with the inside layer of silicone, it is important that there is not too much loss of internal volume. The packaging showed possibilities by placing cutlery down below underneath the silicone bowl. There is lost space due to the curvature of the bowl in which a spoon and fork could neatly fit.

Cooling element (5)
A cooling element can be placed in the bottom of the container. This cooling element can be stored in the freezer until usage. Because of the placement in the bottom of the container, the frozen element is in direct contact with the food due to gravity. The cold element cools the food for an extended amount of time after the container was taken out of the refrigerator. This ensures better food quality on the go as refrigeration continues outside of the fridge too.

Vacuum function (6)
Vacuuming the food inside the container can increase the foods lifespan with some days. The reduction of air in the container prevents the food from oxidizing and limits bacterial growth during storage. As a result the food can be kept in the fridge for extended amounts of time, hopefully resulting in less discarding of the leftovers saved inside the container as the leftover can be consumed for more days before spoilage.

Design language of the product

Figure 32 shows inspirational pictures for desired aesthetics of Backie. The product should be fairly simple, yet powerful. It should express quality and confidence to the user, so there is no doubt about the safety of the product. High contrast can be used for highlighting the use cues in the design.

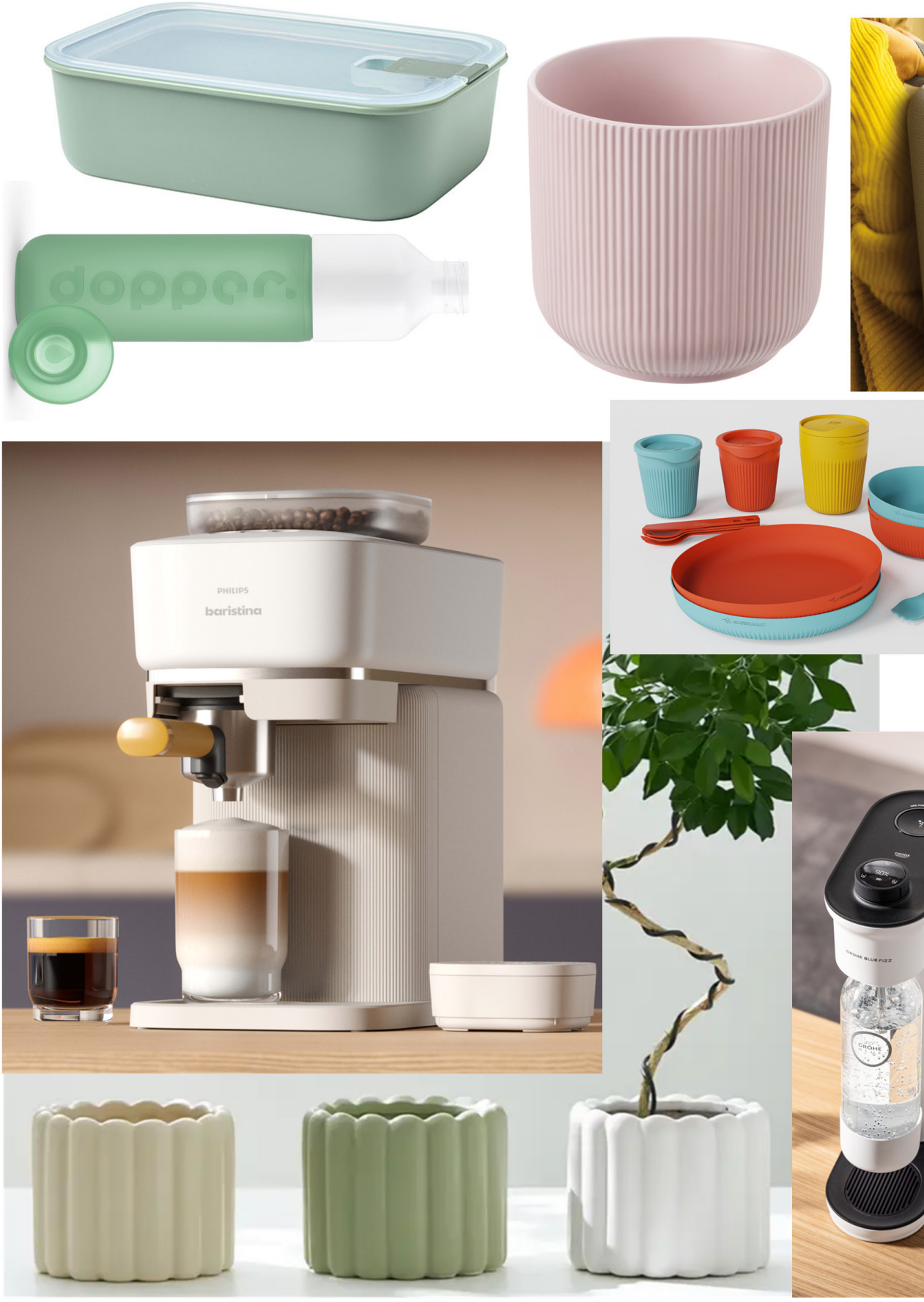


Figure 32: Inspirational products


LARS NYSØM
LARS NYSØM

Chapter 4
Concept development

The main goal of the concept development is to test and validate the various ideas and iterate on the design of Backie. Prototyping the concept results in a physical representation of the idea, it shows potential flaws in the design and offers the opportunity to develop the idea into a real product by testing. This chapter shows how the concept of Backie developed from the initial idea up to the final version that will be used during the user evaluation.

Backie concept

General prototyping

The main goal of the prototyping was to test the most essential parts of Backie, as there were simply too many parts to design. The prototyping was done by focussing on the outer shell, the silicone bowl, the lid, the date tracker and the general working of the concept. Things like the cooling element, cutlery and vacuum pump were designed based on / substituted by existing products, to be able to focus on the most important and challenging parts of the design. The start of the design process continues with the preliminary design in mind.

Prototype 1

Figure 33: Prototype 1

Dimensions

The original dimensions were chosen to be 210 x 160 x 91 mm these dimensions were chosen based on yet existing products and with the idea in mind that there would have to be enough volume to store a sizeable leftover in the container. The dimensions are big enough for a leftover which would be a sufficient portion to eat as a full meal. The products' dimensions are quite compact for the functions that it offers. The dimensions grew a little compared to the initial model, this was to accommodate for the dimensions needed to have the silicone bowl sufficiently strong.
Due to limitations concerning the dimensions of the Ultimaker 3D printers in the PMB faculty workshop, the design was made in a 90% scale dimension.

Materialization of the concept

This concept prototype was made primarily with Polyactic Acid (PLA). This is different to the actual material that will be used in the container, because this will be polypropylene (PP). Polypropylene is widely used as the main material in food containers. Therefore the product looks a little different to the imagined product, as it would be impossible to integrate the clamps in the lid as they would simply break off. Because of this, separate clamps were made to be able to close the product anyways. Other materials that have been considered to use are tempered glass and stainless steel. However, glass would reduce the durability in a product that moves around a lot and would weigh significantly more than Polypropylene. Certain types of stainless steel are also safe to use in a microwave and their application was considered. Due to limitations with the design possibilities and the thermal conductivity of the material the performance of the cooling capabilities would be influenced and user experience could be impacted.

Silicone is the perfect material to use for the inside bowl. It enables the part to be used in the microwave but most importantly also in the oven. The other benefit of using silicone for this part is that the inside bowl and gasket can be integrated into one part, which reduces the overall amount of parts needed for the product. As the silicone inside layer is essential to the products intended performance it was important to prototype with this material as well. Therefore a mould was 3D printed and silicone was poured into this mould to create the part. This worked quite well.

The first design as made with so called shore 15A silicone, which is a very flexible silicone but very widely used in food related products.

Figure 34: All produced parts of prototype 1

Design

The design of the first prototype was inspired by the pictures found on the inspirational product collage. Rounded edges and soft shapes were used in combination with strong lines. The whole design was made with respect to injection moulding techniques and principles. For example, all the shapes are producible with just two mould parts and were designed with draft angles in mind.
The bottom of the outer shell was optimized for placement of the cooling element, with a little raised rim to limit contact area with the bottom of the outer shell. This was done to prevent unnecessary heat transfer between the cooling element and the ambient environment. It essentially worked as an insulation layer. Next to this small protruding corners are added to limit movement of the cooling element.

Silicone bowl

The silicone bowl was designed by merging a bowl with the gasket, keeping in mind that there should be a gap in between this part and the outer shell for the insulation layer of air. The design was reinforced by implementing ribs on the short side of the silicone bowl, improving rigidity and limiting flex. The shape of these reinforcements was made based on the design collage and trying to increase the cross section of the part. The part was made with 2mm wall thickness, with a maximum of 3.5 at the high points of the reinforcement ribs.

Date tracker

The date tracker was shrunk down as the sizing of this part in the preliminary design was way too big. In addition to this, the date tracker was moved from the clamp on the lid and implemented in the design of the outer shell by adding a slot in which the date tracker would slide into. This would hopefully help with the durability of the part and help size down the clips of the lid. The smaller the clips the less likely it is they are opened accidentally by getting stuck.

Evaluation prototype 1

The first version of the prototype showed some flaws in its design. These problems were mainly focussed around the silicone inside bowl. This inside layer was not strong enough to keep its shape under load and would 'drop' into the outer layer if the cooling element was not in place. In addition to this, it also made it more difficult to properly seal the container as the silicone part would be pulled into the Backie and compromised its seal. For this reason, in the next prototype another "shore" of silicone will be used to counter this problem.
The silicone part would move around but is also not that easily grabbable to lift out of the inner shell, so there should be some adjustment to make it easier to lift this part out of the container.
Besides this there was an incongruence in the design language from the inside layer compared to the outside layer of the Backie. The inside layer had big ribs while the outside shell had smaller ribs as a texture. This was not only ugly but also gave a more harsh appearance.
Bearing in mind that the current prototyping medium is not capable of producing flexible parts, the alternative clamps were working fairly well, providing an okay fit to the product and sealing it neatly.
Even though the cutlery fits in the 'lost' volume of the insulating layer, there might be more convenient ways to store the cutlery below the silicone bowl with the food. Prototype 2 will look into this problem a bit more.

Prototype 2

Figure 35: Prototype 2 and silicone bowl design 1 and 2

Silicone bowl development

The second prototype had a different shape of the silicone bowl to improve its strength on this tension. The wall thickness was increased from 2mm to 3.5mm and additional ribs were added to improve the rigidity of the silicone bowl. The maximum wall thickness increased to 5.5mm on the places where the ribs were at their maximum. Additional to the new features, another type of silicone was tested which was a far less flexible version which would hopefully limit the amount of flex of the silicone bowl. This silicone is the so called "Shore 40A", which is flexible, but strong and its consistency is comparable to the eraser on the back of a pencil. To improve the ease of placement, little tabs are added to the corners to line up the silicone layer more easily with the outer shell.
In addition to these changes, the outer shell was adjusted with a little rim around the perimeter in which the silicone part would be locked in place better. This little rim of plastic prevents the silicone bowl from slipping into the outer shell, as it grips into the profile of the silicone gasket. The additional benefit of this rib is that it is easier to align the silicone part with the shell, which makes it easier to use.

Outer shell design

Some changes were introduced to Backies appearance. The outside layer was changed from a pattern of little ribs on the outside to larger ribs which resembled the ribs found on the inside on the silicone part. By doing this Backie has a more coherent design language compared to prototype 1. This also made the design more calm as less is going on on the outside.
Due to the new 'corner tabs' of the silicone bowl, the lid was adjusted to prevent these protruding tabs from getting caught on other things, which might induce premature wear and tear of the product. This was done by implementing 'bumpers' in the lid which followed the shape of the silicone bowl, which protect the silicone.

Cutlery placement

Prototype 2 also had new options to store the cutlery that comes with the Backie. 2 versions were made and tested for evaluation of its convenience and user interaction. 1 of the versions had cutlery that was clipped on the lid of Backie whilst the other had a cover in the lid to store the cutlery in. After some testing it turned out that this was not really the desired appearance of the Backie and with some clever packaging it is also much easier to implement the cutlery in the 'lost' space due to the insulating layers.

Cooling element

Research showed that using water in microwaves is not ideal. This would be a problem in case the cooling element was forgotten during the preparation in the oven or microwave. When water is put in the microwave there is a chance of it superheating. Meaning the water will go beyond its boiling temperature. This can cause an hazard if the water tension is broken and can possibly be dangerous to the user or result in damage to the product.

There are a few options and alternatives to cope with this in Backie.

First of all, studying similar products showed that multiple other food containers with a cooling element would instruct the user not to put the cooling element in the microwave. However, in these products the cooling element would be on top of the food instead of being in the bottom of the container. The invisibility of the cooling element might be problematic for this.

Secondly, another material could be used as a cooling element, water is used because of its low density, high heat transfer and heat capacity. Unfortunately are other materials almost always more dense, more expensive or unable to be used in the microwave. An option could be to use heat/cold gelpacks, which are suitable to be used in the microwave for brief moments.

Prototype 3 will be incorporating this finding by warning users about the presence of the cooling element, but the cooling element will remain in its place for now as other products have the same solution. To remind the user of the cooling element, warnings will be embossed both on Backie and on the cooling element.

Prototype 3

The third and final prototype will be used for the user evaluation. This prototype was mainly a iteration of prototype 2, focussing on getting the details right. Another bump was made on the silicone bowl to lock it in place even better and the lid was adjusted accordingly with new bumpers to protect the silicone from getting stuck on things during transportation. The lid got the product name "Backie" embossed on it and was adjusted to have an improved seal with the silicone. Besides this some user instructions were embossed on top to prevent user error by giving instructions about the usage and warn the users about possible hazards. Besides this, on the bottom of the outer shell in each corner a little bump was made to prevent the product from sucking vacuum to a tabletop. These little bumps suspend the Backie and limit the points of contact with the surface underneath.
Finally, the dimensions of the date tracker were adjusted for a better fit in its' slot in the outer shell.

Figure 36: Prototype 3 (final prototype)

Prototype 3 will be used to evaluate the design of Backie with its intended users, resulting in accurate feedback for improvements.

Sizing of the product.

The prototypes were made on 90% scale to fit on the available 3D printers in the PMB. However, the size of the product at 90% scale was already somewhat on the bigger side, while the actual product would be even bigger. After consideration it was decided that the 90% scale was actually a good size and therefore the final model will be adjusted towards these dimensions.

The next spread will show a timeline of each prototype and its iterations.

	Outer shell	Lid design
Preliminary idea		
Version 1	 Date tracker +exterior design + cooling element preparation	 Cutlery in Backie
Version 2	 Exterior design update + ridge along rim for silicone bowl placement	 Cutlery on top of Backie in separate box  Cutlery on top of Backie clip on lid  "Bumpers" to protect silicone bowl from getting stuck on items
Version 3	 Finetuning ridge along rim for silicone bowl placement	  "Backie" product name and warnings about usage on lid Iterations sealing ribs of li

Silicone container	Prototype
	
 Shore 15A Ribs along width for strength	 Backie version 1
 Shore 40A – stronger silicone Ribs in both directions for strength Increased wall thickness Overhanging corners for better placement	 Backie version 2
 Shore 40A Extra overhanging parts for limiting movement + easier lifting	 Backie version 3

Prototyping process

The prototyping made use of two different methods, 3D printing and silicone pouring. These techniques were applied to make a physical prototype of Backie.
The parts that are white on the prototype are made of 3D printed Polyactic Acid (PLA) plastic. Multiple parts were made using this material and it gave a good impression of what would be possible with more conventional large-scale production methods. Even though FDM printing is very different to injection moulding, the parts were designed with injection moulding in mind.

The downside of such a (relatively) big product is that it takes a fair amount of time for a 3D printer to produce the part. Some of the parts, for example the outer shell took close to 40hrs to be printed on the 3D printers in the PMB. The upside of this method of prototyping is that it is possible to create high-quality parts with decent accuracy. Small iterations are relatively simple to make by adjusting the corresponding SolidWorks files. However, 3D printing is also highly reliable on the printers itself. During the long time the printers are working on the parts there is a high probability that something goes wrong. As a result it has happened that some parts failed and there'd be a day's worth of delay in the process.

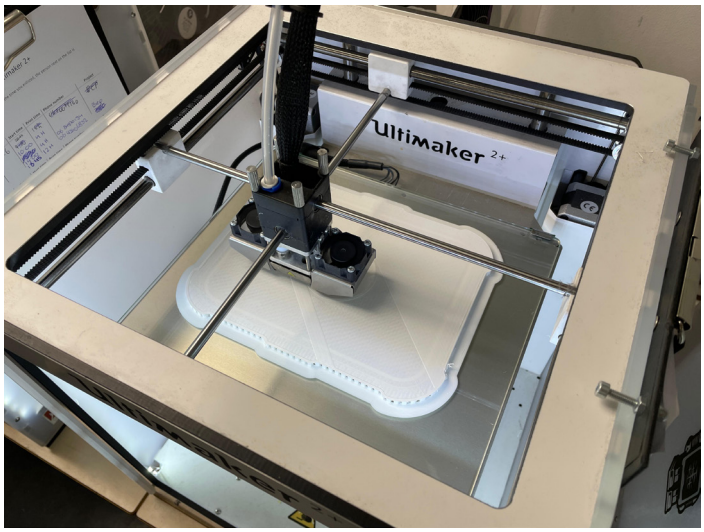


Figure 37: 3D printing with PLA

Next to the PLA parts there is a silicone inside bowl in Backie. This silicone part was essential to the overall working principle of the concept and therefore it was very important to start testing with this material as soon as possible. Silicone parts are usually made by using a mould to pour the silicone into after which it cures to a solid piece of silicone.

The moulds were made by 3D printing PLA in the mould halves which the two parts of the mould would leave a hollow volume which fill up with silicone for the actual part, as visible in figure 38. The production of the moulds was very time-consuming as the parts would easily take up 76hrs of printing. Therefore the moulds were produced during the weekends to save time during the week.

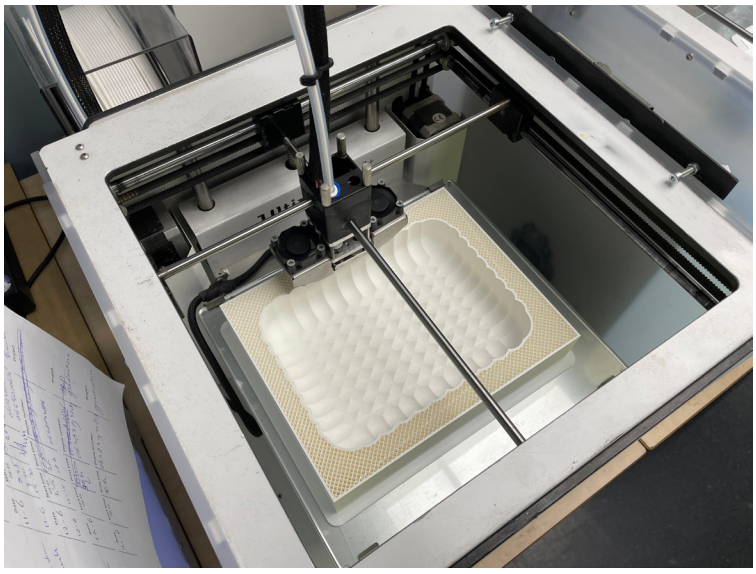


Figure 38: FDM 3D printing of silicone mould

The process of pouring silicone (figure 39) is very interesting and labour intensive. The two components must be weighted carefully and mixed by hand for 5 minutes. This must be done without introducing too much air in the mixture as this will compromise the quality of the part. After mixing, the silicone is placed in a vacuum chamber to remove the residual air out of the mixture. This step must be done twice after which there should be minimal amounts of air left in the silicone. The curing of the silicone starts the moment when the two components are being mixed. The working time is approximately 30-45 minutes so speed is critical for success.

The pouring must be done carefully and with a lot of patience to make sure there is no air trapped in the mould to prevent incomplete parts after curing. To speed up this process the mould was placed in the vacuum chamber to expel the air more quickly before the silicone started curing. The complete curing of the silicone takes several hours and it is best to leave it curing for up to 48hrs before opening the mould.

Figure 39: Silicone parts and production

Even though my best efforts I still managed to have some trapped air in the mould during the silicone pouring. However, one of the great benefits to using silicone is that it can be poured in multiple parts. This means that it is possible to fill up the air bubbles with new silicone once the first pour has set, as long as the same type of silicone is used and the part is free of dust and grease.
In the end 3 versions of the silicone bowl were made, of which two very different versions and one iteration of the second version.

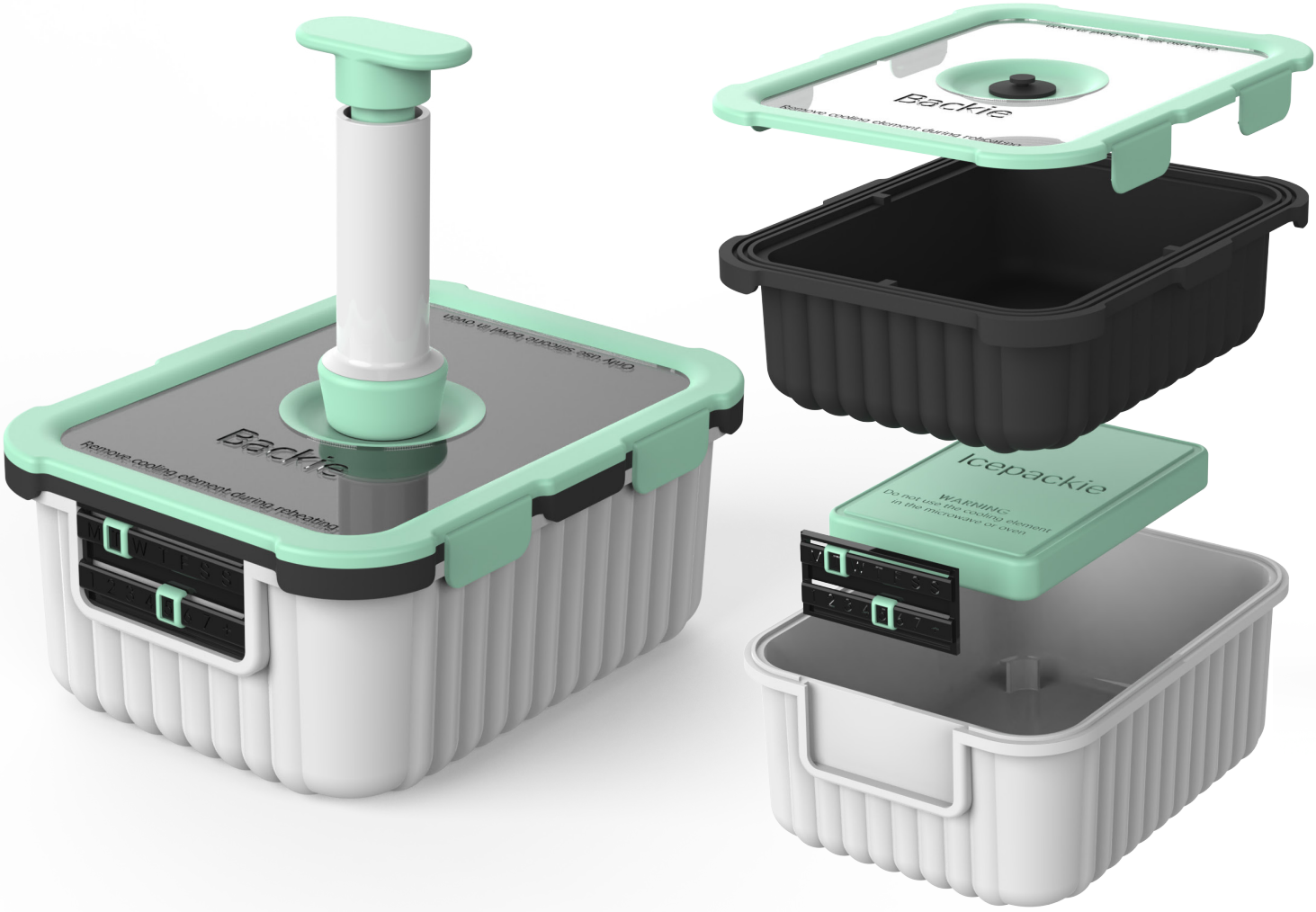
Prototyping was focussed on making the important parts work. The attributes that make up for the concept of Backie were made and developed while non-essential parts were deliberately left out to save valuable time. For example, for this prototype an “off-the-shelf” cooling element is used whereas in the final product a custom cooling element will be used. In addition to this, there is a wish for separating various parts of the food. The idea for this is to add smaller inserts in the silicone bowl, the design of the silicone bowl was made with this in mind.

Chapter 5
Final design

This chapter introduces the final design of Backie, and shows the intended use of the product by the consumer. The parts and their working is explained to get a real understanding of each individual part to the product.

Design proposal: Backie

Leftovers after cooking is a well-known phenomenon in the Dutch households. After preparation of the meal the leftovers are thrown away or saved to be consumed at a later moment in time. However, time starts ticking for the freshness and food safety of the leftover once it is placed in the fridge. People fail to indicate when to consume the leftovers as they are an unforeseen byproduct of cooking, and the leftover is neglected or forgotten until there is no doubt that the leftover has spoiled.
These issues are hopefully being resolved by Backie, by stimulating and enabling consumers to use their leftovers on the go more easily. Additionally, Backie helps to track the production date and stimulates consumption of the leftover.



Store it in a Backie!

Backie

The product is not just any food container that is currently available on the market. Backie has a wide array of functions and possibilities integrated in the design to make it more capable in battling food waste than other food containers. Backie is not only the place to store leftovers and prolong their freshness for consumption, but also enables the user to consume their leftovers in a broader possibility of scenarios and makes it easier to use leftovers for lunch.

The food container can be used to store leftovers for several days in the fridge. To extend the lifetime of the leftover, Backie has an airtight plug that can be used to create a vacuum in the container. Due to the absence of oxygen, the food will deteriorate slower and the leftover remains edible for a longer period.

The most eye-catching exterior feature of Backie is the date tracker, which can be used to indicate when the leftover was produced and for how many days the food should be safe for consumption. The high contrast of the sliders attracts the attention of the user and will give them a quick overview of the lifespan of the leftover. The date tracker tackles the problem of consumers that forget about when the leftover was created, and helps them to identify the freshness more easily.

Secondly, but equally as important, is the inner container made of silicone. The silicone inner container makes Backie versatile and easy to use. Because of the usage of silicone, Backie is able to be used in the microwave but also in the oven. This gives the user more options to prepare the food but also makes it less of a hassle with other things needed to prepare the food, as Backie can be used to prepare the food in.

With its outer dimensions of 196 x 151 x 82mm it is a sufficiently sized food container for storing leftovers while still remaining compact and easy to transport. Bearing in mind all the features that it comes with this is a real compact package.

Backie is the all-in-one solution to store the leftover, identify its freshness and taking it elsewhere for consumption on the go!

Parts

Outer shell

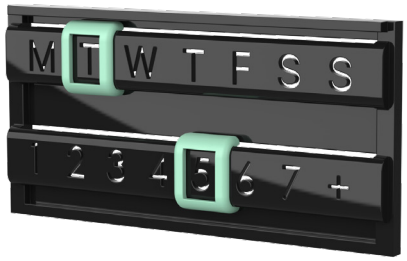
The outer shell of Backie is what will be seen most by the owner. It has a clean and modern look, without being boring due to the wavy pattern used in its design. The outer shell is made from white polypropylene plastic which is a robust and strong material. The outer shell also functions as the casing for the date tracker, which makes it easy to remove for cleaning. Finally there are also placeholders for correctly placing the cooling element and lifting it from the bottom to prevent unnecessary heat transfer.

Silicone bowl

The silicone bowl is what makes this food container different to other food containers on the market. The silicone bowl is the actual part where the leftover is kept in, and has a volume of 875ml.
It is made from shore 40A silicone, which is food-safe, can be used in the fridge and freezer and is usable in the microwave and in the oven up to temperatures of 200 Celsius for longer periods or 300 Celsius for short periods of time. Its shape is reinforced to be stiff enough so it does not lose shape. Furthermore there are tabs for easier placement in the outer shell and lifting the bowl out to prepare the leftover.
The silicone bowl is not only the part that holds the food but it also functions as the gasket for an air and watertight seal of the product, resulting in less parts needed in the final product. Together with the outer shell it creates a insulating layer to keep the leftover fresh for longer periods of time. The bumpers integrated in the design help with aligning the silicone bowl and the outer shell. Furthermore it secures the silicone bowl from falling into the outer shell under load.

Date tracker

The date tracker consists of three parts, one baseplate and two sliders. The baseplate is designed to house two sliders. The first can be used to mark the day on which the leftover was saved in the Backie, while the second slider can be used to indicate the amount of days the leftover will remain safe to be consumed. These parts simply snap-fit on each other and the subassembly is housed in the outer shell. The date tracker and sliders have high-contrast colours to increase the visibility of the feature.



Icepackie

The cooling element in the bottom of the outer shell is called Icepackie. It is a cooling element which ensures passive cooling during transport of Backie. User instructions are located on the upper side of the Icepackie, being embossed in the design for long-term readability.

Lid

The lid is made from transparent and coloured polypropylene. The clips to securely close off the Backie are integrated in the design. The lid is partly transparent to give the users a way to quickly visually inspect the leftover that is stored on its freshness. User instructions and the product's name are embossed in the lid.
The clips that close the Backie are integrated in the lid and when closed, they are protected from accidental opening by the bumps in the design.

Vacuum pump and plug

The vacuum pump can be used to create a vacuum in Backie. By placing the pump on the plug, located in the lid of Backie, oxygen can be removed to preserve the food for even longer. Due to absence of oxygen, bacteria and other microbes are inhibited in their growth.

Cutlery

The cutlery can be stored in the empty space below the silicone bowl. This was chosen as the best solution to give the consumers the option to store the cutlery inside Backie so it is not loose from the product, but also does not get dirty. The unforeseen benefit of this placement is that consumers should be reminded to remove the cutlery and simultaneously remember to remove the cooling element.

Materialization

All materials that are used are food-safe and thus suitable for application in a food-related product. Almost all of the parts are made with Polypropylene (PP) plastic, which is easily manufactured by injection moulding. Polypropylene is safe to be used in a dishwasher, fridge, freezer and safe for microwave usage.
The inside bowl and the airtight plug in the lid are made from silicone rubber. The used silicone is of the type Shore 40A, which is stiff yet fairly flexible. These parts share the same qualities mentioned with the Polypropylene but with some added benefits. Silicone is safe to use in the dishwasher, fridge, freezer , microwave and in the oven up to temperatures of 200 degrees celsius sustained heating or 300 degrees celsius for brief periods of time.

How to use Backie?

Backie can be used as a regular food container with just one minor difference. Because Backie was developed to have two walls with a layer of air in between it is important to consider the thermos insulation when placing hot food in the fridge. It is therefore important to first let the leftover cool down if necessary before placing it in the fridge. Todays' day can be marked and the assumed lifespan of the food can be adjusted on the date tracker.

When Backie is used to bring food to the workplace, the user simply opens Backie, lifts out the silicone part and places the frozen icepack underneath the silicone bowl. This ensures longer refrigeration on the go and thus safekeeps the food safety of the leftover in Backie.

The frozen icepack and cutlery need to be removed before reheating. After that either the complete Backie can be placed in the microwave OR only the silicone inner container can be used for oven usage. The silicone bowl can be placed back in the outer shell for safety and maintaining a warm meal for longer, due to the insulating effect. The included cutlery can be used to eat the leftover directly from Backie. After the meal all the parts of backie can be put together and the entire product can be stored safely upon returning home where it can be cleaned for new usage.

User scenario

There are two main types of envisioned user scenarios for Backie. The first one focusses on taking the leftovers elsewhere. The second scenario focusses on its' use inside the house, showing its functionality as a conventional food storage container.

Scenario 1: Bringing my leftover to the workplace/university

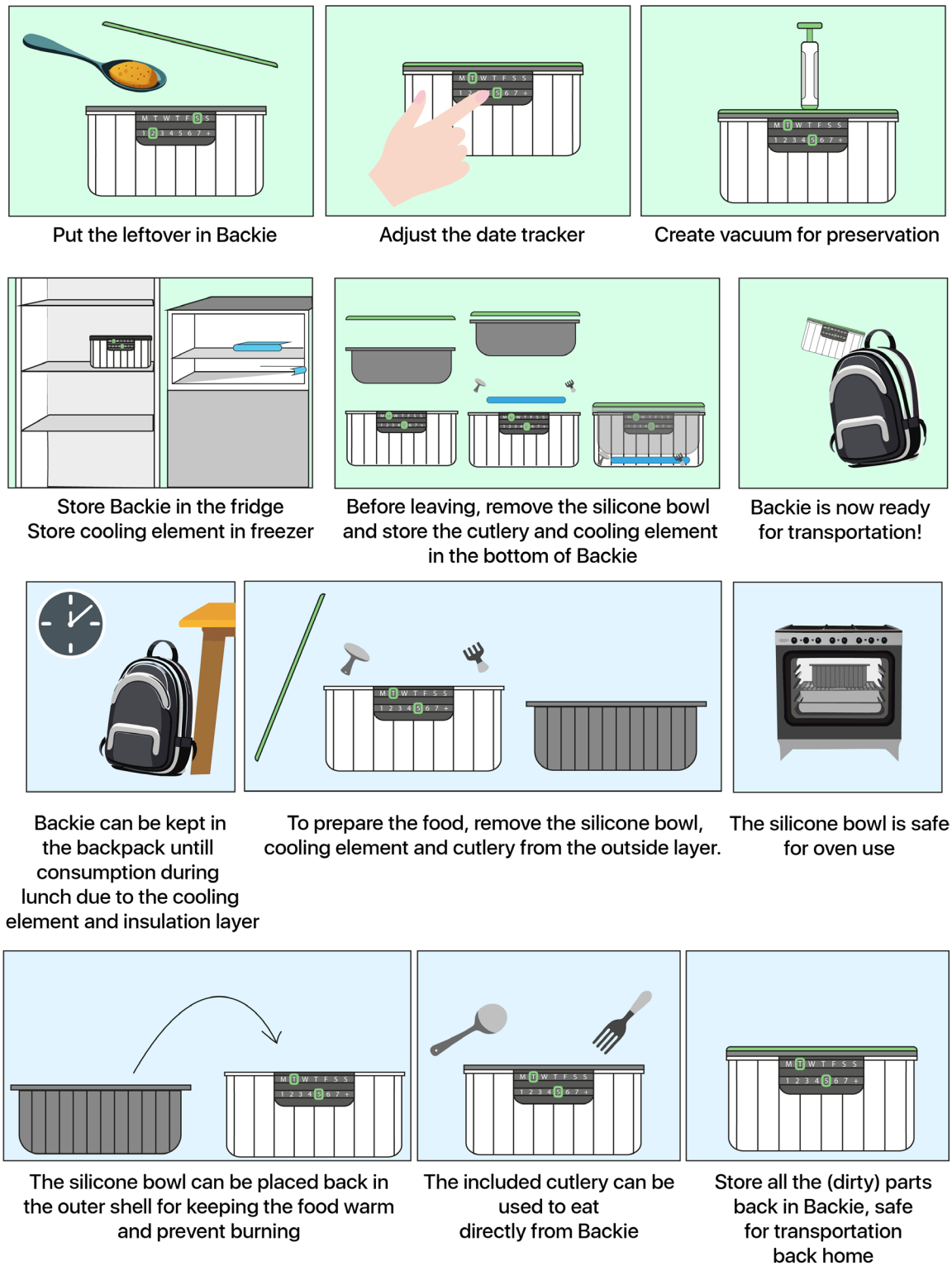
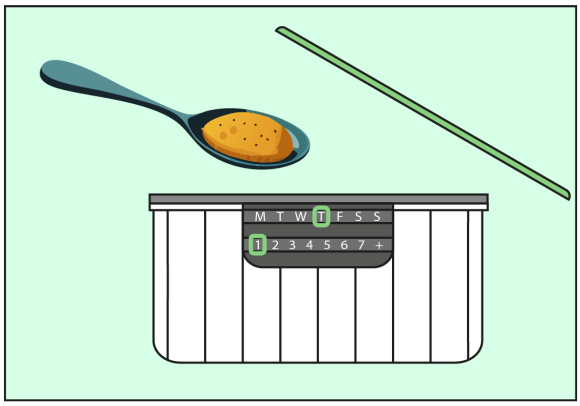
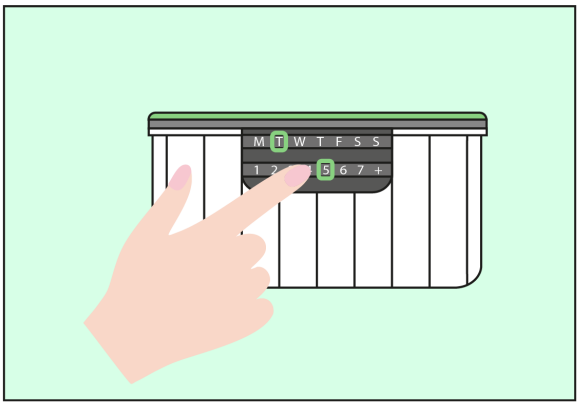


Figure 40: User scenario 1

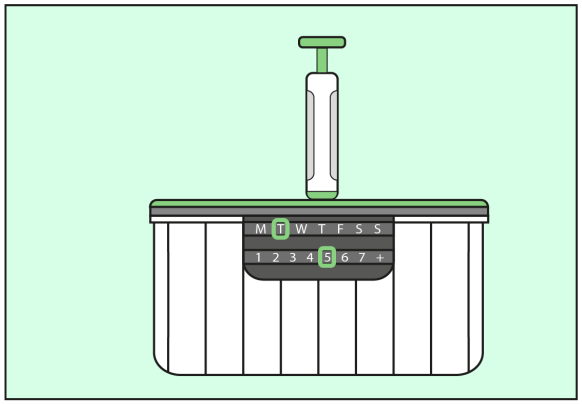
Scenario 2: Saving my leftover for later this week



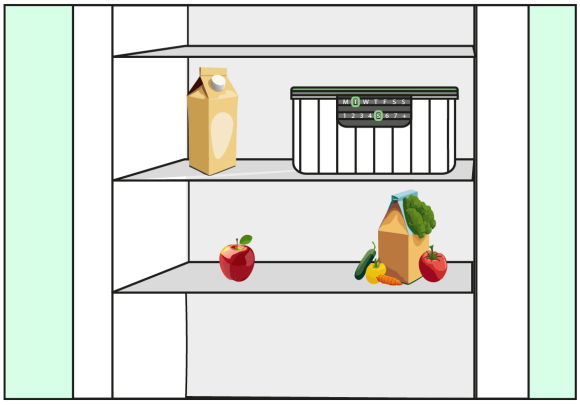
Put the leftover in Backie



Adjust the date tracker



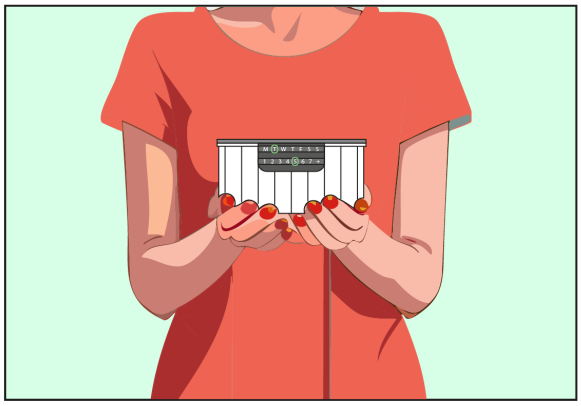
Create vacuum for preservation



Store Backie in the fridge

Later that week

Seeing Backie in the fridge
Noticing the date tracker and realising the leftover is about to expire



Choosing to eat the leftover in Backie

Figure 41: User scenario 2

Chapter 6
Evaluation

User evaluation is essential to measure and test the products' performance and interactions on the goals set by this project. To test whether the design will make an impact as intended by the assignment, an user evaluation test will be performed to get an insight into how Backie is perceived by its' intended users. Based on these findings a final conclusion can be drawn with possible recommendations for further development of Backie.

User evaluation

To evaluate the usage of Backie with the intended users, the 'Product usability evaluation'-method of the Delft Design Guide will be used. Participants will be asked to perform a series of tasks to see the quality of the design and its potential flaws. The outcomes of this user evaluation will function as input for the redesign and/or recommendations.

Research questions

What is the initial impression of the product?

Is Backie changing the way consumers use leftovers?
Will they use the leftovers more often?
Are they able to identify the freshness more easily?

Do the users foresee problems in the usage of Backie?

Is the interaction of the product logical?

How is the product experienced?

Setup

The participants will be selected based on the intended user group as described, 18 to 40 years of age with various household compositions. These participants will be family and friends that have not been involved in the design of Backie so far, to prevent unfair prior knowledge of the presumed interaction. To start the interview the user is handed the physical prototype and is asked to perform a series of tasks in their own kitchen at home and will be monitored by the researcher for observation. The usage will be simulated by pretending the user has created a leftover during cooking and is asked to save it up for later, using the prototype. The prototype is handed disassembled to show the various parts of the prototype. The user has to use the product as they assume to be correct.

First they are asked to save the leftover in the fridge, using the Backie and consequently they are asked to prepare Backie for transport and bring the leftover elsewhere to consume. Finally they are asked to 'heat' the leftover in the oven or microwave and consume it.

Finally a render of the final product will be showed and additional questions will be asked to complete the interview. The PreMo tool (Desmet, 2019) will be used during the evaluation to support the interaction experience.

Understanding the prototype

The first impressions of the product were all very coherent, the participants all saw a clear product made for storing leftovers and/or food. They liked the general appearance of the product and immediately noticed the date tracker on the front of the Backie. The outer shell and its design suggests that it is a very sturdy product and was very confidence inspiring for bringing leftovers elsewhere. The design was perceived as simple, clean and modern. The 'high-end' shape of the outer shell gave the feeling that it was not just any food container, but a more premium product.
Upon handing over the prototype for further inspection, the first thing that became obvious was that the silicone inside layer was different to other food containers on the market and made the users curious about the function. They all put the "leftover" in the silicone bowl as a result and no one has put the leftover in the outer shell.

Figure 42: User evaluation test with participant no. 4

During the interaction with the product, all the participants placed the prototype correctly in the fridge, with the date tracker facing towards the user for easy viewing. Besides this, as the scenario implied that the leftover would be used for consumption in 2 days at work, the participants all separated the cooling element from the Backie and put it in the freezer. Except for participant 2, who said that the small cooling element (of the prototype) would not make much of a difference in keeping the leftover refrigerated and chose not to use it at all, as he did not care about cooling on the go. The placement of the cooling element below the silicone bowl was not the most logical placement according to the participants. There were doubt about the fact you have to take out the silicone bowl every time and how this would hold up in the long term. It did however seem to have the benefit that the cooling element would remain clean and could be bigger compared to other placement options. All participants were successful in placing the cutlery below the silicone bowl, however, due to the lack of a dedicated spot in which the cutlery would be placed, it moved around and interfered with the placement of the silicone bowl. During the test a standard cooling element was used to simulate the actual cooling element in the final product, but this was significantly smaller than the products' cooling element, this might have played a role in the placement of the cutlery, as there is more room than needed.

As for the simulation of the preparing of the leftover, all the participants were successful in only using the silicone bowl in the oven. When simulating microwave usage everybody once again only used the silicone bowl instead of the whole product. This was mainly due to the fact that they foresaw the problem of hot cutlery and removed the cooling element anyways. After the reheating of the leftover the silicone bowl would be placed in the outer shell, for keeping the leftover warm and preventing burning. Two participants indicated that it would be a perfect placeholder to prevent spillage or burning the table.

The sizing of the prototype was perceived as somewhat large, but was deemed logical due to the additional features that the product has. Besides this, participant 3 mentioned that the prototype was relatively heavy, even without the leftover inside. On the other hand, participant 2 was very positive about the sizing, and mentioned that larger food containers often scale up in width and length, whereas Backie has more height which results in better dimensioning.

Due to the prototype being slightly unlike the final product, participant 2 struggled with attaching the clips to close off the Backie. This was due to the fact that the clips were separated from the lid, compared to the final design of the imagined product. The prototype also negatively influenced the readability of the instructions on the lid which compromised this feature somewhat, as there was not enough contrast to catch the eye immediately. the inscriptions on the lid were not as easily readable as imagined, the two different user instructions on either side are missed at a glance or only one of them is read. It is therefore recommended to have them on the same side and more pronounced.

Two of the participants made the remark that the date tracker is a good addition, but it is essential to have a tool or instruction to determine the amount of days that the leftover will be edible for.
The participants were positive about the way Backie might influence the way they use their leftovers. The all-in-one solution from storing until preparation and consuming of the leftover made that the product was perceived as possibly impactful to the problem of food waste. It took away the problems associated with bringing leftovers elsewhere. The addition of the date tracker made for easier identification of the edibility of the leftover inside, instead of estimating when something is unsafe to eat.

Some of the quotes of the participants upon interacting with the prototype and seeing the renders of the final product:

"It looks like the new Dopper"

"It gives me the impression of a premium product"

"The product looks like a luxury item, more suitable designed for portable usage"

"The date tracker is an useful feature, I forget when leftovers were made very often."

"I would love this for mealprepping"

Interaction experience

The 5 participants were asked to review their interaction experience with the PreMo-method (Desmet, 2019). This was done to review their experience after the usage of the product and how it made them feel afterwards. The PreMo method is used to have more accurate descriptions of the emotions felt by the user.

The results of the PreMo evaluation were as visible in figure 43.

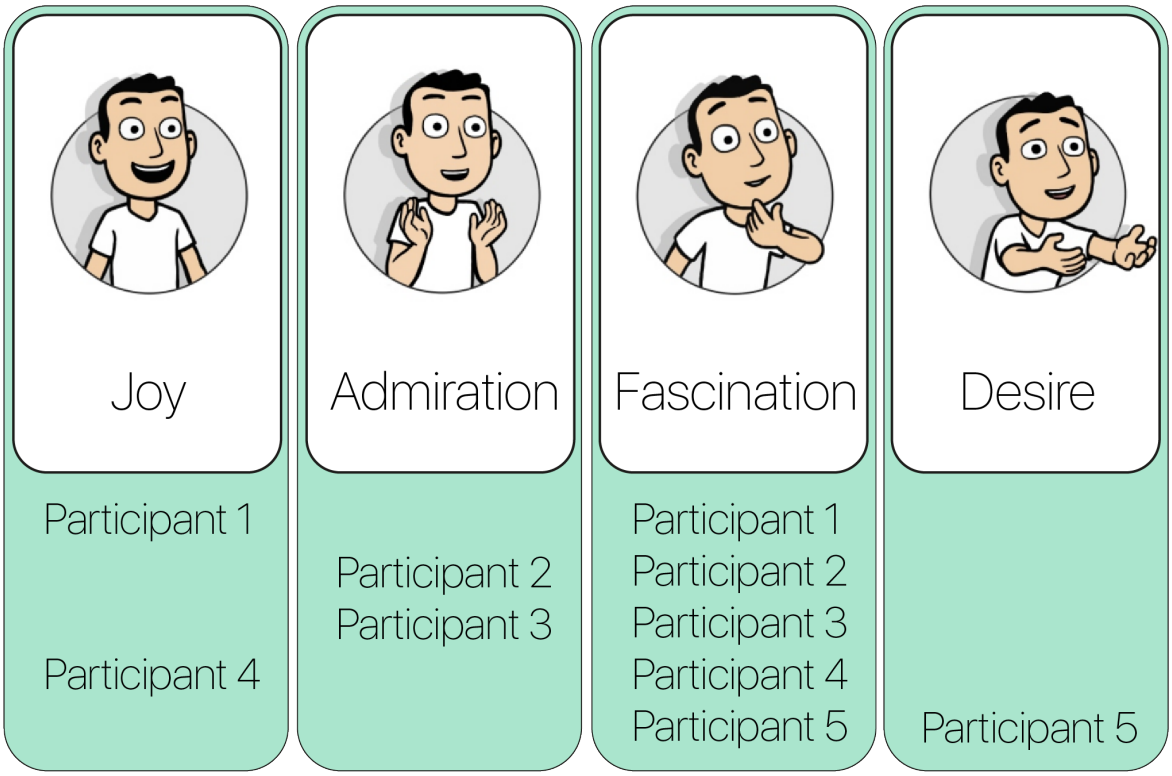


Figure 43: PreMo results

First of all, the most notable emotion was “Fascination”; all of the participants indicated this emotion during the interaction with the prototype. All the features and possibilities that Backie offers evoked this emotion of curiosity. The participants were eager to find out how it worked and what was possible to do with Backie. The other emotions, Joy, admiration and desire illustrate that the product is perceived very positive by the target group.

Evaluation conclusion

The user tests were conducted to find flaws in the design of Backie. The overall design of Backie is good, while there are some details that need some more attention. The details include for example the readability of the instructions and a more pronounced spot for the cutlery. Dedicated spots for the cutlery can improve the user experience as they can be securely put away instead of moving around in the free space a lot. A product flyer would help to get familiar with the product and how the functions work. Additional (basic) information about the expected leftover shelf life based on the product would help determine the maximum storage time more accurately, a flyer or informational folder would be sufficient for this.
Some of the features needed some elaboration on how they worked, but after it was explained the usage was self-explanatory. Therefore it is recommended to develop a user instruction for the first time of using the product, after which all the functions, do's, don'ts and interactions should be familiar to the user prior to usage.

Limitations of the study

As the prototype of Backie is made with different materials compared to the actual proposed design there are a few differences between the prototype and the final design. This is both in materialisation and in physical attributes. For example, due to the fact that the prototype is 3D printed, the prototype has a different closing mechanism for the clamps compared to the 'actual' product. This influences the reliability of the closing power of the Backie as of the prototype and possibly influences the way the product is perceived by the user.
Besides this, the materials used in the prototype also compromise functions of Backie, as the lid is not transparent as portrayed in the renders. Finally, as there is only one prototype which has all the attributes as wanted, there is a certain carefulness needed during the handling of the prototype and the interactions done with it.

Product assessment

This paragraph will discuss the products' potential to be successful based on an analysis of the feasibility, desirability and viability of Backie.

Feasibility

The production of Backie is very likely to be realistic. The materials used for the design are deemed to be conventional as there are numerous products made of polypropylene on the market. The design of Backie was made with injection moulding in mind, making it possible to create each part with 2 mould halves. Therefore it should be no problem to produce Backie with a large-scale production method. Determining a realistic price for the product is difficult at this point in time. This is mainly due to the materials that have been used, more specifically the silicone rubber that is used in the silicone bowl. As the prototyping was done with a small quantity of silicone, the price was significantly higher than a mass-production part would be priced at. Based on the competition with (somewhat) similar products, a product pricing of around €25,- to €30,- would be realistic to strive for. To limit production costs it is possible to make use of buy-in parts, such as the cooling element and cutlery, with a possible reduced user experience as a result.

Desirability

Sustainability is becoming increasingly more important to consumers. A product like Backie might be exactly what the consumer is looking for to reduce their food waste. The various attributes of Backie make for a very versatile product which can be used in a wide array of scenarios. If the price is realistic and not too high it might become a very desirable product. The interaction with the target group during the design process should have resulted in a product that fulfils the needs and wishes of the target group, and therefore a desirable product for the intended users. The user evaluation showed that this product will enable people to identify the freshness of leftovers more easily and allows them to bring them elsewhere more safely and convenient. It has all the features the user group could wish for and therefore hopefully change the amount of leftovers that get wasted. However, the long term effect on the behaviour is not proven and should be evaluated in further research.

Viability

As said, there is a lot of competitors to Backie on the market. The market is quite saturated, but there is always room for innovation. The additional features to Backie like the silicone inner layer make it possible to use the product more versatile and therefore it has some big benefits compared to the competition. There is no competitor that includes all the features that Backie has. The user research showed once more that the additional attributes of Backie contribute to a better user experience. Users were enthusiastic and liked the additional features, which they indicated would make them more likely to use the product.

Evaluation list of requirements and wishes

Backie complies to all the requirements and wishes that are named in the list of requirements and wishes. The original concepts were generated with these requirements in mind, but the translation from concept to final design should still comply.
The current prototype is somewhat limited in testing these requirements for multiple reasons. In theory all of them are met with the design of Backie, yet a near-production prototype will give the final answers on matters like the cooling performance on the go and pricing of the product. This is visible with the "Yes(?)" remark instead of a normal "Yes".
Things like the internal volume of at least 700ml is met as Backie has an internal volume of 875ml. Situated below is a checklist of all requirements, and how Backie performs.

Performance

Yes(?)	The product should be durable.
Yes	The product should enable users to take leftovers more easily to other places.
Yes	The product should ideally be safe to both use in a microwave and oven.
Yes	The product should be able to seal its containments airtight for transportation.
Yes	The product should minimize a decrease in food quality during transportation.
Yes	The product should help identify the food quality/safety for the user.
Yes	The product should have an internal volume of at least 750ml, based on competition.

Environment

Yes	The product should be usable in temperatures ranging from -30 to 220 degrees. Fridge, freezer, microwave and oven.

Life in service

Yes(?)	The product should be usable every day of the week, for a period of at least 2 years.

Maintenance

Yes	Parts that are prone to damaging and decay should be accessible for changing parts.

Target product cost

Yes(?)	The product should cost no more than 30 euros, aiming to be as cheap as possible.

Transport

Yes	The product should be compact and fit in a backpack.
Yes	The product should be easily transportable.

Size and weight

Yes(?)	The product should be as light as possible.

Materials

Yes	The product should be made of food-safe materials.
Yes	The product should be made of dishwasher proof materials.
Yes	The product should be made of microwave-safe materials.
Yes	The product should be able to withstand temperatures between -30 to +220 degrees.

Wishes

Yes	The product should have as few parts as possible.
Yes	The product is manufacturable with conventional production techniques.
Yes	The product is aesthetically pleasing.

Project conclusion

This project was brought into life with the goal of reducing food waste in Dutch households, by creating more flexible behaviour during cooking through a physical product. Due to the literature research and close interaction with the target groups in three various in-depth interviews and questionnaires the opportunity of leftover consumption arose. Due to these findings, the scope of the project shifted towards flexible consumption. Eventually this led to the design statement which was described as following:

"I want to reduce food waste by giving consumers the tools and opportunity to make leftover meals more valuable and versatile to use on a daily basis, by making it more user-friendly and convenient to take leftovers with them to consume in more scenarios and environments."

The design statement resulted in a few design directions which eventually resulted in the development of the concept "Backie". The vision of Backie was to create the most versatile, all-in-one solution that would help users indicate freshness of stored leftovers and allow them to bring these leftovers elsewhere whilst safeguarding food safety and making it more convenient to prepare and consume these leftovers.

The design of Backie evolved from the initial idea to the final design through iterations made during the prototyping of the product. In the end, three 'generations' of prototypes were made which resulted in an improved final design. The last generation of the prototype was used for a user evaluation test. The evaluation showed that the design of Backie was fulfilling the expectations of the user group with a product like this, and highlighted some details which might needed some attention.

The user evaluation proved that Backie is likely to make it easier to bring leftovers someplace else for consumption. All the features and attributes of Backie result in a premium product with clear benefits over 'conventional' food storage containers. The addition of the date tracker was perceived as very useful in tracking the food safety and the other attributes like the silicone inside layer helped to improve the convenience of bringing leftovers elsewhere and preparing these for consumption. The all-in-one solution is likely to change the way leftovers are used on a daily basis, and thus make a positive impact on reducing food waste by Dutch households.

The conclusion of this project is as following: The project was aimed at reducing food waste in Dutch households by making consumers more flexible during cooking by means of a physical product. Backie allows users to be more flexible in consuming their produced leftovers, by stimulating and safeguarding food safety and reminds them to use the leftovers in time. Therefore Backie should result in less food waste in Dutch households as there is more possibilities to consume the leftovers in a day-to-day setting.

Discussion

Firstly, the original aim of the project was to make consumers more flexible in their cooking behaviour. This was mostly aimed at using partly used ingredients in other dishes. However, as the project developed other opportunities arose which resulted in diversion of the original aim of the project. Flexible cooking became less pronounced in the aim of the project whereas flexible consumption was more interesting to focus on according to information found during the target group interviews. Secondly, the project focusses specifically on Dutch households. This meant that all the researches performed were exclusively done with people with Dutch nationalities and no internationals. The main reason for this was to eliminate the possibility of different cultural influences interfering with the consistency of the data. The target group was chosen to be 18-40 years of age, singles, couples and families with young children, as these groups are according to research, relatively the most wasteful households.

Even though Backie was developed with the insights of this target group, it is very likely that it would be interesting for other target groups too. The 18-40 year olds are very likely to have busy weekdays but this would essentially extend to the age group of 40-65+ as well. Everybody needs food containers every now and then. Whereas the features of Backie were chosen with bringing the leftovers elsewhere, the date tracker and vacuum function would also be useful features for usage at home. Therefore Backie would be a product that could make a difference across all households instead of only the target group households.

The evaluation of the product was done with five participants from the target group. Due to the nature of the product it would have been interesting to see the influence on the target groups' behaviour regarding food waste with and without the usage of Backie. However, due to limited time and only one functional prototype it was not viable to research this in the user evaluation, especially as behavioural change is not measurable in such a small time frame. Therefore it was conducted as a much faster research with simulating a lot of the actual interactions of the prototype, focussing on the interactions instead of the behavioural change. This highlighted some details in the design which could be looked into for a better experience. It is however still recommended to research the behavioural change in a longer test in the future.

The testing could have been smoother as the prototype that was used did make use of some off-the-shelf parts, such as the cooling element and the plastic cutlery. The prototyping materials impacted the aesthetics and functionality of the product which might have interfered with the outcome of the user evaluation.

In summary, the design of Backie has been tested and shows potential to be a successful product. An iterative process could result in a better product by making changes in the details of Backie. A final test should be done with a prototype with 'close to production'-quality for a more accurate result of the test. Finally a long-term research should be conducted to evaluate Backies impact on food waste and the behavioural change it might inflict. This is currently not yet proven with the prototype.

Recommendations

If Backie were to enter full-scale production the following matter should be investigated in further research. The recommendations are divided in two categories, the actual Backie and more general details which do not directly have to do with the Backie's design.

Backie prototype

Dedicated spots/trays for the cutlery in the outer shell, so they are separated and do not interfere with the placement of the silicone bowl.This was a problem in the last prototype.

Inserts for the silicone bowl to separate various parts of the leftover (e.g. sauce and rice). As the target group would like to prevent mixing of ingredients of certain meals.

Testing placement options for the cooling element and the effectivity of its' cooling capabilities on the go. The effectivity of the cooling element was not tested so far. There might be other ways to include the cooling element to be more visible and prevent user error.

The placement of warnings and instructions on the lid on one side to be more easily readable and enhance user friendliness.

Options for personalisation in colours and sizing of Backie. The current design is very suitable for customization of the product due to the different parts. Other colour combinations would be desirable and could enhance the product experience.

Another (stiffer) type of silicone could result in a lighter product, as dimensions could be altered to minimize weight.

The current prototype was made with injection moulding in mind, however, wall thicknesses were chosen based on 3D printing of the part during prototyping. For actual production the wall thickness can possibly be thinner, resulting in a lighter product whilst remaining strength and durability.

General

An instructional flyer/manual with the product functions and user manual for the basic features would play a role in a quicker understanding of the prototype and its' intended usage.

Information about the shelf life of various leftovers as an indication how long it can be preserved, so users would be able to use the date tracker more precisely.

All instructions are currently in English writing, whereas the target group are Dutch households. It would make sense to rewrite these in Dutch.

Personal reflection

These last few months have been very educative. Graduating can seem like a daunting task when you are starting the project and you have no idea what the outcome will be. For me it has been an unforgettable experience in which I got to know myself even better. Besides graduating from the bachelor, this is the first big project that I have completed on my own without the backup of a supporting team of other students. I have learned many things over the past few months and I think this project has really been able to reflect what I am capable of as a designer.

It was not always flawless and unfortunately I had some hiccups along the way, which resulted in some delay of the actual graduating date. However, I think this delay has really helped me in making something better of the project as a whole. The main delay was in the first part of the project, up to the midterm presentation, where I lacked some initial findings in the research and gaps needed to be filled. I had found a lot of information but did not know how to connect these findings into a dedicated design direction yet, but I still started to synthesize design directions and concepts. Taking a step back from the planning that I had and putting some effort into making the literature research complete helped the project massively. I did another user research and found the missing piece from the puzzle which resulted in the development of Backie as shown in the report. Even though this meant diverting somewhat from the original project brief upon agreement with the client.

The interaction with the client has not really been like I hoped it to be. This is mainly due to diverting from the original aim of the project. Even though this was agreed upon with the client, it meant that there was less input possible. I wish I had handled this communication better and kept the client more involved in the project.

I learned a lot about myself as well. I am proud to say that I was able to identify that I was not going to make the greenlight meeting and asked for some extra time. I was not performing like I wanted and I felt like I had been lacking in my work and as a result I was behind on my planning. The additional three weeks that I got allowed me to make some more iterations and present a prototype that I was proud of and was worthy as an outcome of a thesis project. I think acknowledging this feeling and acting towards this really shows a professional work ethic.

At the beginning of the project I wrote down learning goals which I wanted to explore during this thesis. Even though not every single one of the goals has been touched upon as I wanted, I still managed to learn about each of them. Prototyping on a high level was one of the main learning goals that I had, especially skills in additive manufacturing. As the project was based around the idea of the silicone inside bowl, it was so important to actually make this part and iterate on the design. Working with the silicone has been the most educative part in the prototyping as you are not only creating the actual silicone part, but also the moulds to produce it with. I had no idea that I would be 3D printing moulds from SolidWorks when I started this project, but it has been one of the most complex things I ever 3D printed. I think the prototype and all its iterations are of quite high quality seen the limited time to produce them.

Working with food makes the design more challenging as you have to keep in mind certain aspects during the design. In practice this comes down to the material selection of the product and the properties it should meet. The goal of making a food container that was able to be used both in the microwave and oven made for a limited group of materials to choose from. After some research, silicone turned out to be the favourable material to use.

Designing a logical product really helped me to gain knowledge about the HCID involved during product design. It is not always as straightforward as you think and user input and evaluations are critical to make a logical product.

I think the project as a whole has been very educative and I am proud of the outcome that is presented in this report. I never imagined I would graduate on making a product like a food container, but the more people I tell about it, the more excited I get. The project has been tough at times, but it all worked out in the end.

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Appendix A

Target group interview 1

Food behaviour of Dutch households

Dear participant,

Thank you for taking the time to participate in this study. My name is Tom van Veldhuisen and I am currently doing research into the behaviour of consumers (age 18-40) and their habits concerning food (waste). This questionnaire is part of my thesis for my graduation project of the master Integrated Product Design at University of Technology Delft (TU Delft).

I am currently researching the behaviour of consumers (age 18-40) concerning their behaviour with food and cooking. Small households in the Netherlands are the most wasteful of all groups, with single person households and young families wasting most edible food of all groups. I hope to get insights into why food is being thrown away, or how people prevent this from happening in Dutch households and how this behaviour can be changed.

The results will be anonymously used for this study. The survey will take about 10 to 15 minutes to complete. The last question will offer the possibility to leave your contact details for further questions and to keep track of a food diary.

For further information or questions you can always get in touch via mailing t.w.h.vanveldhuisen@student.tudelft.nl

Thank you and good luck!

* Verplichte vraag

General questions

1. What is your age? *

Markeer slechts één ovaal.

- 18-24
- 25-29
- 30-34
- 35-40

2. What is your gender? *

Markeer slechts één ovaal.

- Male
- Female
- Other
- Prefer not to say

3. How big is your household? *

Markeer slechts één ovaal.

- 1 person
- 2 person
- 3-4 person
- 4+ person

4. What is the composition of your household? *

Markeer slechts één ovaal.

- 1 adult
- 2 adults
- 2 adults + 1child
- 2 adults + multiple children
- 1 adult + 1 child
- 1 adult + multiple children
- Anders: _____

5. What is your educational level? *

Markeer slechts één ovaal.

- Secondary school (middelbare school)
- Vocational education (MBO or similar)
- Higher professional education (HBO)
- University education (WO)

6. What is your monthly (combined) income (approximately) ?

Markeer slechts één ovaal.

- < €2000,-
- €2000 - €3000,-
- €3000 - €4000,-
- €4000 - €5000,-
- €5000 - €6000,-
- €6000 - €7000,-
- €7000,- +
- Prefer not to say

7. Dietary preference *

Markeer slechts één ovaal.

- No preferences
- Vegetarian
- Vegan
- Anders: _____

Doing groceries

8. Who is mostly responsible for grocery shopping in your household? *

Markeer slechts één ovaal.

- Myself
- Partner (female)
- Partner (male)
- Anders: _____

9. How often is grocery shopping done in your household? *

Markeer slechts één ovaal.

- Less than once a week
- Once a week
- 2-3 times a week
- 3-4 times a week
- 5-6 times a week
- Daily

10. How many days' worth of groceries are usually done in one visit to the supermarket? *

Markeer slechts één ovaal.

- 1 day
- 2-3 days
- 3-4 days
- 5-6 days
- 7+ days

11. Do you check your current stock (voorraad) before shopping? *

Markeer slechts één ovaal.

- Always
- Sometimes, but generally I do
- Sometimes, but generally I do not
- Never

12. Why (not) ? *

13. Do you plan your meals before shopping / do you make a shopping list before you go to the supermarket? *

Markeer slechts één ovaal.

- Yes
- No
- Sometimes

14. Why (not) ? *

15. What is most important while deciding what to eat? (1 = not important, 5 = very important) *

Markeer slechts één ovaal per rij.

	1	2	3	4	5
Cost					
Quality					
Convenience					
Health / Nutritional value					
Sensory perception					

16. What do you do when a specific ingredient is not available, or when you forgot to buy it? *

Markeer slechts één ovaal.

- Get it at another supermarket
- Replace it with another ingredient
- Leave it out of the recipe
- Eat something else
- Anders:

17. How long does it take you to get to the nearest supermarket of your choice? *

Markeer slechts één ovaal.

- < 5 min
- 5-10 minutes
- 10-15 minutes
- 15+ minutes

18. Do you make use of online supermarkets like Flink or Picnic? *

Markeer slechts één ovaal.

- Yes
- Sometimes
- No

19. These online supermarkets often have a minimum order value before you can actually order your food. What do you do if you have only one product that you intend to buy and you're nowhere near the minimum order value?

General food waste

20. Do you check for edibility / food safety of open products? If yes, what do you use to make a decision? *

Vink alle toepasselijke opties aan.

- [ ] No
- [ ] Smell
- [ ] Taste
- [ ] Look
- [ ] Check the foods' texture
- [ ] Check the "best before" date
- [ ] Check the product information
- [ ] Anders:

21. What types of food do you throw out most often? *

Vink alle toepasselijke opties aan.

- [ ] Bread
- [ ] Fruit
- [ ] Vegetables
- [ ] Dairy products (milk, yoghurt etc.)
- [ ] Juices
- [ ] Meats and fish
- [ ] Leftover meals (restjes)
- [ ] Anders:

22. Where does food go bad most frequently? (Fridge, cabinet, fruit basket, etc...) why do you think this happens? *

23. What is your experience with / opinion on leftovers (restjes) ? How do you use these? *

24. What do you do with a small amount of leftover food after dinner? *

Markeer slechts één ovaal.

- I throw it away
- I store it in a container
- Try to eat it anyways --> no leftovers
- Anders:

25. What do you do when you have half an ingredient left after cooking? *

Vink alle toepasselijke opties aan.

- [ ] I always use the whole ingredient
- [ ] I save it to use it later / in another dish
- [ ] I throw it away
- [ ] Anders: _____

26. What do you do when your dinner plans change suddenly and you already bought your food? For example, one person more/less has dinner with you or you eat somewhere else instead. *

_____

27. Do you ever have to throw out food because there was an accident during cooking? (e.g. burnt, wrong flavours etc.) *

Markeer slechts één ovaal.

- ◯ Yes, regulary
- ◯ Sometimes, but not often
- ◯ No, never

28. How would you rate your own cooking skills? *

Markeer slechts één ovaal.

	1	2	3	4	5	
Very	◯	◯	◯	◯	◯	Very good

29. Do you think your cooking skills influence the amount of food that is thrown away? Why? *

_____

30. Imagine you are cooking something new, what do you do when it requires a very specific ingredient which you don't really use in other recipes. What will you do with this ingredient when it has a limited shelf life? (E.g. a vegetable like paksoi, ginger or something more exotic)

_____

31. What things and efforts do you currently do to limit food waste in your household?

_____

Storage

32. Do you have a specific way of filling your fridge? Is there a system or standard places for specific products? *

Markeer slechts één ovaal.

	1	2	3	4	5	
No, i	◯	◯	◯	◯	◯	Yes, highly structured

33. Please explain your answer and your motivation why you do this specifically. *

_____

34. Do you use frozen ingredients in your meals, while there are "fresh" versions too? If yes, what is the reason to do so? *

_____

35. Are there products that you will always have in storage? (e.g. pasta, rice, herbs, specific sauces etc.) can you name some? *

_____

36. Do you have a freezer? If yes, what do you store in there? *

Vink alle toepasselijke opties aan.

- [ ] No
- [ ] Frozen fruits
- [ ] Frozen vegetables
- [ ] Frozen meat and fish
- [ ] Bread
- [ ] Ice cream
- [ ] Leftover meals
- [ ] Anders: _____

General questions

37. Do you use recipes for cooking? *

Markeer slechts één ovaal.

- ◯ Yes, always
- ◯ Yes, often
- ◯ Sometimes
- ◯ Almost never
- ◯ Never
- ◯ Only for inspiration

38. Do you like cooking and why do you cook yourself? *

_____

39. Do you buy so-called premade dishes (kant-en-klaar maaltijden)? Why (not)? *

_____

40. Do you buy fresh-packages (verspakketten)? Why (not)? *

_____

41. What type of food is easiest to improvise with? (e.g. italian, asian, soups, pasta's, curry's etc.) *

_____

42. Would you like to participate in a small follow-up research concerning your food waste? This is a so-called food-diary. *

Markeer slechts één ovaal.

- ◯ Yes
- ◯ No

Food Diary

Dear participant, thank you for wanting to participate in an additional research to gain more data about the specific food waste in Dutch households. You can leave your contact details below and I will contact you for the following research.
The form will ask for your phone number, this has to do with the way in which the data will be collected. Your phone details will be kept private and deleted after the research is completed.

The food diary research will ask you to monitor your behaviour concerning food and what you throw out during a week. This will take about 5 minutes every day for one week. Further information will follow.

43. What is your email? *

_____

44. What is your phone number? *

_____

Appendix B

Food diary

Food Diary research

Dear participants,

Thank you for taking the time to participate in this research. As communicated before, this research will take about 5-10 minutes every day for the period of a week. Each day you will receive a text message with the link to the online form to fill in.

The goal of this research is to get insight into specific consumer behaviours regarding food waste. Even though the questions are short, it's highly appreciated to be as specific as possible and elaborate the choices you've made.

Thank you for your time!

* Verplichte vraag

1. Please enter your first name (for data seperation only) *

2. Please select today's date *

Voorbeeld: 7 januari 2019

3. Did you cook dinner today? *

Markeer slechts één ovaal.

- Yes *Ga naar vraag 4*
- No, I ate somewhere else *Ga naar vraag 19*
- No, I ate leftovers *Ga naar vraag 10*
- No, I ate store-bought / ready-to-eat food / take-out *Ga naar vraag 14*

Dinner

4. What did you cook?

5. For how many people did you cook?

6. What ingredients did you use? (please be as precise as possible)

7. Were any of these leftover ingredients from an earlier meal? If yes, which ingredients and why did you think you could use them in this dish?

8. Did you have any leftovers and/or did you have any partly used ingredients left after dinner?

Markeer slechts één ovaal.

- Yes
- No

9. What were these leftovers and how did you store each indiviual ingredient? (e.g. trash bin, fridge, freezer, normal cabinet, countertop etc.)
Please be as specific as possible

Ga naar vraag 19

Leftovers

10. What leftover did you eat for dinner?

11. Was this a sufficient portion or did you have to add something?
If no, what did you do/cook to make it a sufficient meal?

Markeer slechts één ovaal.

- Yes, it was enough
- Anders:

12. Was there any food left after you finished dinner?

Markeer slechts één ovaal.

- Yes
- No

13. If you had any leftovers, how did you store these? (please be as specific as possible)

Ga naar vraag 19

Store-bought / ready to eat food

14. What did you eat for dinner?

15. Why did you choose to eat this ready-to-eat meal?

16. Was the portion size sufficient? If not, what did you do to have an adequate portion size?

Markeer slechts één ovaal.

- Yes
- Anders:

17. Did you have any leftovers after you finished your dinner?

Markeer slechts één ovaal.

- Yes
- No

18. What did you do with these leftovers? How did you store them or did you throw them away? (be as specific as possible)

Ga naar vraag 19

Fridge update picture

19. Please upload a picture of what is stored inside of your fridge (both the main compartment / shelves and the door storage) *

Verzonden bestanden:

Supermarket

20. Did you buy any food from the supermarket today? If yes, what did you buy? *

Use of leftover food / ingredients

21. Did you eat leftover meals or ingredients today during any other meal except dinner? If yes, what did you eat and/or how did you incorporate this in your meal?

Food waste

22. Did you throw away any food or ingredients today? (please be specific about the ingredient or food, the amount and the reason why you threw it away) *

Other remarks

In case you have something to mention which were not covered in the questions before. Feel free to leave a comment!

23. Other remarks etc. (only if needed)

Thank you for your time! See you tomorrow!

Appendix C

Interview leftovers

What is your daily use of leftover meals?

Do you keep track of when a leftover was made? If so, how; If not, do you ever lose track of it and what is the result?

What are your concerns when you have leftovers?

Do you always eat your leftovers?

Do you eat your leftovers during lunch?

Do you ever bring leftovers to the workplace/school/somewhere else?
Why not? (Limitations)
- Food safety
- Freshness
- Convenience
- Transporting it logistically

What would stimulate you to bring leftovers to work/school etc.?

Are there types of leftovers that are considered to be inconvenient to take with you? What are these and why?

What do you do with your leftover when you have not consumed it at work/school?