# Design an Intervention to Support Food Waste Prevention at Home

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# PREFACE

Dear reader,

First of all, I would like to thank you for taking the time to look into my thesis project!

This project was my first individual big project as a designer. I just started working in the design field after enrolling as a design student in TU Delft two years ago. Previously, I dedicated myself to the engineering area. For me, this thesis is a pride and a reminder of how hard to solve only a single problem in this world. Yes, it was draining my energy and many times, I barely stood to keep working. However, I was also excited to know that I had accomplished one milestone in my life.

Working on this thesis made me feel like wandering somewhere into the unknown. Firstly, I knew what I wanted to do, then I lost and finally just kept striving and believing that this journey would bring me to a good end. And, it did.

Great gratitude I give to God, who always gives me hope to keep moving forward. Also, He keeps and protects me from stress and loneliness on this Covid day.

Special thanks to Henk Kuipers, who has supervised me patiently for seven months. Seeing and listening to your meaningful advice helped me find something to grasp when I was lost. You helped me to grow.

Other special thanks I present to my mentor, Hannah Goss. I always like your smile and spirit when coaching me. It brought a good vibe for me. But, above all, your feedback and recommendation have guided me to arrive at an end that I am proud of.

I feel grateful to meet you for all my Indonesian friends who were always supporting me to overcome those tough days. A friend who has taught me how to acknowledge my feelings. A friend who always dragged me along to go somewhere. And those who have shared their struggles with me. Without you, I think I would be depressed and would not survive to work with my thesis.

Thanks to my international peers. Knowing and learning about diverse cultural backgrounds and different points of view were always intriguing and inspiring. Hopefully, we will meet again as an impactful designer.

Last but not least, I would say my gratitude to my supporting system in Indonesia. Old friends who have listened to my struggles and brought nostalgic colours for my day in the Netherlands. My mom, sister and brother always pray for my healthiness and success. Also, my family who shares happiness and calmness in my hard time.

Back to you, reader.

Thank you, my last word for you, and I hope you enjoy your journey reading through my thesis project.

Fauza Karomatul Masyhuroh
Delft, 2021

# EXECUTIVE SUMMARY

"Food Waste" is defined as food that is ready for consumption but being discarded due to passing the expiry date, getting spoilt, or even the items are in their good condition (FAO, 2013). There are three types of food waste: avoidable, possibly avoidable and unavoidable food waste. Avoidable food waste was decided to be the research scope as its contribution to food waste is highest compared to two other types. It accounts for approximately 61% of food waste (WRAP, 2008). Moreover, reducing avoidable waste means saving edible food from being wasted.

FAO reported that every year one-third of all food produced for human consumption is thrown away (FAO, 2013). Food waste is a wicked problem that causes environmental deterioration and the socio-economic food gap. In the EU level, disposing 89 million tons of food waste per year, consumes 261 million tons of resources which is equal to 170 million tons of $CO_2$ emission (FAO, 2013). If this food is distributed and used properly, 1.3 billion tons of food waste in 2011 is estimated could feed up to 868 million people worldwide (FAO, 2011).

In the Netherlands alone, approximately 1.77 and 2.55 million tons of food waste are produced annually, of which households contribute 37% (Netherlands Nutrition Centre, 2019). This quantity places the consumers as the biggest food waster amongst other actors in the food supply chain. Knowing this fact and the potential benefits of future reduction makes it worth providing an opportunity for the Dutch households to reduce their waste stream.

Food waste at consumer level happens in all stages of household food management: planning, purchasing, storing, preparing, consuming and discarding. To understand the problems regarding food waste prevention in Dutch households context, the project started by conducting user research using an interview and observation methodology. People experienced that most conflicts to reduce food waste exist in the storing and preparing stage. All participants agreed that forgetting food in the closed storage like a refrigerator is common and hard to deal with. Lack of knowledge and skill in cooking also plays a role in food waste reduction. Another prominent issue is an oversized package that makes people discard it due to the inability to finish it before expiring. Then, to determine the research focus of this project, the result of the user research, combined with an expert discussion and literature review, were analysed. As the conclusion, a design statement was derived as follow:

"Design to improve food visibility to support households in the Netherlands in preventing food waste."

In order to explore more about food visibility in consumer daily food practices, second user research was held. Applying a photo diary and following-up interview, the participants were asked to tell about how they take care of food and manage food storages at home.

Moreover, a question about displaying food was also investigated to understand whether the person showed their food at home or not. From the Expert Discussion, one way to improve food visibility is by showing it. However, when people see it, they are prone to consume it. The research outcome concluded that forgetfulness, laziness to check the fridge regularly, and a messy food storage arrangement are why people discard food. Furthermore, the research reveals that people already display a few foods like fruits. However, sometimes this makes the kitchen a bit messy, and some food is still getting rotten. By knowing the most discarded food by the participants, the scope of this project was narrowed down to save fruits, vegetables and food leftovers. Based on the insight from the photo diary and follow-up interview, a problem statement was formulated:

"How might we minimize forgotten and overlooked food at home for people who live in the Netherlands so that as to reduce food waste at the consumer level?"

After determining the design challenge, exploration to find solution ideas began. In this phase, four initial concepts came up. They were analysed, and the most promising idea for each concept was combined, resulting in a final concept called food display cabinet.

Through several iterative processes, a final product named FooDi was developed. As a result, a particular design concept called FooDi emerged.

FooDi is a storage to display fruits and partly used vegetables usually hidden and forgotten in the fridge (e.g. half onion, half paprika or other cut vegetables).

This product encourages the user to eat fruits they purchase in a daily portion and reuse the raw vegetable leftovers as soon as possible. To enhance food visibility, a transparent lid is implemented to see through the cabinet and not miss any food. In addition, the quantity of food to show is limited to prevent food stacking that could lower visibility.

FooDi was designed as short term storage (only for 1-2 days). However, a few possible risks were considered to slow down food deterioration. FooDi prevents quick overripening by splitting ethylene gas producers and absorbers. Moreover, a lid with natural ventilation was applied to keep the stored fruits and vegetables fresh (avoid quick ageing).

At the end of the project, the impact of using FooDi to support people in reducing food waste at home was measured. Thanks to FooDi, households' share in food waste decreased from 37% to 29%. In addition, the user could be able to save edible food worth €120 per year. Finally, by reducing 14.21 million kgs of food waste, FooDi also contributes to solving climate change issues in the Netherlands (preventing 27.42 million kgs $CO_2$ from releasing). If global warming can be stopped, people may see less harsh hurricanes and long heavy rain. Also, annual snow in the Netherlands may return.

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# Chapter 1

# DISCOVER

This chapter explains the current condition, impacts, and facts of food waste globally, in the Netherlands, specifically in households. The research was done by literature review and field research. Through layered user research from an early interview and observation, an expert discussion and in-depth user research (photo diary and follow-up interview), food waste issues at home were revealed. Lastly, these problems are summarized in the form of a problem statement and design vision.

# 1.1 FOOD WASTE

## 1.1.1 Definition

Food is a natural organic substance needed to feed humans to survive (Falk, 1994 p.69). Food-seeking became easier through food technology advances and industrialization than in World War II's age when food was scarce. Nowadays, food availability is splendid and very affordable for anyone. Nonetheless, this abundance has brought a serious consequence of food waste and food loss to incline sharply (Moffatt, 2020).

In general, food waste and food loss mean the edible portion of animals and plants produced by agricultural farms and food facilities that are not consumed by people (Lipinski, B. et al., 2013). However, to explain the scope of this project, those terms need to be specified.

"Food Loss" is described as any alteration in the quality and availability of food that restrains it from reaching the consumers or end of the food supply chain (FAO, 1981). Stjepan Tanic from FAO mentioned that food loss appears in the early stage of the food chain, such as damaged crops due to pest attacks in the agricultural process and inefficiencies in food processing and production. These losses cause food nutritional and economical values to decline and are usually discarded before arriving at the consumer's plate.



Figure 1. Agriculture food loss



Figure 2. Consumer food waste

"Food Waste" refers to food that is ready for consumption but being disposed of due to passing the expiry date, getting spoilt, or even the items are in their good condition (FAO, 2013). This event occurs at the end of the supply chain, i.e. retail and consumption stages. The loss is connected to the retailers' selling policy or strategy and the consumer's behaviour of food handling at home (Parfitt et al., 2010).

According to WRAP (Waste And Resources Action Programme) in 2008, food waste is distinguished into three types:

- *Avoidable:* waste of edible food which could have been consumed, but being discarded because it was left and got stale or spoilt, prepared yet uneaten, and even still in good conditions (e.g. meal leftovers, slices of bread, browning bananas)

- *Possibly avoidable:* edible food that some people avoid eating (e.g. meat fat, bread crusts, apple peels) or that can be consumed using a special preparation method (e.g. potato skins, broccoli stalks)

- *Unavoidable:* perceived as inedible food which under normal circumstances cannot be eaten (e.g. eggshells, tea bags, meat bones, coffee residues)

(see Figure 3)

This research explored the way to save edible food from ending up in the garbage dump. Hence, the goal is solving food waste issues, not food loss. Moreover, avoidable food waste was the research scope as its contribution to food waste is highest compared to two other types. It accounts for approximately 61% of food waste, meanwhile possibly avoidable and unavoidable is 19% and 20% respectively. With better management of the avoidable waste, more food can be saved and eaten (WRAP, 2008).
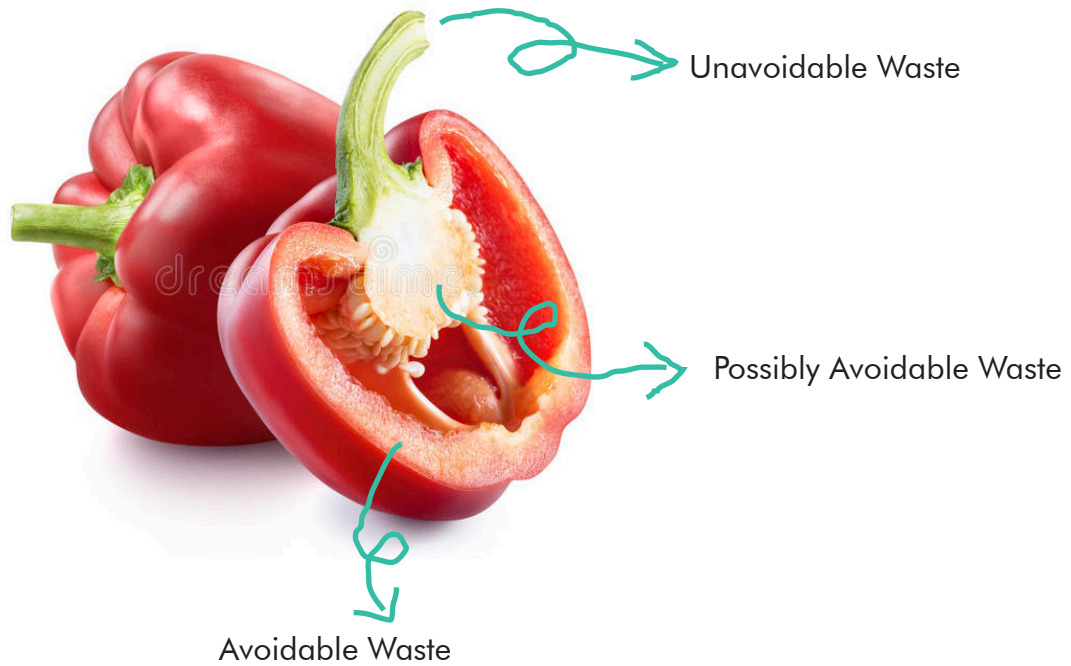
Unavoidable Waste

Possibly Avoidable Waste

Avoidable Waste

Figure 3. Three types of food waste

# 1.1.2 Global Scale

*"Food waste burdens waste management systems, exacerbate food insecurity, making it a major contributor to the three planetary crises of climate change—nature and biodiversity loss, pollution and waste."*

- Andersen (Executive Director of the United Nations Environment Programme UNEP 2019)

## Current Circumstances

FAO (Food and Agriculture Organization) announced that one-third of all food produced for human consumption is wasted (FAO, 2013). The latest report in 2019 stated that approximately 1.02 billion tons of food went to waste globally 2019, and roughly 17% of food produced for human consumption is disposed of each year (Tommy Forbes, 2021).

Excessive food waste is a wicked problem that causes not only environmental deterioration but also social suffers.

## Environmental Deterioration

In the environmental aspect, throwing away food is associated with wasting water, energy, arable lands, soil and money. The environmental burden of food production for consumption in the Netherlands only is 229 ReCiPe points per person (land use, greenhouse gases and energy consumption combined). At the EU level, disposing of 88 million tons of food waste per year consumes 261 million tons of resources, equal to 170 million tons of $CO_2$ emission (FAO, 2013). Worldwide, food waste releases about 500kg of $CO_2$ and lets 250km3 of water per year per person, as well as 28% of arable land, spent in vain(Temminghoff and N. Damen, 2013).

FAO in 2015 showed that if food waste were a country, it would be standing in the top three countries which emit greenhouse gas, after China and America (see Figure 4).

Economically, wasting enormous valuable resources brings large financial consequences where the food waste in the EU in 2012 was estimated at 143 billion euros (Stenmark et al., 2016).

## Social Suffering

From the social point of view, the issue arises as a social gap in food between one being hungry and undernourished (8.9% of the world's population) and others are wasting a lot of food (UN, 2020). If this food is distributed and used properly, 1.3 billion tons of food waste in 2011 is estimated could feed up to 868 million people worldwide (FAO, 2011).

The United Nations has taken action to combat food waste. Through policies, agreements and the Sustainable Development Goals 12.3, the UN set a goal to 'halving per capita food waste by consumers and supermarkets by 2030 compared to 2015'. Even though the effort seems on track, more innovative and effective interventions are still needed to achieve the goal.
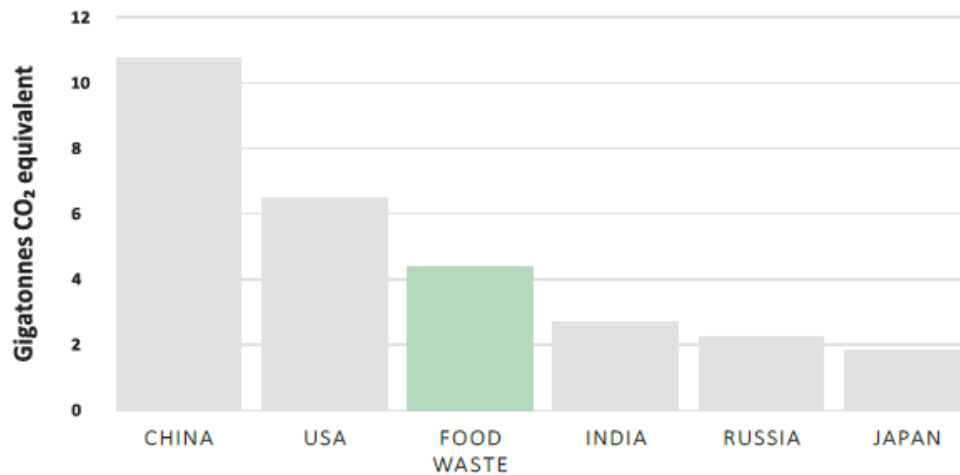
Figure 4. Food waste CO2 emission globally

Source: Food Wastage Footprint and Climate Change (FAO, 2015)

## Developing and Developed Countries

Food loss and food waste exist in every country globally, even though their contribution is greatly different (see Figure 5). Regarding the total of food for consumption that is lost or wasted, developed countries share more than 20% of the food available in their territory. Even worse, North America and Oceania region waste almost half of the food they have. The contribution of developing countries except Sub-Saharan Africa is just under Europe.

As depicted on the chart, the percentage gap between developed and developing countries are not significant. However, a noticeable distinction appears in which stage the food loss or waste takes place. Previous explanation stated that at least 57% of the total share of the developed countries occurs in the market and consumption stages of the food chain. In those means, ' food waste' is dominating. On the other hand, on average, the developing countries yield 'food loss' more than food waste.

The difference underlies on level of the food technology development and management strategy. Developing countries still utilize manual or low technology, which causes technical limitations and inefficiency in harvesting techniques, storage and cooling facilities for the agricultural and post-harvesting process. In addition, poor management and finances also affect the food loss generation (Gustavsson et al.,2011; UNEP, n.d.).

Meanwhile, in developed countries, food tech advances lead to efficient production, which yields abundant available and affordable food. However, in contrast, it gives an unexpected negative consequence. For example, the consumer often buys excessively or prepares more food than is consumed.

In the UK, at least 450,000 tons of edible food is thrown away annually due to misunderstanding of the "use by" or "sell by" date by the consumers (Lyndhurst, B., 2011). In hospitality industries, uneaten food shares approximately 17% of food waste, and dine-in customers make up about 55% of food left on the plate (Bloom, J., 2011).

In the early part, it was set that goal of this project is taking part in combatting 'food waste'. Therefore the scope area is narrowed down to developed countries, specifically the Netherlands.

Netherlands is one of the EU countries that has a big concern to combat food waste. The Ministry of Agriculture, Nature and Food Quality of the Netherlands has endorsed one of the objectives of the UN Sustainable Development Goals (SDG 12.3) mentioned above.

The Netherlands Nutrition Centre states that *"Currently, the most important topic in food to examine is Healthy, Safe and More Sustainable food"*. Sustainable food includes the impact of food on the environment and food waste.

This country measures and evaluates food waste carefully and as accurate as possible. As a result, the food waste data and information is quite complete. Data availability is essential to support research phase, especially for literature review and scientific reasoning.

Lastly, in the context of research feasibility, the Netherlands is the most reachable country to conduct a field research (e.g. easier to do a user research) within the time constraint of this project.
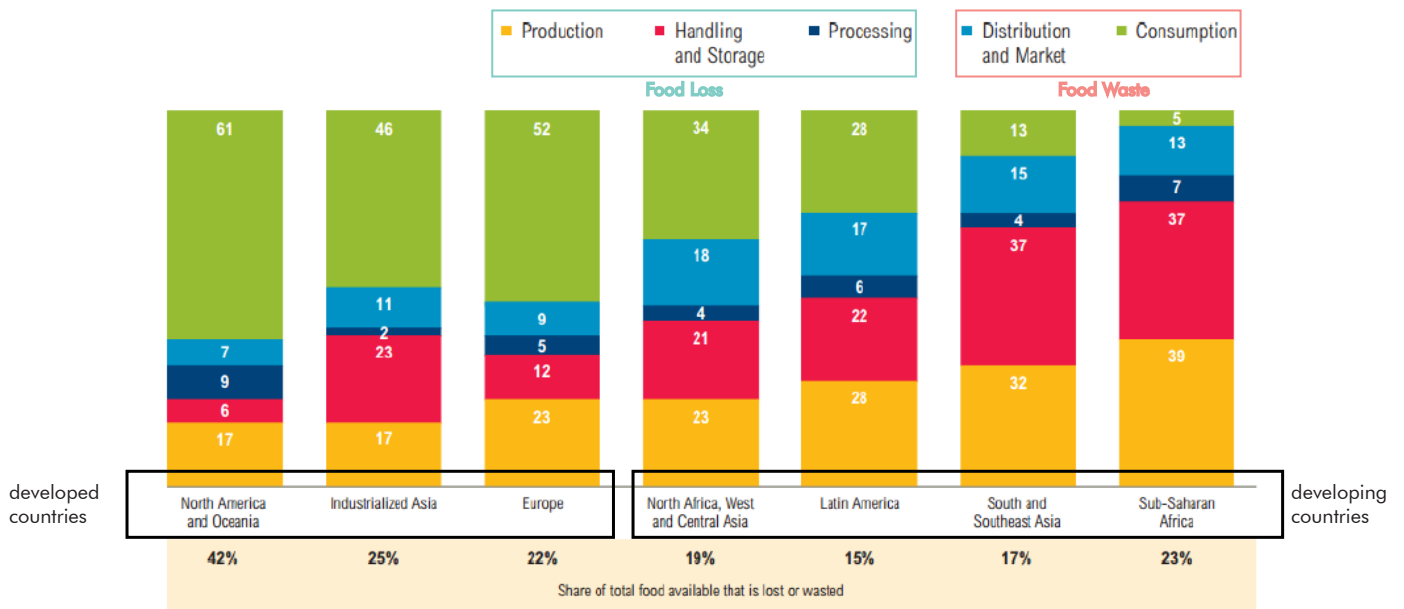
Figure 5. Food lost or wasted by region and stage in value chain, 2009 (Percent of kcal lost and wasted)

Source: Lipinski et al., 2013

## 1.1.3 In the Netherlands

It has been explained previously that the developed countries make up a higher amount of 'food waste' than 'food loss', which creates no exception for the Netherlands. As depicted in Figure 6, the blue area which represents 'food waste' is larger (60%) than 'food loss' (40%). The Netherlands Nutrition Centre revealed that the quantity of food waste in the Netherlands was between 1.77 and 2.55 billion kgs per year. The consumers or Dutch households were responsible for 37% or approximately 0.6 to 1 billion kgs of the whole weight of food waste in the Dutch food supply chain (Soethoudt. H, Bos-Brouwers. H, 2014). This quantity places the consumers as the biggest food waster amongst other actors, contributing under 15%.

A reduction of 55 - 140 million tons of food waste equals US$80 and 200 billion production value and could save immense available food for people who need it the most. Reducing future food waste from households by 20% - 50% was estimated to deliver savings between 110 and 280 million tons of food (WRAP, 2015). Moreover, as the consumption stage happens at the end of the food chain, the squandered valuable resources are accumulated alongside the wasting of edible food (Stenmark et al., 2016).

Knowing the immense impact of food waste at the consumption level and the potential benefits of future reduction makes it worth providing an opportunity for the Dutch households to reduce their waste stream.
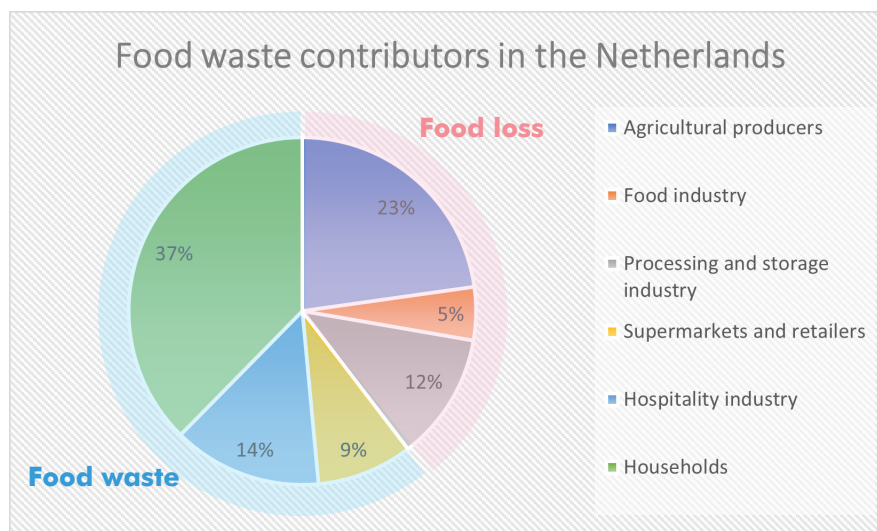


Figure 6. Food loss and waste actors in the Netherlands 2012

# 1.1.4 Dutch Households

Each year, one Dutch consumer wastes approximately 41 kilos of solid waste (all types of food excluding beverages), reflecting 13% of the food that is purchased in vain (see Figure 7) (Van Dooren, C, 2016). Even worse, the major part (54%) of household's food waste is categorized as avoidable, which means that edible food or food purchased and cooked with the purpose of human consumption remains uneaten and is discarded. This amount of waste equals €145 money lost (Van Dooren, C., 2018).
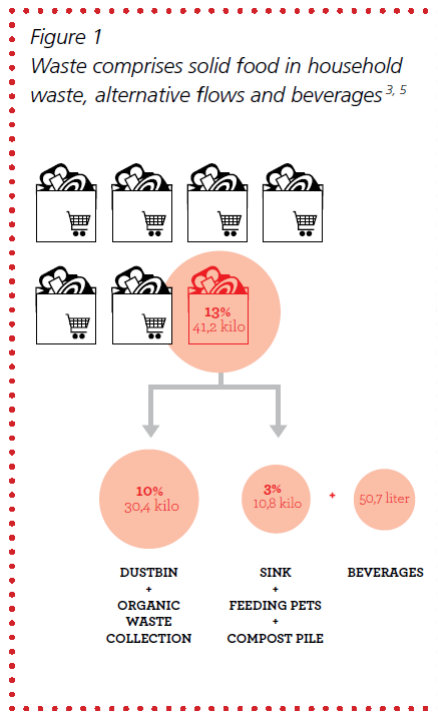


*Figure 1*
*Waste comprises solid food in household waste, alternative flows and beverages* [3, 5]

Figure 7. Dutch consumers food waste

Source: Netherlands Nutrition Centre Report, 2019

## *Most Wasted Food*

Based on the Nutrition Centre of the Netherlands synthesis report on food waste 2019, people purchased 377 kg solid groceries per person per year (pppy). However, unfortunately, 50 kg of the food was not consumed (Temminghoff, 2019); 34.3 kg (68.6%) is avoidable waste, and 15.7kg (32.4%) is unavoidable. So then, it can be said that approximately 9.5% of edible food was wasted this year (Nutrition Centre Netherland, 2019).

Figure 8 shows the most wasted avoidable food product at the household level. The highest contributor is bread, with a share of 21% (7.2 kg), followed by veggies (including potato), semi-liquid dairy products, and fruits scored 19% (6.52 kg), 15% (5.14 kg) and 9% (3.08 kg) respectively. All calculation is in pppy unit (per person per year) and excluded unavoidable waste type (e.g. peels, stalks, eggshells, and so forth).
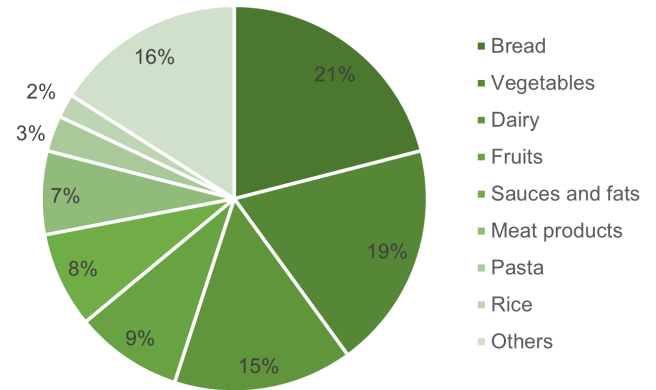


Figure 8. Most wasted solid products at home 2019

Source: Netherland Nutrition Centre Report, 2019

## *Food Management Stages*

Food waste in households concentrates on two aspects: the accumulation of food items that are never prepared for consumption (overconsumption) and disposed of when they reach their use-by date; and the 'leftovers' from prepared meals that make their way, often indirectly, into the bin (Evans, 2012). Four main factors that influence consumers to waste food are attitudinal factors, external forces, personal capabilities and habit or routine (Farr-Wharton et al., 2014).

Attitudinal factors show our internal motivation to be a "good provider" for families and convenience by always preserving abundant healthy food. External forces which affect consumer's behaviour are low food cost, discounts, marketing, and advertisement. Personal capability explains a lack of knowledge and skill in food management, such as proper storage or food preparation. Routine refers to daily habits or practices that could lead to waste food, such as impulsive purchasing and having no willingness to consume leftovers anymore.

All these factors are embedded in the flow of household food management. Each stage in the food handling system could be influenced by several factors at the same time. Figure 9 shows the cycle of food management of the consumers at home. The arrows represent the sequence of how usually people execute their food practices.

### Planning

Planning is the starting point of handling household food. Normally, people create a plan in the form of a shopping list or food menu note. This action guides them when buying groceries only to take what they need (van Dooren, C., & Mensink, F., 2018). But, as not all consumers do food planning properly (only memorize it), they often purchase redundantly, which can be a source of food waste.
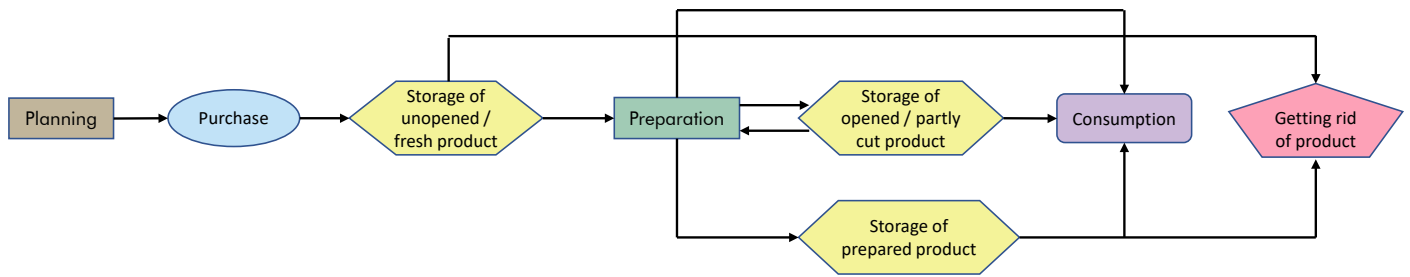
Figure 9. The flow of household food management

## Purchasing

Buying is the process of provisioning food for households. In this era, people can do groceries by visiting supermarkets or online (e.g. Picnic, Jumbo online, Hello Fresh, and so on). This activity is highly influenced by external factors, i.e. discount, advertisement and cheap price. The consumers could be easily driven to act beyond what's already planned. When seeing a cost reduction, people may think that is a good deal, so they do not only buy food doubled but also add unnecessary items with the thought that they may need it in the future (van Dooren, C. & V. Klostermann, 2013).

## Storing

Storing plays a crucial role in household food management because many iterations occur in this stage which determines the end life of food. To keep the food properly in the correct locations, people need knowledge, i.e. food shelf life and the right storing method for perishable food. Moreover, it also depends on the variety and ability of storing-equipments owned by the consumers. Better tools and diverse options can help store food longer and safer. On the other hand, people with low knowledge and proper devices usually waste more (van Dooren, C., & Mensink, F., 2018).

## Preparing

Preparing is any action needed to serve a meal or dish, i.e. cutting, boiling, baking, frying, sorting, etc. Produced food waste is a bit large in this phase, for instance, stalks, disliked food parts, peels, and shells. However, most of the waste is categorized as unavoidable. Cooking skills and measuring the dish portions have a major effect on preventing food waste at home. Consumers with good cooking skills are known to waste less because they can reuse leftovers or process food part that is inedible for common people (van Dooren, C., & Mensink, F., 2018). On the other hand, frequently calculating servings size incorrectly leads people to cook too much, possibly wasted later (van Dooren, C., & Mensink, F., 2018).

## Consuming

Many consumers find this the most exciting stage, yet not a few perceive eating as only a necessity to survive. The personal preference during the eating moment, especially taste preference, gives an impact on how consumers treat the food. People feel it difficult to eat less favorable foods merely to reduce food waste. Commonly, this event occurs because food taste does not meet the consumer's expectation. Some people may have higher tolerance to deal with it, but others may not. This fluctuation of taste preference affects the amount of food waste produced by households (van Geffen, L., et al, 2020).

## Discarding

Disposing is the end of the food journey in a household. The next phase usually happens outside the house and is under external actors' control, i.e. government or waste management.
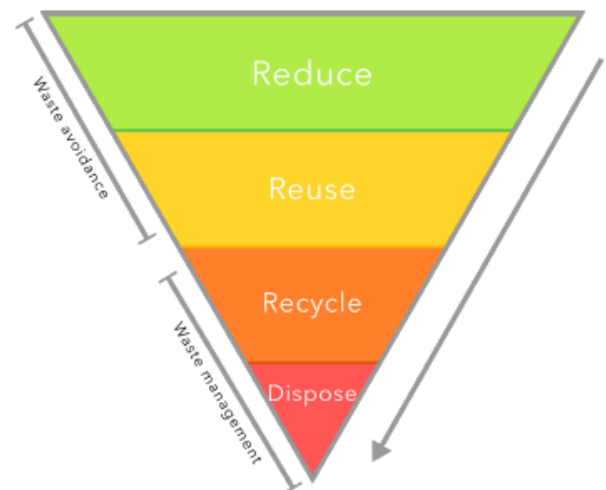


Figure 10. Food recovery model

Source: Reducing the food wastage footprint, FAO, 2013

# 1.1.4 Takeaways

1. The main goal of this graduation project is to solve food waste issues, not food loss.

2. Avoidable food waste is the research scope to tackle as its contribution to food waste is much higher (61%) than possibly avoidable and unavoidable, 19% and 20%, respectively.

3. Developed countries share more food waste than developing countries, especially in the consumption phase (more than 50% of total food loss and food waste).

4. Research that calculates food waste streams in the Netherlands revealed that the consumption phase yields the most food waste (37%) compared to other stages in the food chain. This fact indicates that many improvements are required in this area.

5. Reducing future food waste from households by 20% - 50% was estimated to deliver savings between 110 and 280 million tons of food (WRAP, 2015).

6. There is wasting potential in every stage of household food management. As this project focuses on prevention or reduction (waste avoidance), the step 'getting rid of food product' was eliminated or not considered. Also, processing disposed of food is not the consumer's authority (see Figure 10).

Lastly, further user research was conducted using interview and observation methods to explore and understand what kind of food practices lead consumers to waste food.

# 1.2 USER RESEARCH I

## 1.2.1 Early Interview and Observation

The interview's goal was to figure out pain points in preventing food waste in Dutch households context. In addition, this early user research was expected to explore food waste problems encountered by real consumers in general. Therefore, all food-management stages were involved, except for the "discarding phase".

*Participant*



6 persons     2 persons

Netherlands   Indonesia   China   India
2     4     1     1

1     7    with family, housemates or sharing kitchen

**Housing Type:**
Shared Student housing = 4
Studio = 1
Private house = 2
Shared house (non-student) = 1

Eight people participated in the early interview and observation. The respondents were from various cultural background. Since the Netherlands accommodates many international people to stay, more or less their daily food practice also contributes to food waste production or reduction in the Netherlands. They become part of the Dutch household. Therefore, understanding their behaviour and adaptation and how they experience struggling with food waste could be meaningful.

Knowing the information about housing type and the person the consumers live with is required to see how these environments may influence the consumers' food management.

*Interview*

The interview was conducted online and offline, depending on the participant's preference and situation. Online interview was held via video call, and for the offline happened in the interviewee's house. The questions were divided into five sections:

1. Opening: demographic data and living environment

2. Routine: planning and purchasing habits, type of food the consumers usually buy and eat

3. Preparation: how people cook their food (knowledge and skill), failures in preparing and also disposing of items during this process

4. Consumption: eating ritual, talking about leftover generation, storing and reusing; also how people identify food edibility (judge food quality from getting stale, spoilt or fungus)

5. Closing: self-evaluation regarding food waste at home and people's vision toward a better way to prevent food waste. In addition, any food cultural adaptation that the interviewees encountered when moving to the Netherlands.

(Detail question is written in Appendix A)

*Observation*

After the oral interview, the participants were asked to walk around their kitchen and dining room. They showed cooking appliances or tools supporting their food practice (e.g. fridge, cupboard, freezer, and rice cooker) and food laying around. The interviewer observed the stuff and asked a few questions regarding the object, such as the functionality, experience using the equipment and the reason for doing certain arrangements in their storage.

Observation also occurred during the oral interview as some participants were preparing food at that moment. Therefore, any interesting action of cooking, eating and discarding were captured and questioned after.

## Result

Regardless of their cultural backgrounds, people experienced that most conflicts to reduce food waste exist in the storing and preparing stage (see the full result at Appendix A). All participants agreed that forgetting food in the closed storage like a refrigerator is common and hard to deal with. Frequently, the food is hidden in the deeper level or covered by other items. Hence they did not notice it when opening the fridge. Instead, they found it during cleaning in bad shape (already rotten or got spoilt). In order to tackle that issue, a few participants tried to check the fridge more regularly and carefully (before going shopping). However, sometimes they forget or are lazy to do checking the refrigerator regularly and consequently, they produce more food waste.



Figure 11. Spring onion waste

In the preparation phase, food waste came from a lack of knowledge and skill in cooking. For example, a participant cut spring onions, only used the leaves and disposed of the white part (see Figure 11). She thought it was not edible until the interviewer told her. Another proof is about broccoli stem. Generally, people do not use broccoli stems because they think the taste could be a bit undesirable. However, one participant stated that he had ever tried to cook broccoli stem. Nevertheless, as he thought, the flavour is a bit off.

In contrast, another participant said that she sometimes included broccoli stem for her dish. "It is edible and tasty. But, we have to cook it longer than the flower. It has to be tender". This contradictive experience shows how knowledge and skills play roles in reducing food waste.

Another prominent issue is an oversized package. The consumer wanted to buy only the necessary amount to prevent wasting food. However, for certain items such as cabbage and packaged meat, a smaller version is not available. In this case, they had to purchase it, and sometimes these products get bad before being finished.

An oversized package is quite problematic, but it is out of the consumer's control. To intervene, it needs the involvement of the retailers. They can provide buying based on desired weight, even though it means to cut some parts (not one piece) as Indian and Indonesian markets do. However, it could be unacceptable by the seller as it might reduce the profit. Therefore, a deep understanding of how they work and do the business must be explored.

Lastly is about planning. The participants experienced that shopping groceries without any advanced plan or list led to over-purchasing, specifically when the store offers discounts.

(see Appendix A to read the full analysis)

## Conclusion

The interview result reveals that obstacles in food management often happen to anyone (all participants), regardless of their demographic or cultural background. For example, people frequently forget food in the fridge because it is hidden in the deeper level or covered by other items. They also discard food parts during preparation and discount temptation.

However, the level of wasting is different, depending on the knowledge, skills and personal situation, for instance, in preparing food (e.g. the consumer with more skill tends to waste less). And in the consumption (e.g. several participants keep eating the expired food as long as the quality is still good, yet some do not due to health concerns).

Focusing on tackling the inclusive problem experienced by the consumers regardless of their background or less dependent on their conditions may give a vaster impact in preventing food waste at home.

The information about the problems will be used for further research (basis or guideline for the expert discussion and narrowing down the research focus in the later section).

## 1.2.2 Expert Discussion

The goal of the discussion was to understand food waste problems in the Dutch household from an expert point of view and intervention opportunity. The interviewee was Erica van Herpen, an associate professor in the Marketing and Consumer Behaviour Group of Wageningen University & Research. She has topic areas in consumer evaluation, use, and choice from (food) product assortments. Her previous research about "household food waste as the consequence of competing motivations, lack of opportunities, and insufficient abilities" was one of the basic knowledge for the talks. Other resources were from insights drawn from the earlier interview, observation, and literature review.

Two main topics during the talk were the challenges that Dutch households face reducing food waste at home and possible solution or intervention should perform.

*Challenges to Reduce Food Waste at Home*

The expert stated that food waste is not the top priority for consumers. People perceive it as distant as they do not feel the impact directly and have less idea how much they waste and how others are doing. Food waste is a non-personal matter. Hence it can get easily overruled by other interests, e.g. food pleasure, healthy diet or price (Lindenberg and Steg, 2007; Nielsen, 2017). Consumers are most likely to overlook food waste when the reduction action conflicts with the existing goals (Nielsen, 2017).

A clear example is a dilemma between being a good provider and food waste in a family. Parents want to provide enough healthy food for their children by keeping fruit in the basket. However, this might deteriorate the food quicker.

Another challenge that she brought up was unexpected events. People often experience sudden occasions like getting invited to dinner or party or eating outside, making them not eat food they have at home. People should be encouraged to buy only a small amount of food regularly, instead of purchasing abundantly at once.

The level of food-management skills also contributes to food waste.

"People with higher knowledge in preserving food and cooking waste less. Nevertheless, most of this knowledge is owned by the previous generation, which now kind of disappeared, so people do not know how to store food properly."

Lastly, Erica mentioned that forgetting food is also the common reason for of disposing food. The consumers unintentionally arrange the food storages where the new one covers the older food. As the older food is out of sight, people tend to forget it until it has deteriorated. Enhancing food visibility is crucial because when people can see it, they are prone to consume it. However, the design should be intuitive, i.e. short learning process, to help people adapt easier to the intervention, which stimulates food waste reduction quicker.

# 1.2.3 Research Focus

From research done by Netherland Nutrition Centre in 2018, Early Interview and Observation, and the Expert Discussion, obstacles people encounter to reduce food waste at home were drawn (shown on the graph below). Moreover, to narrow down the research focus, the phase of household food management were clustered into three design directions. Finally, after analysing each direction's benefits and challenges, one direction that might give a bigger impact was determined.

Problems of reducing food waste at home:

| Source | Planning | Buying | Storing |
|---|---|---|---|
| Literature Review: Consumer Food Waste Fact Sheet Netherlands Nutrition Centre 2019 (van Dooren, C., 2018). | | • Large portion size<br>• Abundant purchase | • Do not reuse the leftover<br>• Spoilage due to false storing method<br>• Forget the food at home |
| Early Interview and Observation | • Do not plan what to buy | • Impulsive buying due to discount | • Forget food or leftovers in the fridge (located in the corner, covered by other products, out of sight)<br>• Stock up food too much |
| Expert Discussion | • Unexpected events like dinner invitation or party | • Purchase too many items | • Low knowledge about storing food properly<br>• Low food visibility: hidden food in the storage which becomes forgotten and get stale<br>• Health vs food waste: displaying healthy items such as fruits and vegetables to consume healthier food, but for some food types it can decrease the quality quicker |

| Source | Preparing | Consuming |
|---|---|---|
| Literature Review: Consumer Food Waste Fact Sheet (Netherlands Nutrition Centre 2018) | • Prepared too much food<br>• Used the wrong preparation method, which ruins the dish | • No time to consume all food<br>• Dislike the food taste |
| Early Interview and Observation | • Lack of knowledge to decide whether some part of food is still edible or not<br>• Discard edible part of vegetables or other food<br>• Less knowledge on how to reuse remained food (leftover) | • Discard certain food due to "dislike" reason<br>• Inflexibility towards past best-before (expiry) date |
| Expert Discussion | • Do not know how to reuse meal leftover or a few remaining ingredients | • Enjoyment vs food waste: people do not want to eat leftover as it tastes less fresh<br>• Encourage people to eat what they have |

# Benefits and Challenges Analysis

| Design Direction | 1. Design for better planning and wiser purchase | 2. Design for enhancing people's knowledge effectively | 3. Design for better storing to encourage consumers to finish food they stock up |
|---|---|---|---|
| **Goals** | 1. To prevent buy redundantly<br>2. To reduce leftover production as the common source of food waste<br>3. Assist busy people to handle daily food which aligns with their dynamic life<br>4. Create flexible planning to let people feel more freedom than having a strict schedule/plan, which may change quickly | 1. Bridging tons of available information about handling food correctly to the consumer in an effective way<br>2. Improve people's knowledge about judging food edibility (expiry date, stale or spoilt) and preparing leftover<br>3. Enhance food preparation skills<br>4. Share information about how other people are doing related to food waste prevention actions | 1. Make people consume older food first, then the new one<br>2. Remind consumers about the food they keep to prevent buying the same product<br>3. A warning system to remind people using nearly spoilt food or leftover<br>4. Improve visibility of hidden food from consumer's sight |
| **Benefits** | 1. By purchasing only "enough" amount, less food will be stored<br>2. More frequent shopping makes consumers always have fresh food<br>3. Flexible planning: at a certain point, it can give leeway to buy impulsively<br>4. Reduce fear of wasting stored food when facing an unexpected event<br>5. flexible planning-> create several types of plans, depending on what people want (however, in default, the system must reduce the amount of purchased food). | 1. People might not get too paranoid about consuming expired food after knowing the truth<br>2. Information about individual portion: reduce leftover<br>3. Once people learn, the knowledge and skill will stay in their mind<br>4. Improved preparation skill: decrease the possibility to dispose of food due to wrong cooking way<br>5. Information about positive effect reducing food waste: motivate people to keep doing better<br>6. Create a sense of belonging of a community when people know how others do | 1. Do not change what people usually do or just slightly (redesign storing equipment)<br>2. Reduce the chance of spoilt food<br>3. Alleviate consumers' struggle in forgetting food. Visible food: more consumption, less waste<br>4. Food reminder: help to check food storage easier before purchasing<br>5. Quite independent from the user's mood or lifestyle<br>6. Less effort or shorter learning process as it is already part of daily practice |
| **Challenges** | 1. Research states that lowering food purchasing volume is not the main cause of less waste. Its contribution is only 3.5% of the food waste reduction (Nutrition Centre Netherland, 2019).<br>2. Highly dependent on the users: do they follow the instructions? consumer's mood, feelings, other people's encouragement, time availability, and so forth<br>3. A bigger effort may need to adapt to the new behaviour<br>4. This could be a short term solution (people might not follow it anymore or go back to the status quo). | 1. Implementation of new knowledge or skill might be executed differently<br>2. Very dependent on the users because the intervention is only informing<br>3. It could take a long process to memorize new information<br>4. Although people's understanding increases, in the end, they may start to ignore<br>5. Set the target group carefully because different demographics may require various media<br>6. Comparing with others might be discouraging at some point | 1. The users may overlook the reminding system or feel annoyed<br>2. The product cost may be higher than two other directions<br>3. If the storage is more convenient, it might lead to purchasing more food<br>4. More consumption could be bad if the food is unhealthy<br>5. Convincing people reuse leftover or remaining ingredients |

## Discussion and Decision

In order to choose the most potential design direction to explore further, a few parameters were created. The benefits and challenges were analysed with the parameters.

**Amount of Effort:** In his book "Hooked", Nir Eyal conveys that "to initiate action, doing must be easier than thinking". Creating a new way of planning may take much time to adapt because people have already gotten used to their current practices. They may need more motivation and persuasion to implement the new behaviour. Providing essential information to prevent food waste is crucial. However, depending on the person, the time to understand new knowledge may be longer, and it needs many iterations to memorise it. Design for better food storage at home does not change or only slightly change food practices. It redesigns objects that support storing system. As a consequence, this intervention could be quicker to adopt. It yields subtler intervention, i.e. infuses into people's daily life without needing high attention.

**The product should be robust:** get less impact from external factors, i.e. low dependency on the user's dynamic situation. As Erica (a consumer behaviour expert) said, mood or people's condition highly influences daily food practice. Hence, this aspect is important to ensure that the intervention can effectively prevent food waste. In the challenges section, the robustness of the three design directions is clear. The form of the first and second directions are information or guidance-based, which may rely more on the users' motivation to follow the instructions. At a bad moment, e.g. they have a tough day, they may feel overwhelmed with the information and ignore it (back to the old practice).

On the other hand, the third direction seems less dependent on the user's condition because the product may become a part of the food practice environment (modify existing product). Therefore, people need to use it regardless of their condition. However, the reminder might reduce the robustness as it involves the user's cognitive ability to decide (freedom to obey or not).

**User–product engagement:** how strong and easy the design will be attached to the users. Long attention is required to create long-lasting, sustainable food practices and significantly prevent food waste at home. From those three directions, enhancing knowledge and skill in sustainable food management could produce the highest engagement. Once the ability sticks in mind, it will last forever. Nevertheless, this must be aligned with the implementation to gain significant change and needs time to build a strong engagement. The third direction may have the weakest engagement as the product may be too familiar. However, the benefit is the easiness to attach.

Based on those three parameters, it can be concluded that Direction 3, "Design for better storing to encourage consumers to finish food they stock up", has the most potential to help the consumers prevent food waste at home.

Moreover, there are other reasons to leave the first and the second directions. Purchasing stage happens outside the house. The external involvement is too big,

i.e. retailer discount or advertisement could shift the project focus from the consumer to the retailer level, which is not the project's goal. Also, the intervention is desired to give the users full control or authority to influence their daily practices at home. Furthermore, providing correct information is critical. However, if this solution stands alone, it might not be helpful significantly. Dutch government through Nutrition Centre Netherlands already put some efforts to reduce household food waste by providing important information on their website.

Nevertheless, a digital solution seems to be less effective to intervene in consumer food practices (Dott, J., 2020). Lastly, based on the literature review, early interview and expert discussion, most of them highlight storage issues related to food visibility. Therefore, the previous statement of Design Direction 3 was revised into:

*"Design to improve food visibility to support households in the Netherlands in preventing food waste"*

In order to explore more about food visibility in the daily food practises at home, second user research was conducted and is explained in the next section

# 1.3 USER RESEARCH II

This user research aimed to understand consumer food practices regarding food visibility at home and ask for opinions about a few proposed ideas. For this study, a combination of a photo diary and online interviews was conducted based on four research questions. The result was analysed qualitatively, and some insights were drawn from the research.

## Target Group

There were three aspects to consider to determine the participants. Firstly, the consumer age should be between 20 to 55 years old. In this age, most people have authority (independent or hold responsibility) to handle their food at home, including budget and food management, as shown in Figure 9. Consumer below that age range was excluded because their food is taken care of by their parents (zero to deficient authority). The elderly were also kept out from the research as they tend to throw food away less. Experiencing food scarcity during the Second World War makes them believe that wasting food is unacceptable (Lyndhurst, B., Cox, J., & Downing, P., 2007).

The second aspect was the type of household which tells about the number of people in a house and how food facilities support is shared. The house environment and with whom the consumers live more or less might influence their daily food practices. For this user research, there was no specific household type to focus on. Instead, heterogeneity was required to gain richer information and insights, e.g. single household, family, living with a partner, or even shared house.

One of the means to find intervention opportunities is to collect inspiration from cultures other than Dutch. Therefore, the participant with the diverse cultural background was chosen as the final criterion. The target group consisted of Dutch and international people who reside in the Netherlands. Dutch is meant to be a person who grew up within Dutch Culture, not the immigrants. International means people who still hold their original culture regarding food practices and stay in the Netherlands, so in daily, they experience Dutch environment. In this situation, the international participant can reflect on their current habit and previous life in the native country.

## Context

The research was focused on exploring consumer food practices regarding food visibility at home. The meaning of food visibility in this context are:

1. Vision: how food can be seen easily (displayed food in the open space or inside the food storages: how easy to see everything)

2. Human cognitive: awareness, attention and memory of having food, e.g. how long store the food, expiry date matters

## Research Setup

### Research Questions

Based on the aim of the research and context explained above, there are three main research questions to ask:

1. How do people take care of their food at home?

2. Do people display certain food? Why and what type of food is that?

3. What are the differences between Dutch culture and other cultures in managing food at home?

These research questions were interpreted as the photo diary tasks and questions during the follow-up interview.

### Methodology

Photo diary is a user research method that captures a glimpse of how a person lives and empowers them to tell their own stories (Design Kit, 2021). This methodology is suitable to gather personal information related to the daily food practices of consumers. With a few instructions, the participants would reveal their food habit context through photos they took. As they do it by themselves, the result could be more accurate to represent their daily life and meaningful for the research. The photo diary was distributed in the form of an online booklet using the Miro Board application. Moreover, the follow-up interview was also conducted virtually due to the Covid-19 restriction.

### Participants



5 persons    4 persons

Netherlands 3    Indonesia 1    China 2    India 1    Germany 2

3    6    with family, housemates or sharing kitchen

**Housing Type:**
Shared Student housing = 2
Studio = 3
Private house = 4

The total participants were nine people from five different cultural backgrounds. Including culture diversity was aimed to understand how they adapt with the Netherlands food system to the current situation and collect more inspirations about their original culture in taking care of the food.

## Photo Diary

Photo diary research was created in the form of a personal Miro Board (online board). Each participant had their board to fill out. The period to work with the board was five days, including the weekends. However, due to some circumstances, a few participants asked for a time extension to finish it.

The goal of using the diary is to capture a daily journey of the participant and their food, specifically how they manage food at home. Moreover, it was used as a guide for a final interview conducted after finishing the diary. In the booklet, there were eight activities to work with, which were divided into several pages. Each task had its instruction and questions to answer, also a space to upload a few photos to take. The diary was designed not to take more than 15 minutes a day.

The example of the photo diary with the answer is shown in the pictures below (see Appendix B for the full version and clearer images).

Task 1: Participant Demographic

The participant was asked about general information, such as age, occupation, and house type they live in. These questions were required to know the participant's environment and get familiar with the Miro Board.

Task 2: Groceries Arrangement

In this section, the respondent should take photos of any places they use to keep food. The aim of having this task was to understand where and how people store their food at home. By showing them, leftovers observation could be done. If there are noticeable leftovers, the participant was asked what they do with it and how they reuse it.

Moreover, knowing the amount of stocked food and the number of used storage was expected to give a picture of the possibility of losing track and forgetting the food. The more storage consumers utilize, the higher the chance, even though this statement may not generally apply.

The respondent of this booklet uses various storage (see Figure 12) as he lives with his family. However, he barely loses track of food because since he was a kid, the setup never changed. Also, his family has a poster of a food storage guide that helps them store properly and has less discarded food.
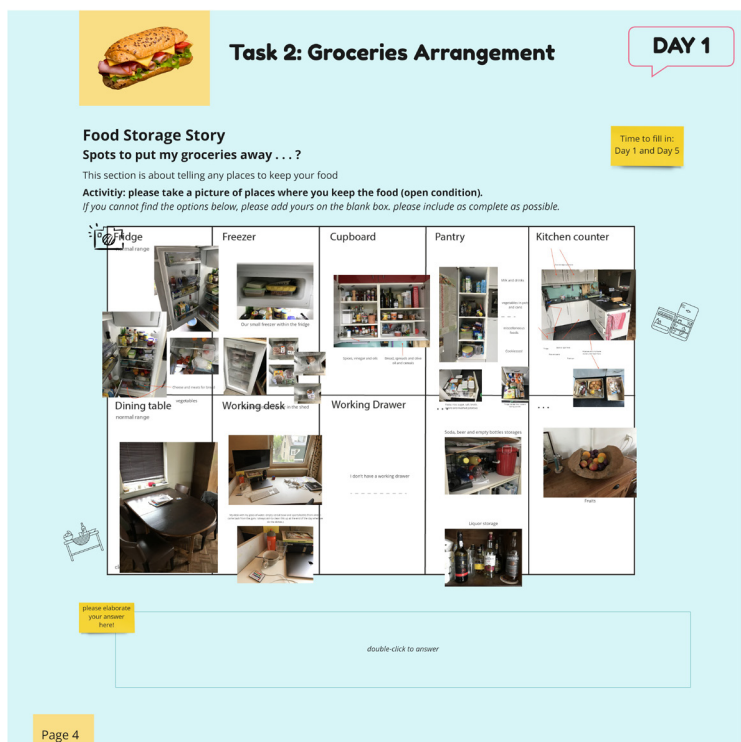


Figure 12. Photo Diary Task 2

Task 3: Organising Food Storages

Task 3 asked the participant to answer some inquiries about managing food storage they mentioned in Task 2. They also need to score their tidiness level in organizing food storage.

There were two hypotheses to test through Task 3:
1. If people check the storage more careful and frequent, an incident to have hidden and spoilt food could be prevented

2. If people manage their food neatly, consumers could easily track the food (remember where everything is settled)

The answers were analysed to envision intervention possibility in this aspect.

Figure 13. Photo Diary Task 3

Task 4: Displaying Food

In this task, only one question was asked: whether the person displays their food at home or not.

Based on the Expert Discussion, one way to improve food visibility is by showing it in open space. When people see it, they tend to consume it. Therefore, Task 5 was designed to know whether the participant already displayed some food at current practice and what food they commonly show.

Figure 14. Photo Diary Task 5

Task 6: Your Ideas, Your Vision

Task 6 invited the participants to envision any intervention they thought could be helpful. The responses were used to enrich the ideation phase and understand the kind of solutions that is desirable.



Figure 15. Photo Diary Task 6

Task 7: Origin Culture

Origin culture means the prominent cultural background where the person grew up. Here, the participant wrote about how their cultural background does taking care of food at home. To answer it, they reflected on their childhood or how their parents do food practices. The goal was to compare how these diverse cultures might influence the respondent's food practices (did it create a big difference or not?)



Figure 16. Photo Diary Task 7

## Follow-up Interview

The online interview was scheduled after the participants finished the diary. There were three general questions asked to all participants and other queries derived from people's answers. The interview lasted for 30-60 minutes. The purpose of conducting the follow-up interview was to clarify unclear statements of the participants and dig deeper about interesting information. When talking and reflecting on the photo diary answers, it was expected to gain richer and deeper knowledge to answer the research questions.

The general questions were considerations when purchasing food (the options: healthiness, price, enjoyment, trying new stuff, hospitality and soon), how people they live with effect the respondent's food behaviour and how they perceive food visibility at home.

Other typical questions were about what people do with food leftovers they have and the reasons behind throwing away certain food. An example of the complete version (question and answer) is provided in Appendix B.

# Result

*Taking Care of Food at Home*

## Food meaning

These are quotes from the participants:

"Daily eating is a basic necessity for the body (no time to think about it)."

"Food is enjoyment and time with the family. But, occasionally, we need a quick one."

"I am a foodie. I like tasteful food, but can't do this daily (time constraint)."

"Food is almost the most important aspect of my day."

People feel that having a good meal is pleasing but not the top priority for a busy life. When people are busy, they care less about their food intake and management. However, there is one exception for a wife with toddlers. Regardless of the limited time, she tries to achieve both, i.e. taste, healthy and quick preparation.

**Takeaway:**
**Having a good meal is pleasing, but that value is highly depending on the moment (situation)**

## Tracking Food at Home

Most participants use their eyes to check and the memory to remind them of what food they have. All participants regularly check their storage before cooking (this is just a common activity to see what food to eat). Some investigate the storage before buying new stuff. This action is frequently done for fresh food such as vegetables, fruits and leftovers. For the middle to long-lasting products, people do not pay attention that much. One person writes down any item that runs out on a piece of paper to remind them what to buy.

People seldom do deep cleaning (i.e. check all food, filter and discard all spoilt food) on their food storage. It could be from once a month to once a year. The action of sorting or filtering food quality is quite time-consuming. For example, finding hidden food or distinguishing spoilt food from the good one. Participants find it difficult to do this more frequently.

In the current situation, people often lose track because of forgetfulness or laziness to see their storage before shopping, even for a moment. As a consequence, they end up stocking the same food redundantly or buying too many items.

Experience and opinion about food tracker tools: People feel it unnecessary to use a food tracker tool for those with a small amount of food. However, they admit that if there is a product that can assist them in maintaining their memory about food at home effortlessly, they may consider using it. A few participants have tried a food tracker app. However, they criticize that it was cumbersome and time-consuming to enter and remove all food names manually.

**Takeaways:**
1. **Forgetfulness and laziness are the reason people discard food as at some moment they perceive handling food properly are less valuable than another urgent task.**
2. **Focus on saving fresh or perishable food types as they are the most wasted food**
3. **Support to track the food may be helpful as long as it is effortless.**

## Organizing Food Storages

Reorganize Food Storage

People divide the practice of reorganizing food storage into two, which are quick and total rearrangement. A quick rearrangement is performed almost every day when the consumer is about cooking or grabbing food. The main activity is checking food availability for cooking, taking it out from the storage, and returning unused ingredients to their original place while reorganizing the storage a little. This action only involves visible food located in the front part or a few compartments of the refrigerator or cupboard. The quick reorganization may help increase food visibility at the surface level. However, people often miss perishable food hidden in the deeper level of the storage.

A total rearrangement is usually executed from once a month to once a year. Generally, at this moment, people check for almost all the food they keep at home. In the case of fridge and freezer, people may take out and investigate the edibility of the food like expiry date and its safety to consume. Whilst for the cupboard or pantry they check the remaining life time of the products. The total rearrangement exposes hidden and forgotten food in the back of the storage. At this moment, people may realize how much food they waste and feel regret. They may reflect on these bad practices and act better if they know how to do it. Thus, the same mistakes can be avoided.

The tidiness of Food Storages

Tidiness score average: 2.05 out of 5
Three participants feel their neatness of organizing food storages grades at least three and six persons assess their storage's score equal or less than two.
Most participants admit that not overall storages are tidy. They do not mind having it a bit messy as long as it is out of sight, like inside cabinet and pantry, and also easy to find certain food within a short time. People perceive storage as chaotic if they see food laying down in the open space randomly or without a proper container. One interviewee said that he could improve kitchen tidiness if he bought a spice box for spices and other ingredients on the kitchen counter. So, it will not be messy while cooking.

Correlation between food organization and food waste:
1. Messy food arrangement decreases food visibility which causes people to become less aware or forget of that product. For example, one person feels guilty when throwing expired food stored in the fridge for too long due to its invisibility. This is because she did not have much time to manage her fridge neatly.
2. A tidy food arrangement facilitates the consumers to see through their food better. It reminds them to eat the product in time and helps investigate the amount of food at home. A participant stated that seeing food, specifically, the fresh one will trigger her to consume it soon and buy only when the food runs out.

## Food Ending

This session talks about discarded food by participants throughout the user research. Food waste is judged to determine whether the disposing action is acceptable or not. Admissable judgment is given for the unavoidable food waste, whereas unacceptable means the food is categorized as avoidable waste. Figure 17 presents several avoidable foods that participants disposed of.

Arguments for throwing away that food:

1. The food served was too big. When purchasing the fries, the respondent ordered a bot more because he was with friends. However, in the end, they were full and could not finish it. He did not save the leftover for later as he thought the taste would be less tasty.



Figure 17. Discarded avoidable food

2. The food product expired or got rotten, for example, sliced beef and mixed vegetables. The participants could not finish it in time because they were busy and forgot to have the food.

3. Prepared too much food, e.g. pasta. The person said, "It happened because I simply cooked too much".

The reasons they mentioned were unacceptable since those actions are preventable. When disposing of this food, some felt guilty and would try not to do it again. But, on the other hand, a few felt fine to throw away undesirable food.
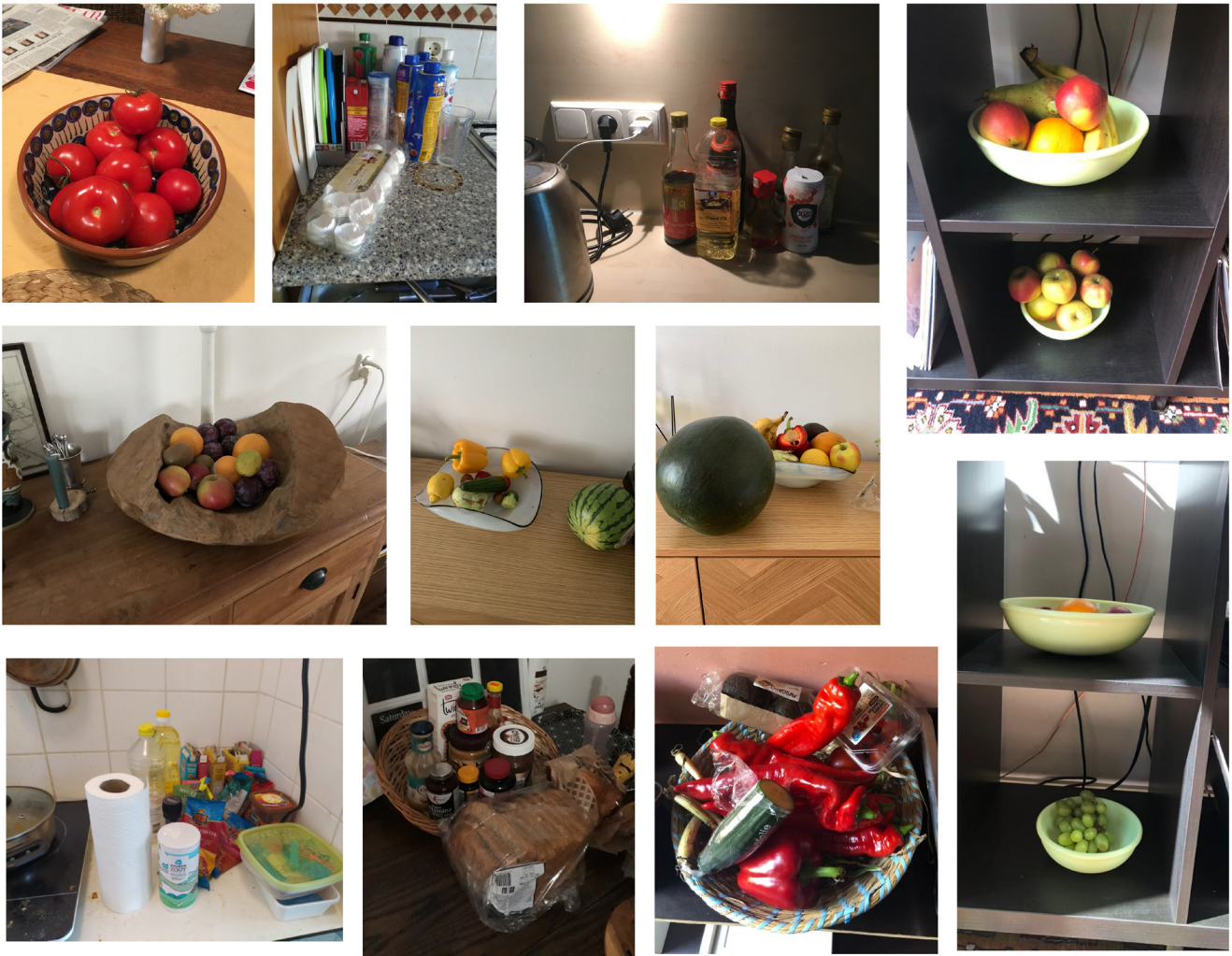
Figure 18. Displayed food

## Displaying Food and Food Visibility

People think food visibility is crucial for fresh or perishable food, but not for long shelf life items. People (specifically European background) already show fruit and a few vegetables in a bowl in the current practice. They tried to remind themselves to either consume healthier choice or eat it soon before getting bad. They put away long-lasting food in the closed storage like cupboards and pantry to create a neat and clean kitchen.

The European interviewees do not like food to lay down everywhere; fruit and veggies are enough. On the other hand, Asian participants have more items to display, such as spices and sauces, placed near the stove to ease them grabbing it when cooking and Snack or fruit to treat guests (Chinese culture).

Issue related to displaying food:

- Depending on the seasons (temperature and relative humidity in the room), the shelf life of displayed food may change. Most participants said they tried to finish it within a week. They reorganized the bowl when they purchased new items, i.e. move the older food above the new one. However, a few foods were still discarded because it was rotting.

- The tidiness of the room, if too much food is shown, it could be messy

**Takeaway:**
**In the current practice, people already display food. However, sometimes this makes the kitchen a bit messy, and some food is still discarded due to getting rotten. So they expect to show food in a neat and pretty way and ease them organising older and newer food to prevent spoilage.**

## Cultural Aspect

*Dutch:*
To store their food, Dutch people use the freezer a lot to save food, including bread. They also have a pantry and cupboard to keep dry and long-lasting food. Moreover, to help them track the amount of food they stock up, Dutch people label the food container and categorize it. They put several fruits in a bowl on the kitchen counter and perishable food in the fridge.

*Indian:*
Indian people consume perishable items on the same day because they like to eat fresh warm meals. Therefore, they buy food in a small amount for one-day consumption. Most foods are stored in cupboards or kitchen counters. Indian people use various spices for cooking that do not need to be chilled. However, for a certain food, they also utilize a fridge.

*Chinese:*
Chinese people put fresh food in the fridge. They store noddle and rice in the closet and have an open shelf kitchen to keep spices and sauces. Snacks and fruits are displayed in the living room for guests or family time. Generally, Chinese people buy in a small shop for a few ingredients to cook, and the younger generation tends to buy online shopping.

*Indonesian:*
Indonesian store some fresh food in the fridge. They commonly put their meals on the dining table and cover them with a special lid. Certain fruit and tubers are kept outside the refrigerator, and snacks are in the cupboard. At least once a month, Indonesian cleans their freezer and fridge to melt elt down the ice buildup to keep it working well in storing food.

*German:*
They have a basement to store food with more freezers or just a dark spot. Fruit and veggies are in the fridge, and some are displayed in a bowl. Moreover, German also like to show alcoholic beverages. They keep the dry food in transparent containers with a label (name).

In managing food storage at home, all five cultures show many similarities. However, as the dish to eat is different, it influences people's prominent storage and the type of food they show. Dutch and German use fridge and freezer most of the time. Meanwhile, Asians keep a lot of food on the open shelf or cupboard to store spices, sauces and dry food. All cultures display fruits in the open space, but Asian people also show spices and condiments for cooking their meals.

Respecting the way people track down food stock at home, regardless of cultural background, all participants use eyes to track all food they have at home.

## Conclusion

1. Having a good meal is pleasing, but that value is highly depending on the moment (situation)

2. Forgetfulness and laziness are the reason people discard food as at some moment they perceive handling food properly is less valuable than another urgent task

3. Focus to save fruits, vegetables and food leftovers as they are the most wasted food

4. A support to track the food may be helpful as long as it is effortless

5. Tidiness of food arrangement influences the amount of wasted food. For example, a messy food setting may reduce food visibility, leading to forgetting hidden food in the storage. Consequently, this food may lay down too long until it gets damaged, and discarding is the last option.

6. Focus on resolving the food waste problems due to people forgetfulness

7. At the current practice, people already display a few of food. However, sometimes this makes the kitchen a bit messy, and some food is still discarded due to getting rotten. They expect to show food in a neat and pretty way, also ease them to organize older and new food.

8. In general, regardless of cultural backgrounds, problems people face about food waste are similar (e.g. forgetting food, buying too much). The most difference appears on the food type to eat. Therefore, an inclusive and innovative intervention could be more impactful to support households to prevent food waste.

# 1.4 PROBLEM STATEMENT

Based on the photo diary and follow-up interview, a user/consumer journey map of the current situation was derived. The grey area is the problem that becomes the focus in this graduation project, which is about helping people keep aware of food and reduce food waste due to forgetfulness. In the form of a problem statement, this issue was formulated as follow:

User Journey Map of Food Arrangement at Home
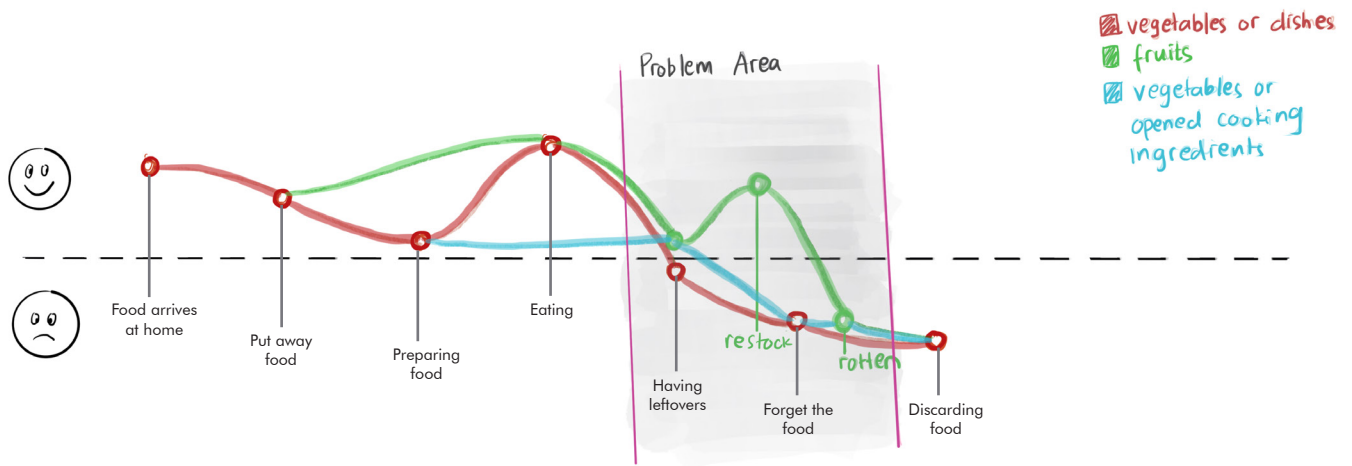


Figure 19. User journey map regarding food visibility issues

## PROBLEM STATEMENT

*"How might we minimize forgotten and overlooked food at home for people who live in the Netherlands so that as to reduce food waste at the consumer level?"*

**Chapter 2**

# IDEATION

Chapter Ideation tells about four intervention ideas to answer the problem statement. Afterwards, those ideas were analysed its benefits and challenges for implementation. Based on the analysis, a final idea was determined.

# 2.1 PROBLEMS TO ADDRESS

From the conclusion of the previous chapter, there are two main issues of household food waste to tackle in this project:

1) Forgetfulness: this can be caused by messy storage management, laziness to check the storage regularly, losing track of food (too many items or do not care)

2) Improper storing method: lack of knowledge, do not have proper or suitable storage, contradicted motivation and correct storing (ex: apples are put on the fruit bowl, instead of the fridge. It should be in the refrigerator, but people want to see it to encourage them eating healthy food)

The following impact caused by those two problems:

Forgetfulness -> the food may be untouched or unconsumed for so long

Improper storing -> shorten the food shelf life

Those two occurrences may cause the food spoilt, or rotten -> food becomes inedible -> thrown away

The two issues above are broken down into five matters to overcome by the proposed solutions or ideas:

1. People often lose track of their food at home: how much perishable food the consumer has. This relates to reminding people about the food they have and encouraging them to consume it soon, or if they buy new food, they should eat the older first (if the item is similar or same) -> make sure that the food does not end up in the garbage

2. Forgetfulness: hidden perishable food. how to increase food visibility (within people's sight range) or inform the users about the concealed food in the fridge

3. Lack of knowledge of correct storage impacts more food to waste. Enhancing or indirectly educating users on how to store perishable food correctly may lengthen or help maintain the shelf life so that less food will get bad soon. The information should be complete and practical, yet not overwhelming. People may feel control over their food. People usually waste food unintentionally. They feel regretful and powerless after wasting food.

4. Messy food arrangement: increase forgetfulness. Support the consumers to have a tidy food setting to see through everything and not miss the food to get bad. A chaotic food arrangement means food lying around on the kitchen counter without a container or in the fridge. The fresh food and leftovers are mixed, so the consumers will easily forget the food they have. People feel that if they can arrange their storage better and see all perishable food, it may help them prevent more food waste.

5. Lazy or forget to check the food storages regularly. This laziness often leads to buying redundant products (same items over and over again). Having abundant food, especially perishable, may cause more food waste as the consumers cannot finish it before it expires. Sometimes, people are not lazy, but just forget it, and they must hardly memorize what they have when shopping. A reminder to check the food storage before restocking food is necessary to help the consumers buy what they need only, prevent more wasted food and save money.

The ideas below are designed to solve the problems. However, one idea might only handle two or three issues, not all at once. Therefore, in the discussion and decision, each concept is analysed to cope with the problem and compare and create a comprehensive solution.

# 2.2 IDEA EXPLORATION

## Idea 1 "Food Saver"

Food Saver is a product to store food leftovers and display fruits and vegetables. It consists of two independent products; the first product supports the users in organizing their food leftover in the fridge. The second one presents fruits and vegetables nicely outside the refrigerator. This product is also a reminder for the user of having almost expired food. As both products complement each other, the user should get both products when purchasing Food Saver.
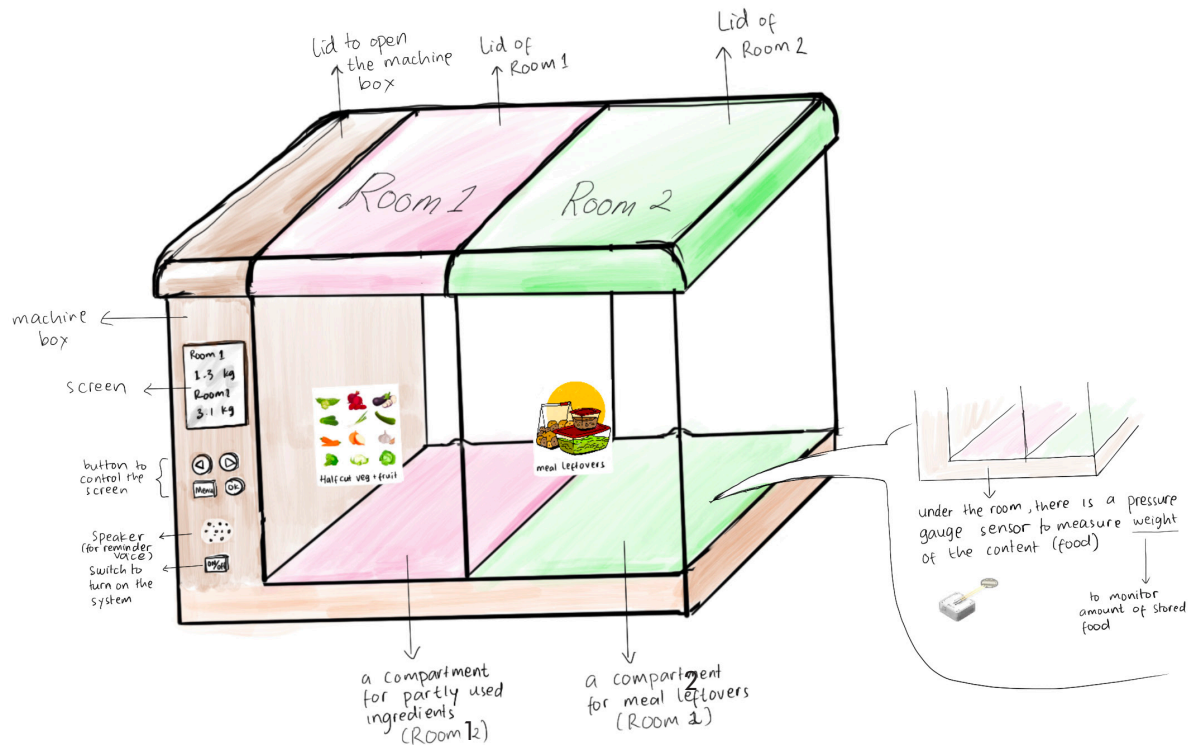


Figure 20. Food Saver Product 1

Product 1 is supposed to be placed in the fridge (Figure 21) to store food leftovers. In common practice, people usually have more than one type of leftover, which at least partially used ingredient and meal leftover. Almost all participants of the photo diary have leftovers in their fridge. They use various package to keep it (e.g. aluminium foil, the original box, a Tupperware, a bowl or without any cover) and put it anywhere in the fridge. If the person does not reuse the leftover right away, this random setting may cause forgetfulness of the food. The food can be covered by other food, hidden in the corner and may never be consumed.

Using Product 1, which has partitions, the consumers get a special container for different leftovers (see Figure 20). They can put the leftovers by following a mark (sticker) on each section: partly used ingredients in Room 1 and meal leftover in Room 2. This division eases the system to keep track of certain leftovers. The container body is transparent to let the user see through it and has a lid to keep the content from external contamination. As the leftovers are stored in one place, the user will not miss them anymore.

Furthermore, Product 1 is equipped with a pressure sensor at the bottom of each partition to monitor the content amount. When the user fills Product 1 with food leftovers, the system measures the weight of every section, save the value and the storing date. Every time the sensor identifies a weight change, the stored value will be updated automatically.

After a few days passed, just before the dinner, the system compares the lastest value with the initial one to determine the amount of remaining leftover. Suppose the weight is still the same or just slightly reduced. In that case, the system will beep, and a small LED will blink as a reminder for the users to reuse the leftovers soon.

When the user finishes all leftovers (the sensor detects zero weight), the system will reset and be ready to start again. People mentioned that they usually do not eat leftovers from the previous dinner due to forgetting the food. This feature may help them keep track of leftovers at home and consume it on time before it gets worse.

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Product 2 is located in the kitchen counter or nearby spots. It displays the user's fruits and vegetables prettier and maintains its shelf life (see Figure 22). The participants conveyed that showing fresh fruits is important to remind them to eat healthily. They also said that fruit bowls could be part of the kitchen decoration. However, they face quick ripening or browning matter before finishing the fruits or vegetables. Some people might still consume it, but others do not feel like eating brown or withered items, which then discard them.

This event occurs because the new fruits pile up the old fruits. Moreover, an incorrect combination of food stored together also accelerates the ripening process (existence of ethylene gas), e.g. bananas and apples. Lastly, displaying certain fruits and vegetables that should be in the fridge, outside the refrigerator. Therefore, a way to keep the items inside Product 2 fresh is necessary.

Three compartments offered by the product is intended to separate ethylene producers and ethylene-sensitive fruits and vegetables. If those two types do not meet directly, quick decay can be prevented and extend the lifetime. Moreover, a tight lid is used to regulate airflow inside the container. Reducing the exposure of fruits to oxygen can retard an oxidation reaction (a chemical process that causes browning and softening). The lid is transparent to keep the visibility of fruits and vegetables from the user's sight. A particular compartment is designed for partially used displayed fruits or vegetables to keep it fresh. It has a surface with a special material to help slow down browning on the cut area. To use it, the user should make the cut area to touch the product surface.
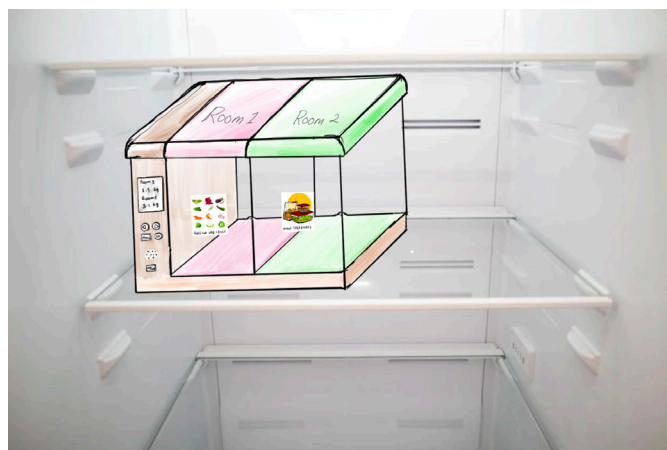


Figure 21. Product 1 in the fridge

Lastly, a manual book is also accommodated. The information is about working with Product 1, e.g. setting, turning on-off, maintenance, and soon, and a storing guide for Product 2 (i.e. what fruits should be separated). In addition, there are several stickers of the group of fruits and vegetables which should be put together. The user is free to stick which sticker on which compartment to learn how to store that food correctly.
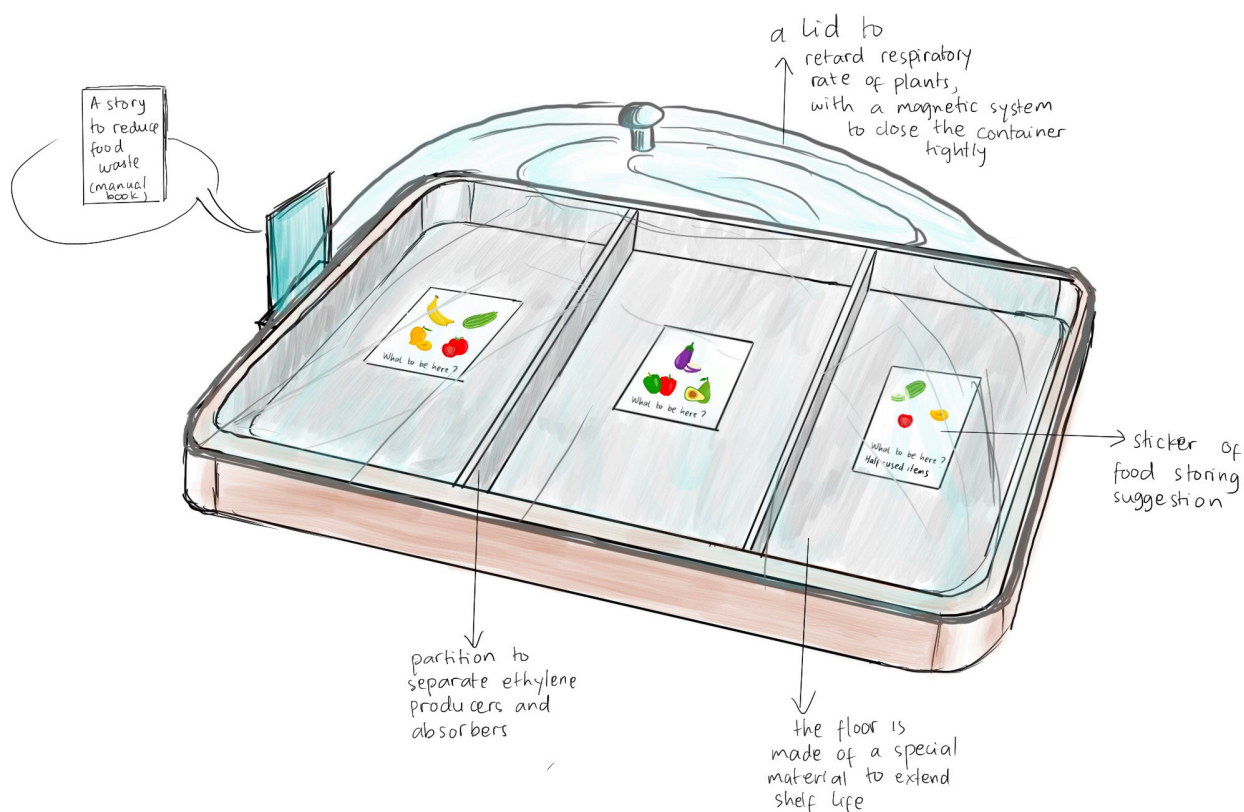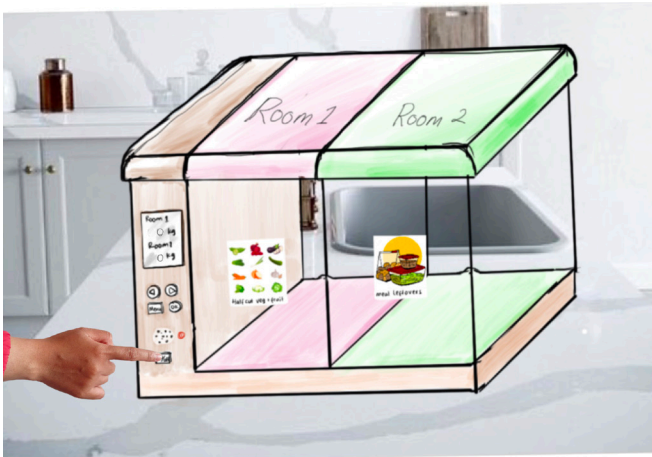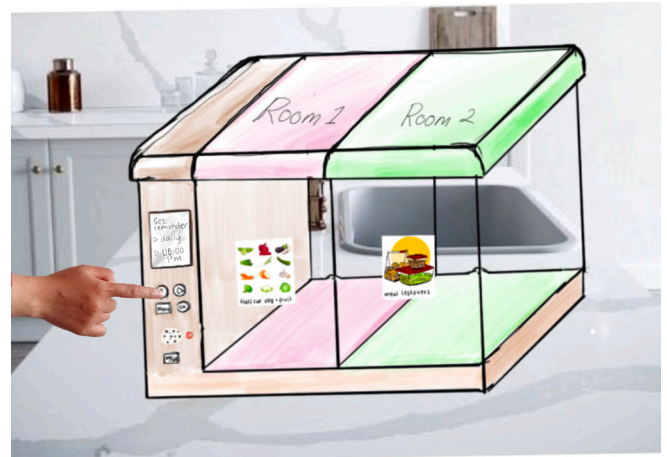


Figure 22. Food Saver Product 2

# How to use Idea 1, "Food Saver"?



Turn on Product 1(initial weight is zero)



Set regular reminder time (people can use the default setting, i.e. before eating time, or manually change it).
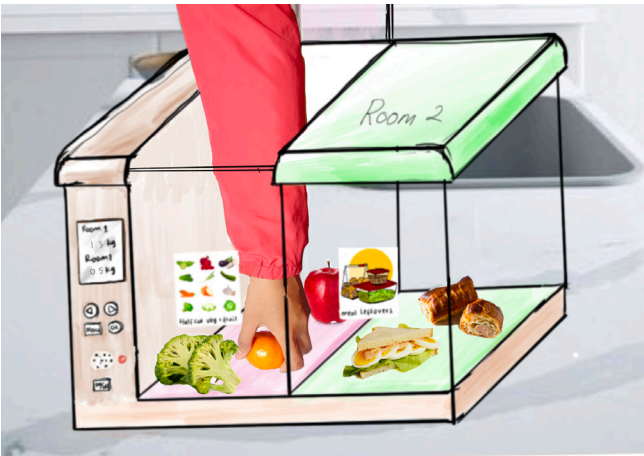


The user keeps the food in both containers by following the guidance (which partition is for which purpose). Product 1 will measure the weight of food in each chamber, save the date and data.



Then, put Product 1 in the fridge.



The user reads the guidebook



When the time comes, the container will notify the user to consume a certain food.

The food in Product 2 is divided into a few partitions as well. This feature is a way to separate ethylene producers and absorbers and prolong the food lifetime—the user stores fruits, vegetables and partly used ingredients into Product 2.

The user closes the lid

# Idea 2 "Food Marker"

Food Marker is a product to assist the consumers in recording the amount of short-lived food (i.e. fruits, vegetables, and leftovers) at home and count its lifetime.

Part of household food waste originates from perishable food that turns bad after being stored for so long and does not get a chance to be consumed. This problem happens because the consumers do over-buying and cannot finish all items before they expire. Moreover, another cause is lost track of total perishable food left at home, i.e. forget to have a certain food. In this product, there are three components to support the householder to keep aware of perishable food: food pins, a bowl lid, and a support app.
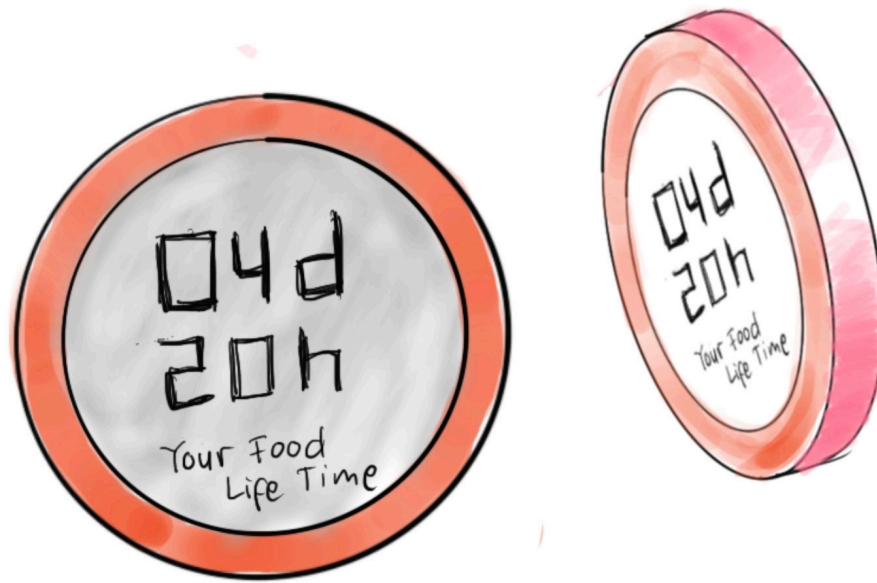


Figure 23. Food Marker Pin

Food pins are special pins attached to the food containers by the users to mark storage with perishable food (see Figures 23 and 24). Once the pin is switched on, it automatically connects to the following app. Afterwards, the app asks the user to manually enter the food name and shelf life or use the searching feature. If the app's library recognizes the food, the system generates the shelf life information by itself. Then click 'start' to activate a food timer to count down the food lifetime.

Short-lived food needs more attention compared to other food. Therefore, a counter feature is necessary to increase the alertness of the food decay process. Indeed, having a timer can be stressful if the users see the number frequently. Hence it is only visible when accessing the app and installed in the pin. Showing the clock through the pin is important to drag the user's attention (create a sense of urgency specifically for leftovers (VanHooker, 2019)) during dinner time. They are expected to prioritize consuming items with the least time. On the other hand, building this awareness of time may relax the consumer (VanHooker, 2019). They know when the food will get expired. Therefore, they can estimate or plan the consumption date and what to cook in advance.

Sticking the pin on the food container makes forgetfulness due to low visibility in the fridge irrelevant. Even though the users keep putting the food as they usually do, the pin will remind them if it identifies untouched food. As a response, the system sends a notification to the app, blinking led and a beeping sound in the pin. These indicators induce the users to check their refrigerators and find the sources (food containers).
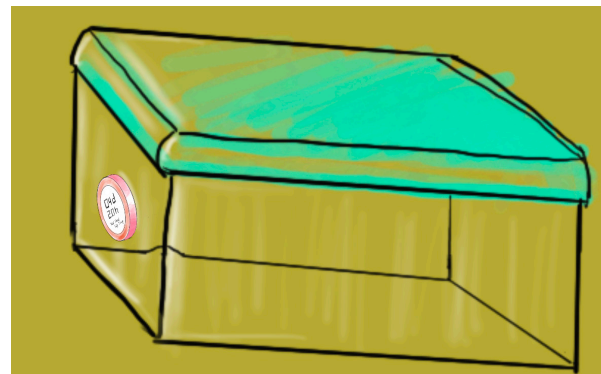


Figure 24. Pin on the container
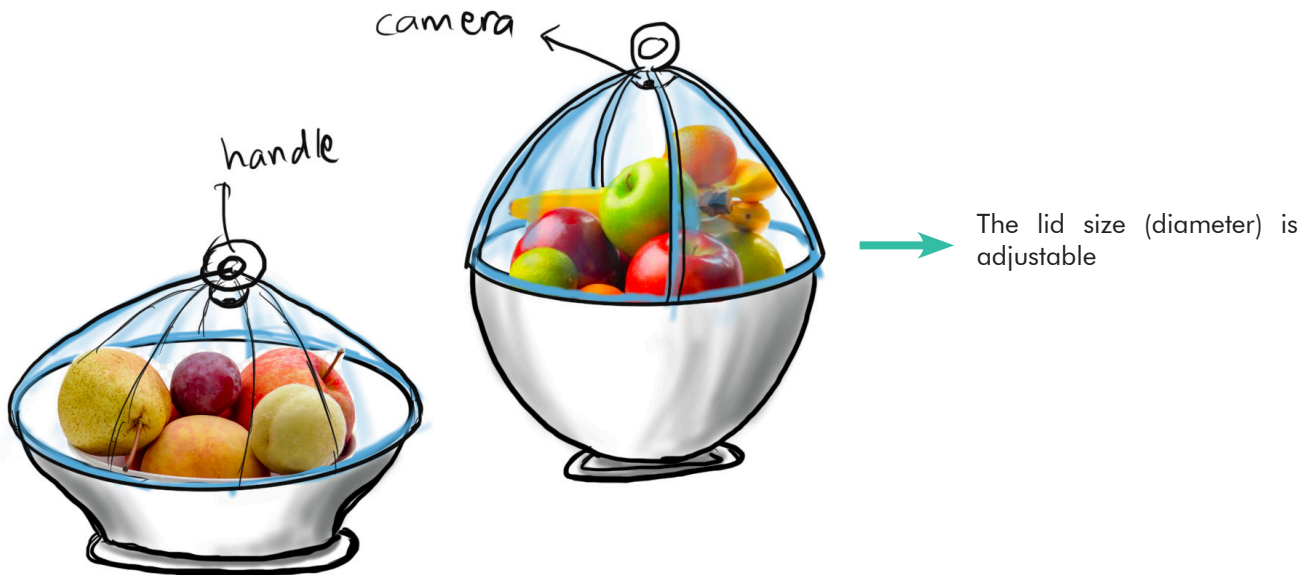
35

The lid size (diameter) is adjustable

Figure 25. Food Marker Bowl Lid

A bowl lid is a transparent cover for a bowl or plate that displays fruits and vegetables on the kitchen counter or the like (see Figure 25). It has adjustable dimensions to fit the diverse size of bowls and plates. The lid is equipped with an embedded sensor (camera) to track the ripening process of fruits. It can communicate with the app and warn the users if the food starts getting bad through a notification to pay more attention. This feature anticipates fruit waste due to browning or getting rotten.
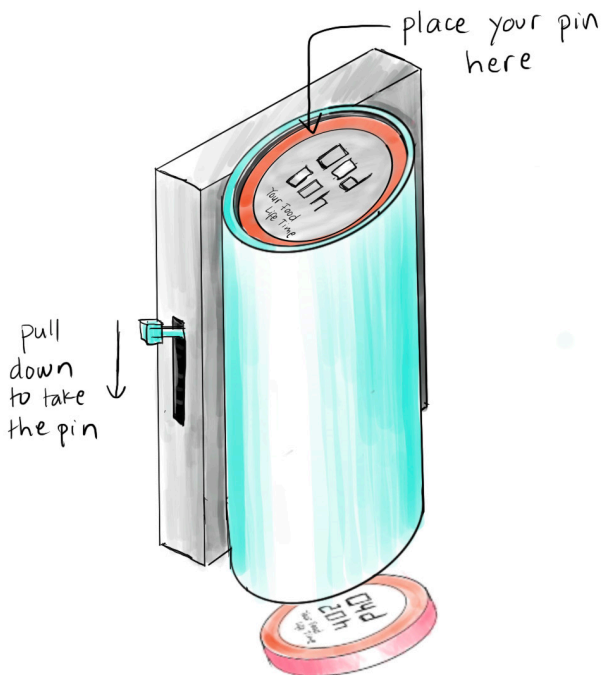


Figure 27. Food Marker app



Figure 26. Pin holder

Briefly, the app is a sort of portable tracker for the users. It updates the status of the stored food (amount of short lifetime food left, fruit condition in the bowl, and provides a real-time counter of the food shelf life). In this era, apps are massively used by people. It can help people to monitor perishable food or leftovers they have at home remotely. People who like to stop by for shopping after work can check the app to avoid purchasing redundant types of food or help prevent impulsive buying.

Moreover, the app provides recipe recommendations for partly used ingredients. Some people with lower cooking skills admit that they often have no idea how to reuse the leftovers (van Dooren, C., & Mensink, F., 2018). They might think of the same menu over time, which bores them. Therefore, accommodating the users with recipe recommendations is expected to assist them in preparing a few remaining ingredients and cooking various dishes instead of disposing of them.

Regularly, the app evaluates the stored food, how the users follow the instruction to consume the food, and how much money they have saved from preventing food waste. In addition, it shares information about the positive impacts of reducing food waste, which is essential to engage consumers in avoiding food waste at home. People may imagine what goods they may bring of having sustainable food practice to the environment and hunger people. However, at some point, they do not feel related anymore as they do not experience the benefits directly or it feels far.

Consumers know that wasting food is wrong, yet at a certain level, it is inevitable. There is no standard or clear threshold line between acceptable wasting and not. They also do not know how others combat food waste. As a result, people might feel fighting alone and eventually back to a less sustainable lifestyle or stagnate. Hence, sharing good news, the progress of the little movement in handling food waste, and showing money-saving they made, may encourage them to keep acting better.

## How to use Idea 2, "Food Marker"?
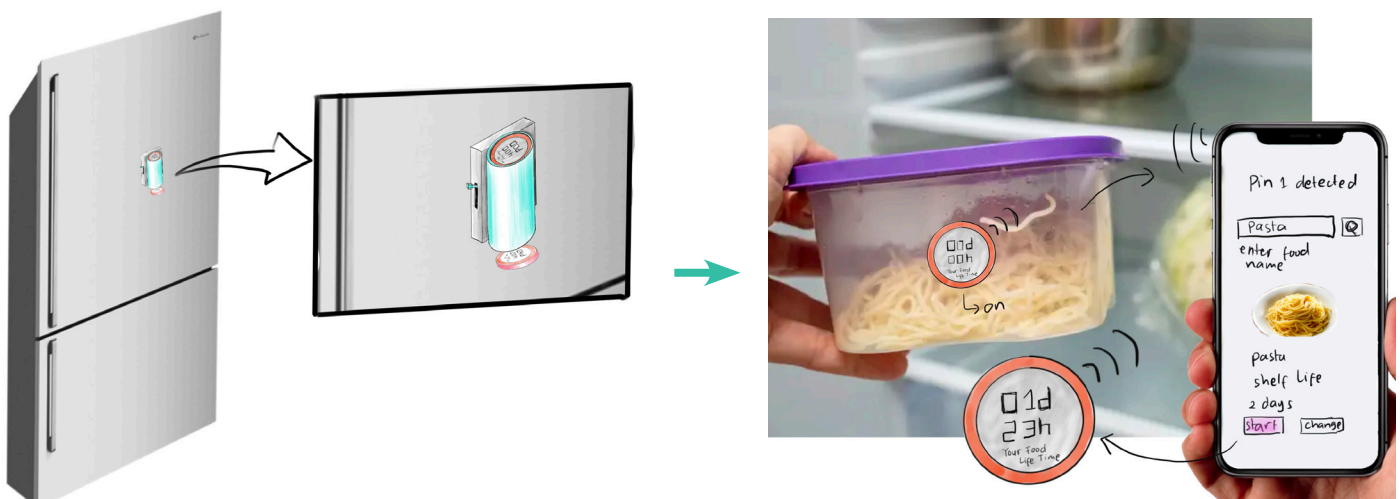


Take a pin from the pin holder by pulling a small lever on the side down and attaching the pin onto a food container.



The user places the short life food in that container and switches on the pin. The app automatically detects the pin and notify the users to input the food name and its shelf life. Suppose the product is one of the food in the app library. In that case, the system will automatically generate the shelf life information. Then, click start.
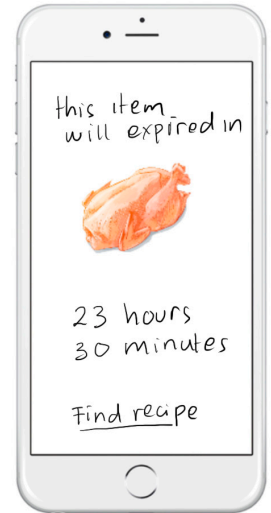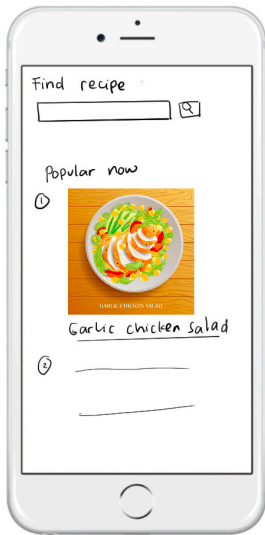
The app gives a regular reminder to consume the food before cooking or eating time. The users are encouraged to check containers with the pin right at that time. Also, a reminder to take fruit they display.

When the food time is running out, the app notifies the users. It also sends a signal to the pins to react (double notifications if the users miss the warning).
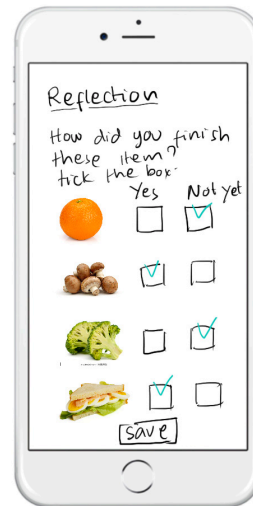




For the lid, the users just put them on the bowl and let it works. Once it notices some fruits start getting rotten, it will alert the users after the time is up.

The app will ask the users to confirm their consumption regarding the stored food. each success will be converted to information about the good impact of that contribution to the environment like how much energy or food they save, or $CO_2$ release reduced, or money saved

# Idea 3 "Food Tracker"

Food Tracker is an app capable of generating food lists automatically from online shopping carts and receipts when people purchase food. The app is connected to a personal account of supermarket membership and online groceries service.

The focus is narrowed into short-lived food, i.e. fresh fruits and vegetables and leftovers. Thus the system filters these kinds from the long-lived items to create the food list and save the other food as a history, available for later access. The prominent function of Food Keeper is supporting the consumers to track purchased food at home in the most effortless way. Moreover, the app increases food visibility digitally through food images.

Using the image to show the food (increase food visibility digitally)

Food shelf life

The amount of food is updated after a regular evaluation

Click the food name, more information will be available (storing suggestion, nutrition value, etc.)
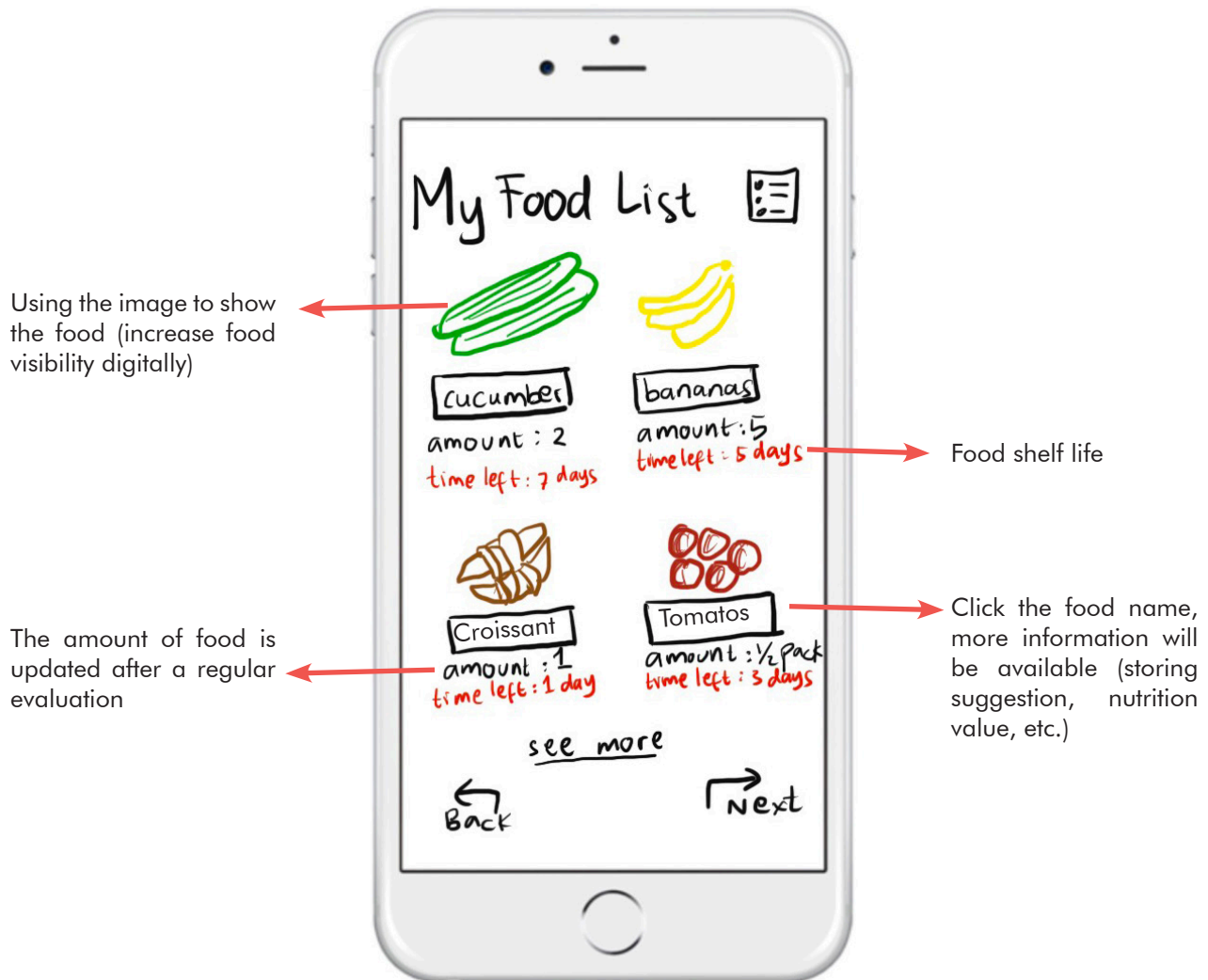


Figure 28. Food Tracker App

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Keeping track of food at home is crucial in reducing household food waste, as explained in the previous subchapter (Chapter Ideation, Problems to address). These days, people are already busy with work. The participants of the photo diary conveyed that they do not have time to write down all food they have at home. Instead, they try to memorize it, even though much food is missed and end up stocking up more food and disposing of some.

In this app, the user will not be bothered by entering the food name one by one as the existing 'food list' apps, except for the meal leftover since it can be anything. Initially, the system only had a standard library that contained typical cuisines or dishes in the Netherlands. If the app cannot find it in the library, the user should manually type the name and additional information. The system will store it to enrich the data and to ease the users for future access. Also, whenever the user buys new food, the food list will be updated automatically.

Food in the list is categorized into three groups: fruits, vegetables, and leftovers, to ease the user finds food they want. As the system has prior knowledge about the expiry date, in default, food is sorted by the shortest shelf life. Doing so can encourage the consumers to use older food first (FEFO method: First Expired First Out). Prioritizing food consumption based on freshness is an alternative to reduce food waste in the warehouse or distribution stage of the food supply chain (Scheviak, 2020). In this case, food products that are closest to expiration should be delivered first than others.

Implementing the FEFO method at the household level is expected to save more food. However, to avoid the feeling of being forced to cook specific ingredients that the user may not know what to prepare with those items, showing dish recipe suggestions is preferable. The menu is produced from the combination of food in the list (short and long-lived products). Therefore, people do not need to think about which food should be used. Instead, they only need to choose the menu they want and follow the cooking instructions.

Although the app has recommended which food to consume earlier, there is no guarantee that the user will follow it. As a consequence, a few foods may be abandoned. If the system notices particular food stays on the list too long and approaches its expiry time, it will notify the users. An explicit reminder is required to evoke a bit sense of urgency to use the food soon.

Furthermore, the user needs to remove used food from the list to keep the food list accurate and updated. After dinner time, the app regularly requests the user to give a tick on the consumed food. However, suppose people take a recommended dish. In that case, they just need to confirm it and let the system remove used ingredients from the list.

Once in two weeks, Food Tracker summarizes all used food, unfinished one (thrown away) and the user practice using the app. This feature aims to support people in understanding their regular habits towards food waste. The summary tells a change that happens to them after using the product. It also shows the action's good impact (using the app and implementing what the app commands). Some people do not really pay attention to their food waste because they do not know how good their current practice is in preventing food waste. They also do not feel the impact directly when trying to reduce it. Therefore, evaluation by providing advice to act better and share the good impact of preventing household food waste are required to engage people to be more sustainable in food.

Having a Food Tracker lets people feel in control over their food at home. They can record and watch over the food remotely and easily. It helps the user avoid buying the same unwanted food and decrease their guilt by discarding their food.

## How to use Idea 3, "Food Tracker"?
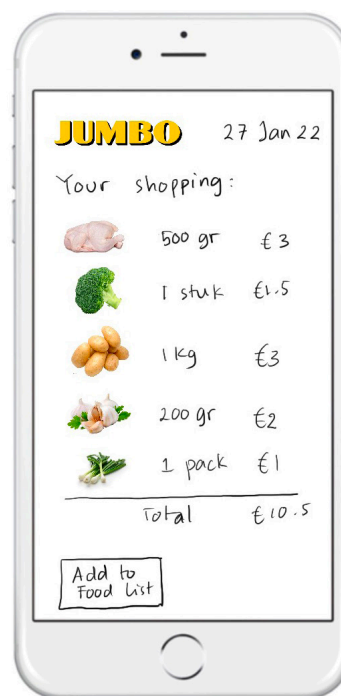


Offline case: the consumer purchases groceries and uses their supermarket card to input the shopping list. Online: buy online; once the consumer pays for the food, the system will save the food items in the cart as a food list. Every time the consumer buys food, it will be updated automatically.
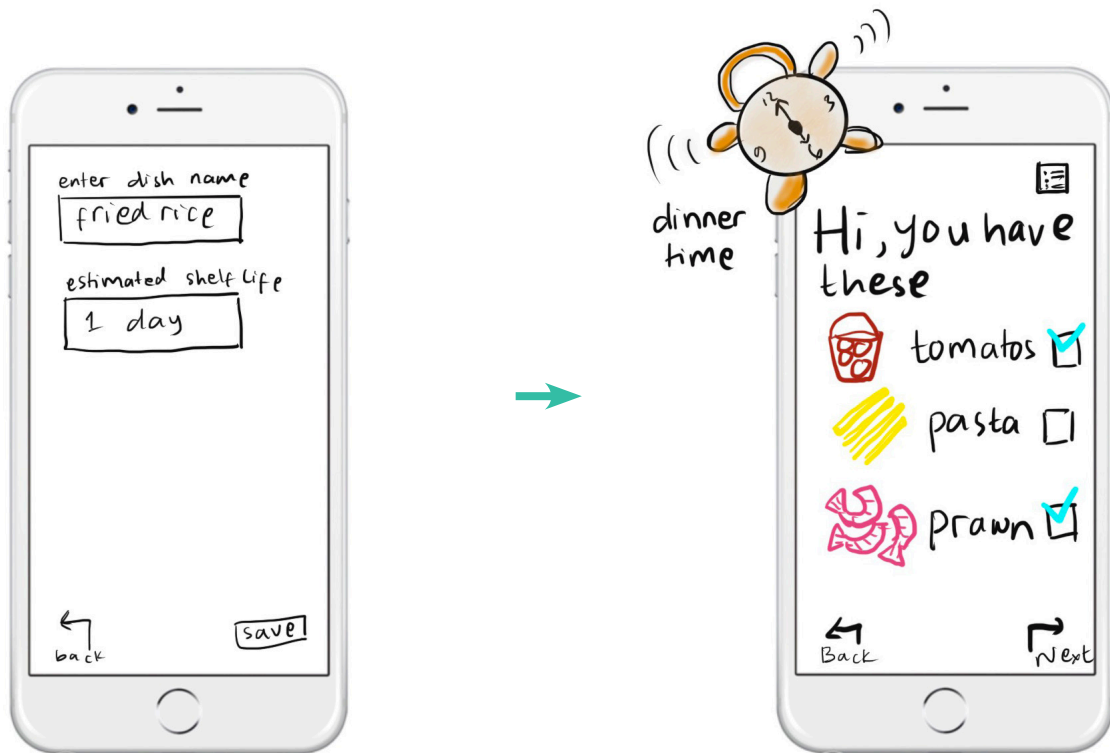
The system has prior knowledge about the expiry date of the food, and it will create a default order of the food list based on expiry date information and estimation. For meal leftover, the user can manually enter meal leftover. The system automatically approximates its lifetime and save the data.

Regularly, the app will ask the user about their food consumption (Have they used the food?). The user set the reminder time or follow the default setting (before dinner time). Then, they confirm their answer by ticking a shown list.
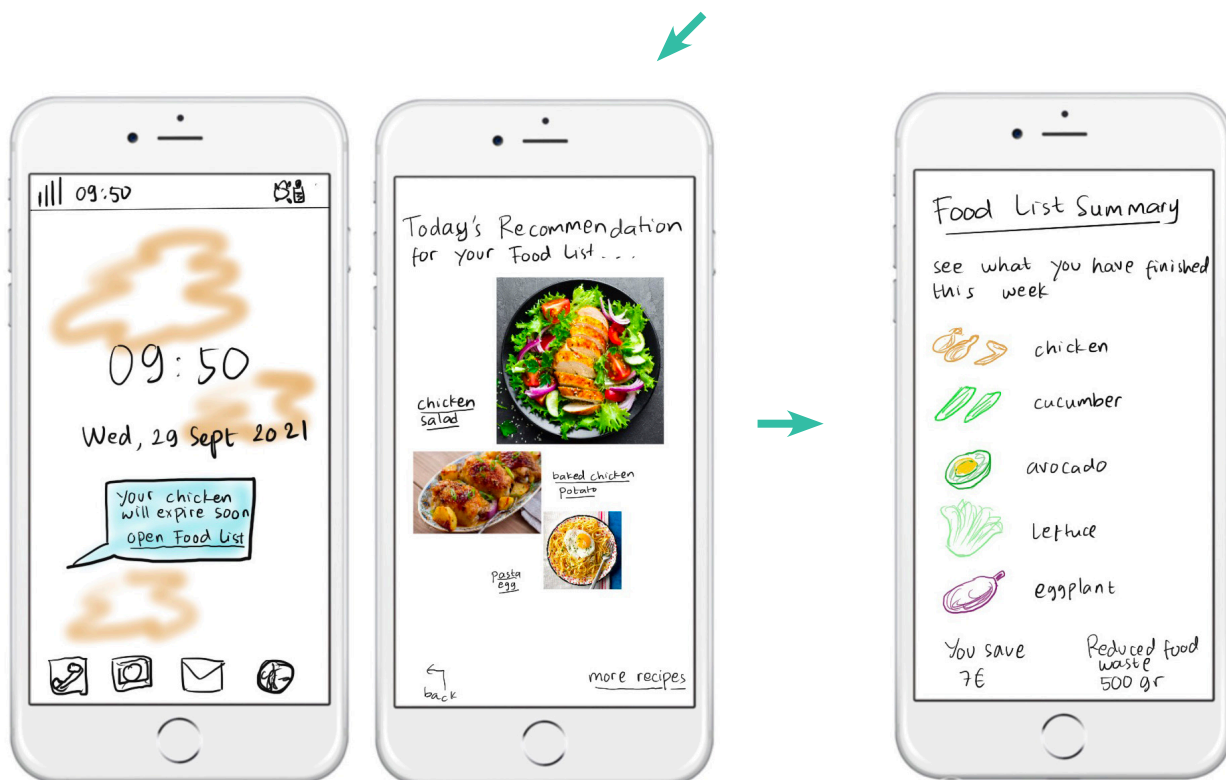


When the app detects food items in the list approaching their ending time, it will notify the users and suggest a cooking menu (if the food is raw material) or how to reuse/modify it (if leftover).

Once in two weeks, the app will summarize all finished food and congratulate the user by showing the good impact of the action (environmental influence and social). If people cannot finish some food and end up discarding it, the system tries to read the pattern or understand the reason and suggest food to buy or amount of food (practice evaluation)

# Idea 4 "Attentie Spot"

Attentie Spot is a product that creates a special zone to store food leftovers in the fridge. The main purpose of Idea 4 is similar to Idea 1, which is to improve the visibility of short-lived food in the refrigerator. Attentie Spot wants to support the consumers to display the food nicely while extending its shelf life. The product has two elements to achieve the goal: storing blocks/storage walls and a food display cabinet.
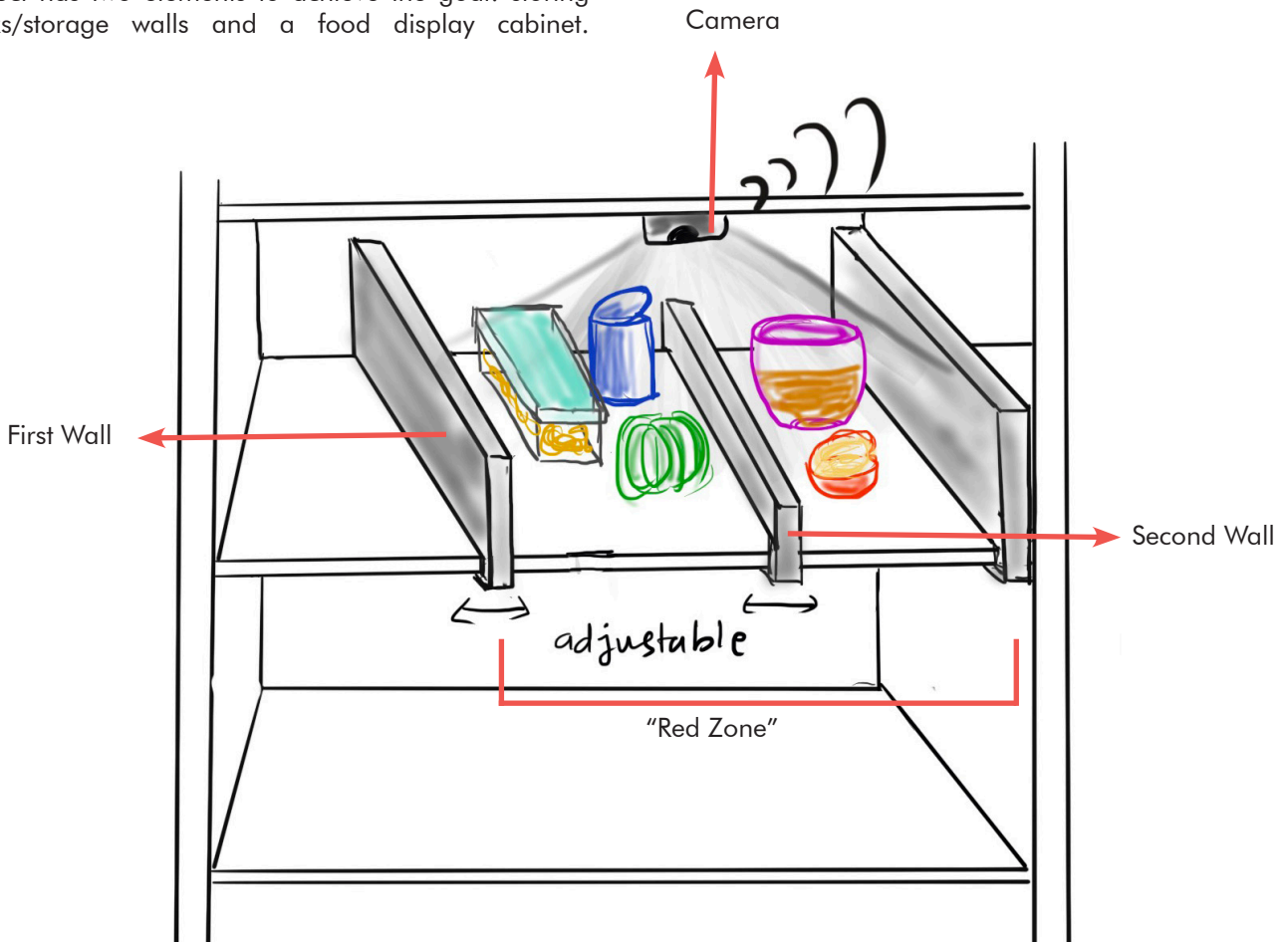


Figure 29. Attentie Spot in the fridge

Storing blocks creates a particular area to store leftovers (meal leftovers and partly used ingredients) in the fridge, called the "red zone" (see Figure 29). The name was picked because it commonly represents 'danger territory' or 'attention-getting', which means that food within this zone needs consideration. The product consists of assembly-disassembly walls and a portable camera.

The first wall (higher) is meant to border leftovers and other food in the refrigerator. The second (shorter) is used to distinguish meal leftovers and partly used ingredients. By constructing this wall, the leftovers location will be concentrated in one place. It will not be scattered among other food, hidden in the corner and being forgotten. It helps the user to arrange their fridge better and monitor leftovers more easily. Since the wall is temporarily hooked to the glass plate, it can be shifted to enlarge or decrease the area as the user pleases (freedom) or the number of leftovers stored.



Figure 30. Attentie Spot Camera

Figure 31. Attentie Spot display cabinet
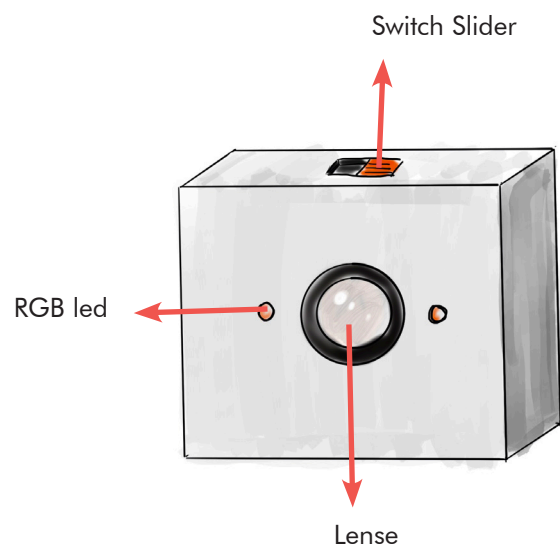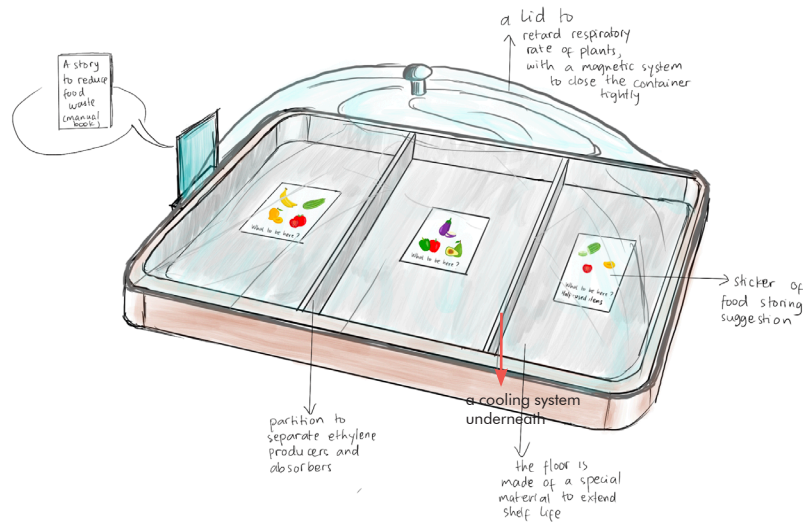
The camera has a function to inspect the consumption of the leftovers in the red zone. The user only needs to stick it on the fridge's ceiling and switch it on to install the camera. When the camera identifies an untouched item, i.e. food stays in the zone for a few days and has never been taken out. Then, it will turn on a reminder in light and sound indicator. A human voice is chosen to anticipate the stress of hearing the reminder and being friendly. This voice will say something like, "My dear, I spot untouched food. You should check your red zone".

Moreover, the camera device is equipped with RGB led (see Figure 30). The light has a function to attract the first attention of the user whenever they open the refrigerator and choose food from the red zone first, then other compartments. For example, a red-orange led will illuminate the red zone when the user opens the fridge. As red and yellowish are a colour that stimulates appetite, happiness and comfort (Hartel, 2021), food under this light is intended to appeal to the consumers to take it.

Finishing food before getting bad is critical in reducing household food waste. Instead of reminding people utilizing too many reminders that may stress them out, a smoother way of making the red zone intriguing is preferable.

A food display cabinet in Idea 4 is similar to Product 2 from Idea 1. It is designed to display fruits and vegetables fresh longer and safer. The cabinet has several compartments to save different food types based on ethylene production and sensitivity to restrain the continuous ripening process. A transparent lid is also applied to reduce food-oxygen chemical reaction that leads to browning appearance. The product is also equipped with a special compartment with a cooling system, which differentiates it from Product 2 Idea 1. This system lets the user store a few green-leafy vegetables or fruits that should be put in the fridge. However, the purpose remains the same, which is saving half-used ingredients from being abandoned.

## How to use Idea 4, "Attentie Spot"?
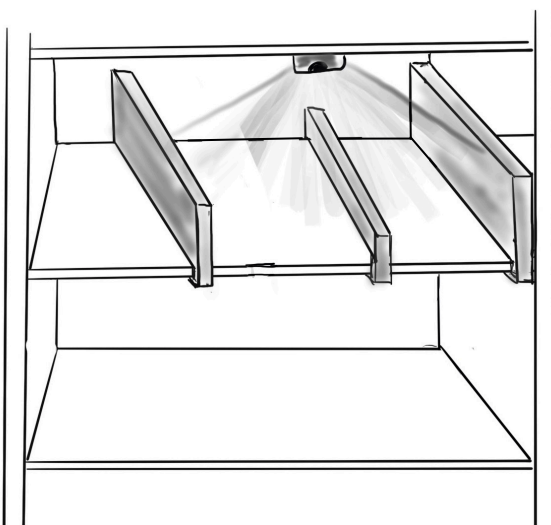


The user installs the storage partition in their refrigerator. The turn on the system (call it "red zone"). Set regular reminder time (people can use the default setting or manually change it).
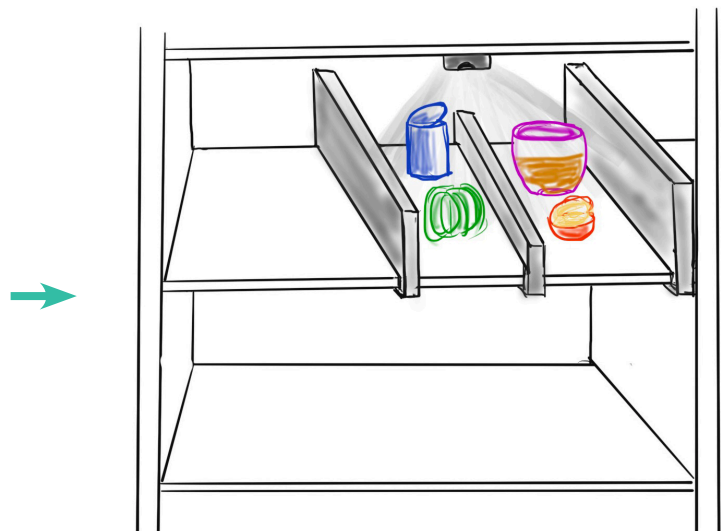
The user puts the intended food within the red zone. Then, the system uses image data to monitor the leftovers.
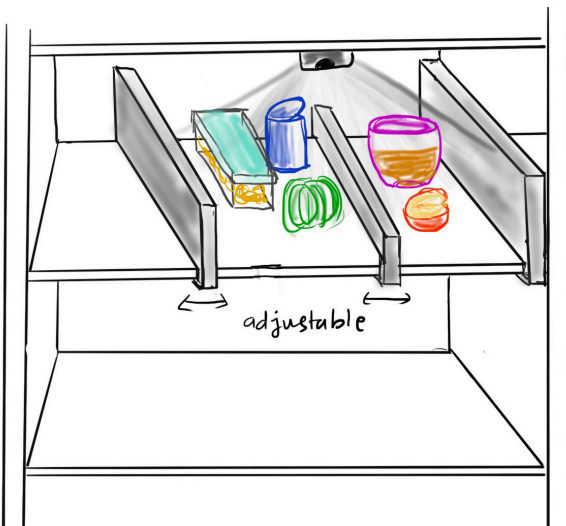
The user can expand or reduce the red zone area (readjust feature). When the system detects a difference, it updates the data.
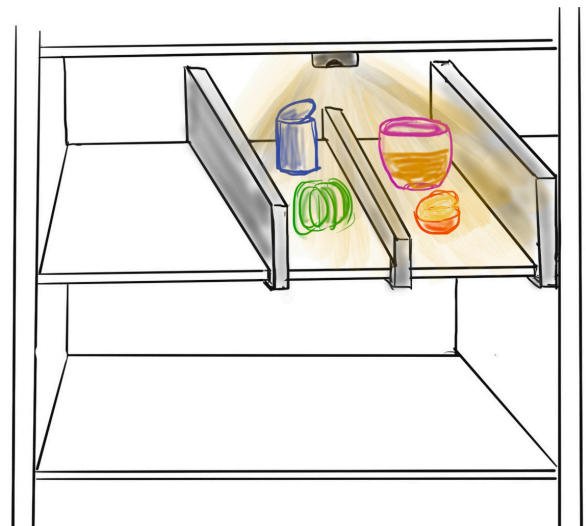


The user opens the fridge, a yellowish light turns on
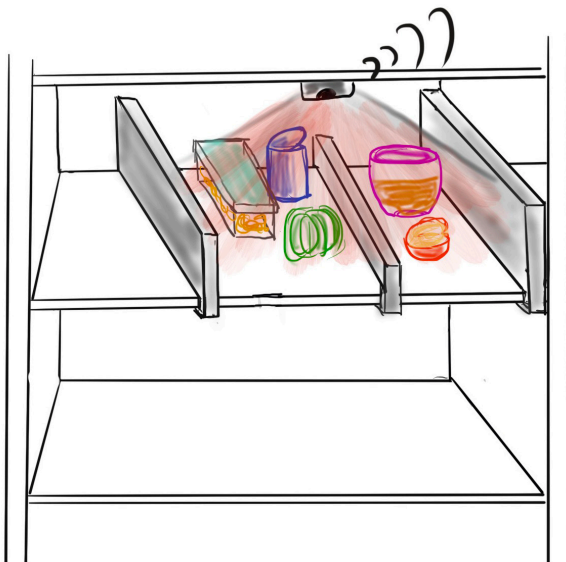


The system identifies food that lay within the zone for long. Then, it warns the user by releasing sound.



The fruits and vegetables displayed in a food display cabinet are divided into a few partitions. This way, shelf life can be extended.

The container utilizes material that can slow down food oxidation (direct contact), also a mechanism to regulate humidity or other factors that might accelerate oxidation (if possible, prefer without electricity or very low energy) -> similar to idea 1

# 2.3 ANALYSIS AND DECISION

## Parameters for Analysis

### Impactfulness

Impactfulness assesses how effective the idea to support consumers prevent food waste at home. This aspect can be seen from an estimation of how much food waste the user may produce if they do not follow the rules (amount of hole to cheat). Furthermore, from comparing the benefit and challenges to using it, the solution is quite effective or has a high impact if the advantage is bigger than the drawback.

### Convenience

Convenience relates to the amount of effort that the user should give to do all required tasks. Moreover, this parameter addresses time consumption when interacting with the product. The higher the effort level and time spent to accomplish the tasks, it might be bothering. However, engagement and influence might never be built if the effort and interaction time is too low. Therefore, the number of tasks and time should be only enough. Furthermore, convenience also covers annoyance levels, i.e. the feature should not cause stress, especially a reminder system. Lastly, the easiness to install and maintaining the product should be considered.
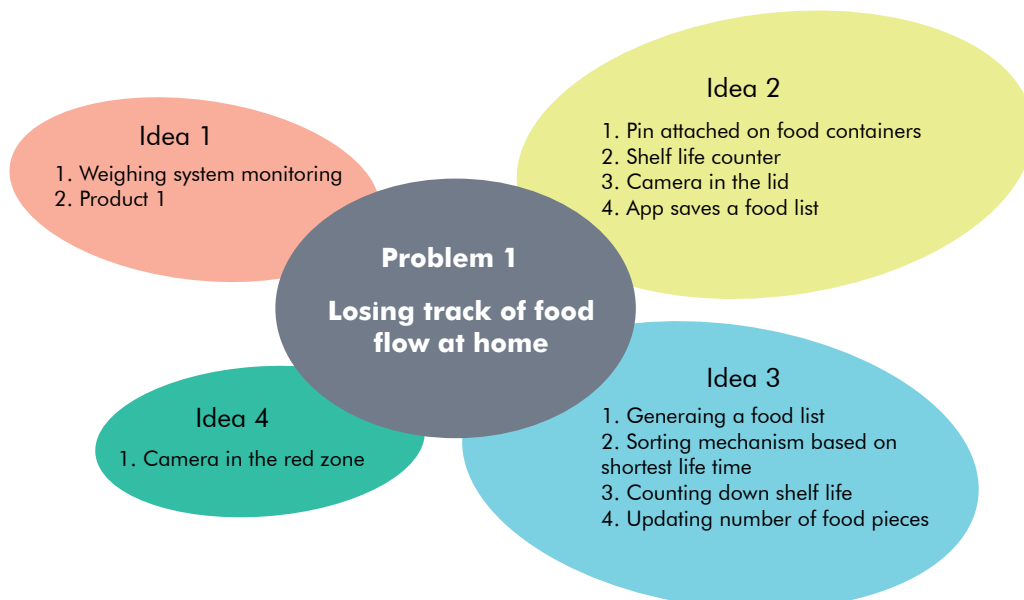
### Adaptability

Adaptability talks about the learning process to use the product for the first time. Therefore, this parameter is associated with how different the new practice uses the product and the old habit. If this gap is small, the user may feel supported instead of "have to".

### Energy Use

This aspect means the energy used to operate the product. From a sustainability perspective, the product should consume low energy (electricity). The main goal of the product is reducing food waste or achieving sustainable food practices. Hence, the solution should be part of sustainability as well.

### Affordability

The product should not cost the consumer a lot of money. In order to attract more people, the solution needs to be a low investment, or it should have worthwhile added value for spending money.

## Idea—Problem Map

After explaining four ideas in detail, these interventions were analysed how their features solve the issues. Then, using the parameters, they were compared to obtain the best way in overcoming every problem. The map is divided based on five problems to address. Solutions from previous ideas surround each problem circle. One idea does not always resolve all issues. The bigger circle of the idea means more features are dedicated to tackling that specific trouble

### Problem 1: Losing track of food flow at home



Idea 1
1. Weighing system monitoring
2. Product 1

Idea 2
1. Pin attached on food containers
2. Shelf life counter
3. Camera in the lid
4. App saves a food list

**Problem 1**
**Losing track of food flow at home**

Idea 4
1. Camera in the red zone

Idea 3
1. Generaing a food list
2. Sorting mechanism based on shortest life time
3. Counting down shelf life
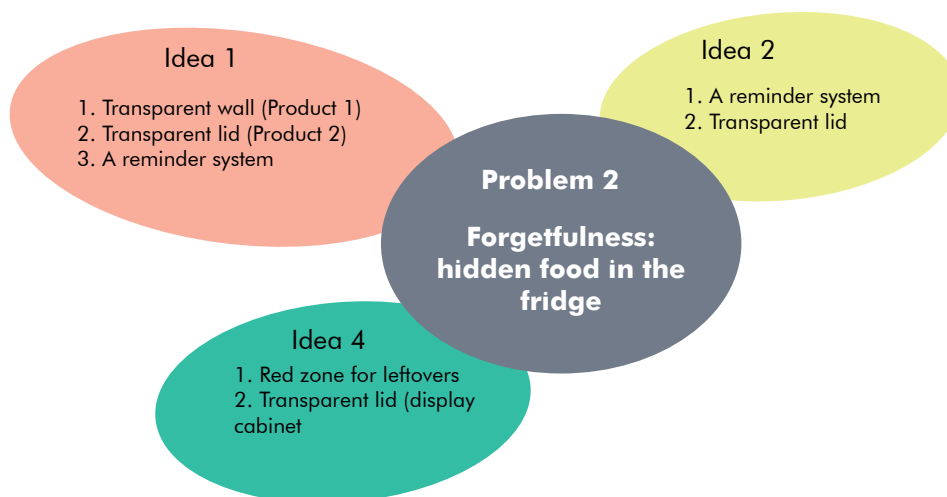4. Updating number of food pieces

The weighing system from Idea 1 monitors how much food is stored and taken by measuring weight change in Product 1. However, weight cannot tell much about food consumption. This is because the system makes a weak assumption: "taking food" means "eating". Another scenario may occur. For example, the food is spoilt and thrown away. In terms of preventing food waste, weighing the food has a lot of flaws. In order to make it more robust, an additional sensor is needed.

Monitoring food with camera Idea 4 could be more accurate than the weighing system. Nevertheless, the camera can work the best if the food is visible, not inside a container. A camera uses food image data to record the food condition. Also, installing a camera to track food seems to be exaggerated and costly. People might not want to invest a lot of money to save a few savings from reducing food waste. Moreover, in terms of energy use, the camera spends the most energy compared to other solutions.

Food Saver Product 1 from Idea 1 is designed for saving meal leftovers and partly used ingredients. Putting them in one place could ease the user to follow the leftover's flow. When they access the product, they see and know what food should be consumed.

At a glance, counting food shelf life looks like a good trigger for consumers to eat their food on time. However, psychologically, a feeling of urgency could constrain the freedom to select food to use. As a consequence, they may overlook it.

An integrated app of idea 3 is the most effortless way to record perishable food at home. But manually updating the list by removing eaten food could be cumbersome. Furthermore, an app alone without a physical product could be less engaging for a long period.

**Decision Problem 1:**

Keeping track of the whole perishable food could be stressful, even though consumers get various support. Only focusing on fruits and vegetables could be more useful, since those two products are number 3 and 4 the most wasted food. The solution can be simpler yet highly impactful.

Among resolutions offered by four ideas, the only solution that suits to monitor fruits and vegetable consumption at home is Product 1 from Idea 1 but leaving the weighing system monitoring. Designing a special container to store these food products is more feasible, simpler and cheaper, than installing a camera or shelf life counter. Further, hard technology like cameras and weighing sensors requires high maintenance because they work under low temperatures. The app does not need a direct cost investment, but having only an app without a tangible product could be less effective. People are already overwhelmed with the abundance of apps and notifications from their phones.

## Problem 2: Forgetfulness: hidden food in the fridge



Idea 1
1. Transparent wall (Product 1)
2. Transparent lid (Product 2)
3. A reminder system

Idea 2
1. A reminder system
2. Transparent lid

Problem 2
Forgetfulness: hidden food in the fridge

Idea 4
1. Red zone for leftovers
2. Transparent lid (display cabinet

To avoid short-lived food hidden in the refrigerator, Idea 1 and 4 provide a special place to collect them in one place. This method helps the user finds their food quicker and reduces food waste due to being unnoticeable. However, the visibility in a fridge range is limited. Although the product is transparent, the possibility to be covered by other food still exists.

Moreover, they offer a food displayer to increase the visibility of fruits and vegetables outside the fridge by applying transparent material. Idea 2 also implements this transparency to let the user views the content.

The pin system in Idea 2 is supposed to help prevent food waste from meal leftovers (anything stored in a closed container). However, since the focus is shifted to fruits and vegetables, this system may be unnecessary.
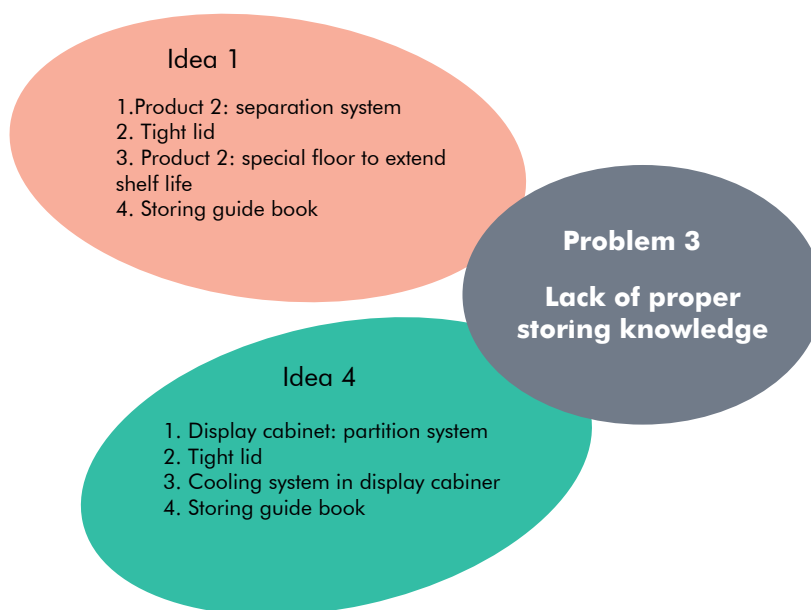
A reminder system is useful for remembering what food they store and may reveal the concealed food. But, the user may turn off the pin if it makes them feel anxious or nervous too much.

**Decision Problem 2:**

Trying to enhance food visibility inside the refrigerator still has limitations. Unless the food is in the front line of compartments, the user might miss it. Therefore, a better idea is to display this food in an open space, like the food display. Although this means some factors should be considered. e.g. food safety and quality. Those two things only matter if the product keeps the food for a long time. But, if it is only for a short period, it would not be that problematic.

Moreover, implementing transparency is an explicit way to improve food visibility. The user can see and notice the food easily. Adding this feature to the final product could encourage people to consume the food to prevent food waste at home.

## *Problem 3: Lack of proper food storing and maintain shelf life*

Idea 1

1. Product 2: separation system
2. Tight lid
3. Product 2: special floor to extend shelf life
4. Storing guide book

**Problem 3**

**Lack of proper storing knowledge**

Idea 4

1. Display cabinet: partition system
2. Tight lid
3. Cooling system in display cabiner
4. Storing guide book

The idea to tackle problem 3 is the same. Product 2 in Idea 1 and the food display cabinet from Idea 4 are similar. The difference only lies in a cooling system implemented in a food display cabinet.
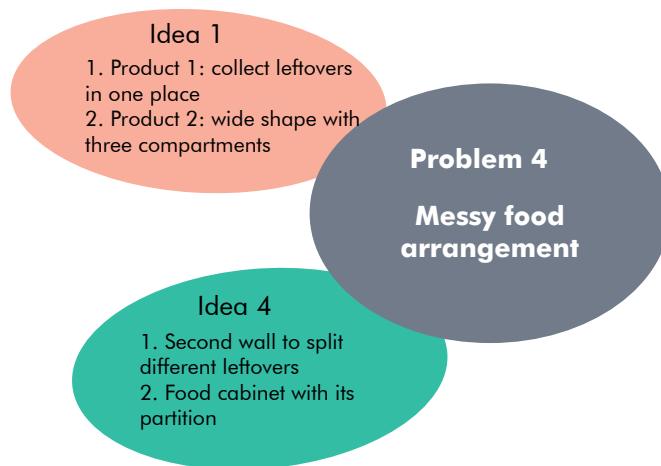
In terms of maintaining food lifetime, all ways mentioned above are relevant. Each point complement to other because they deal with the different storing problem. The separation system is to split ethylene gas producers and absorbers. The tight lid is for limiting oxygen exposure to retard the decaying process of fresh food. The cooling system and the special floor material are meant to help half-cut food stay fresh longer.

To enhance people's knowledge of correct food storing, a guide book is offered. The idea of informing this information to the user is good. However, further exploration is needed to find a better way of communicating the knowledge.

**Decision Problem 3:**

Combining those methods is the best way to build an ideal storage outside the fridge. Also, the idea of guiding people to apply proper storage in daily practice is inspiring to develop.

## Problem 4: Messy Food Arrangement

**Idea 1**
1. Product 1: collect leftovers in one place
2. Product 2: wide shape with three compartments

**Problem 4**
**Messy food arrangement**

**Idea 4**
1. Second wall to split different leftovers
2. Food cabinet with its partition

Food Saver Product 1 brings a good idea to collect all leftovers in the fridge in one place, instead of spreading them all over the refrigerator. In practice, this solution could be difficult as the leftovers may vary. Putting them together in a closed container might be messy and contaminate each other, specifically for meal leftovers. Moreover, sometimes the amount of food leftovers is unpredictable. To accommodate every single leftover, it should be big enough. Otherwise, some leftovers would be scattered. To determine the container size, it would make a bit trade-off with the fridge dimension.

In this case, the wall of Idea 4 looks better than Product 1 from Idea 1. This is because the "red zone" produces an open leftover area inside the fridge.

The user can freely place their leftovers there using Tupperware or a bowl. Then, the area width can be adjusted according to the amount of food leftover the user has. This is a good idea to build a leftover space inside a refrigerator.

However, arranging these walls requires patience. When the user is in a hurry and needs to put their food quickly, they may ignore it.
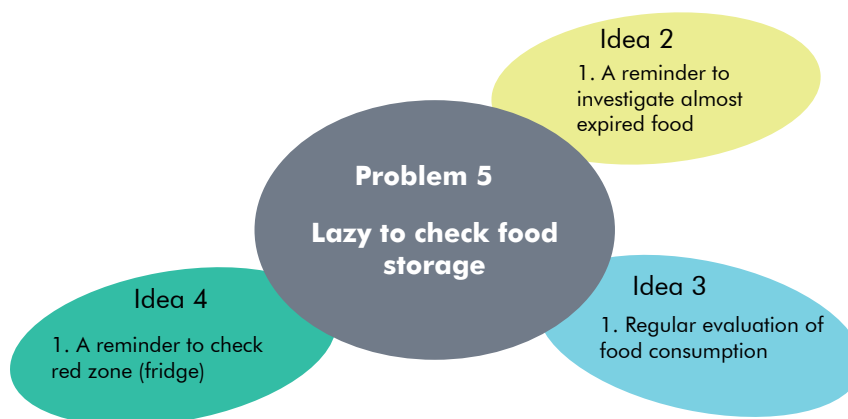
Product 2 Idea 1 and the food cabinet of Idea 4 is basically the same product. They manage perishable food outside the fridge. The difference only lies in a cooling system applied in Idea 4. Separating stored food in a few compartments help to manage the food tidier. This method could reduce the possibility of piling up food.

**Decision Problem 4:**

Managing meal leftovers neatly seems hard to do. The amount and kind are varied, and a fridge has limited space. Dealing with this might not be effective to prevent food waste.

Arranging food outside the fridge is more feasible. Even though it does not mean that the space becomes unlimited outside the refrigerator, but at least some trade-off could be handled.

## Problem 5: Lazy to check food storage regularly

**Idea 2**
1. A reminder to investigate almost expired food

**Problem 5**
**Lazy to check food storage**

**Idea 4**
1. A reminder to check red zone (fridge)

**Idea 3**
1. Regular evaluation of food consumption

Idea 2, "Food Marker", offers two reminders. One is installed in the pin in the form of a beeping sound and led blinking. Secondly, Food Marker App will create a notification when it identifies almost expired food appears. In order to take attention, the beeping sound should be quite loud. However, an intense noise at home is undesirable. A certain sound frequency can be selected to create an empathetic voice to deal with that issue, as Idea 4 does. But, if it turns on too frequent, the user probably still does not want it.

Blinking led inside the fridge sounds useless. Unless the user opens the chiller's door, they will not notice it.

Idea 3 creates a checklist in the app to update the amount of food. The user is shown their food list and asked to tick all food they have used. If they forget, they are expected to check their storage. The big drawback of this method is the user might only use their memory to accomplish the task. Thus, in the end, they do not check their food storage.

**Decision Problem 5:**

Instead of building a reminder system that can be annoying and ignored, modifying the user-product interaction might encourage people to check their main food storage. The product could utilize existing user motivation to trigger the action. In this way, people might feel "want to do" it, rather than "being forced".

Existing motivation related to fruits and vegetables is a healthy life. People purchase it and expect to consume it every day. Therefore, the product can support them by providing and displaying these items that should be consumed within 24 hours (a daily portion). Refilling action will encourage the user to check their main storage like fridge and cupboard. There is no specific reminder. Also, as the cabinet is transparent, the user can see how many fruits or vegetables are left there.

# 2.4 CONCLUSION

Based on the analysis and decision above, the final product will save fruits and vegetables, including half-cut items. The product is used to display them outside the fridge to minimize forgotten and overlooked food. Hence, people can see the food directly. To motivate regular consumption, the amount of shown food is limited for a daily portion. When people only see a few pieces, they might be more encouraged than seeing a pile of fruits. It is like asking the user to eat little by little consistently.

Moreover, designing one-day storage would be simpler than a long term storage system. The product might use less complicated and advanced technology to support the product function. Here are some requirements derived from the previous analysis.

1. Focus on saving fruits and partly-used vegetables

2. Design a special container to store and monitor fruits and veggies consumption.

3. The product should have low maintenance and be easy to install

4. Should be simple and not use a very high tech

5. If the product has an app, it is supposed to be a support, not the main solution

6. The product should be placed outside the fridge so that the user can see the fruits and vegetables

7. The product should ensure food safety and keep the quality

8. The product should provide a sufficient level of transparency to let the user see through the food

9. The product should consider the ethylene gas and plant respiration rate to slow down the decaying process of food. This action will make the fruits and vegetables remain fresh

10. The solution should guide the consumer to practice better food storing

11. The user-product interaction should not be stressful

12. The product should encourage the user to consume the food within 24 hours or max 48 hours

13. The product should be simple

# Chapter 3

# CONCEPTUALIZATION

The conceptualization part contains the process of concept development. It begins with the Food Display Cabinet concept, followed by the requirements that should be met to realize a comprehensive concept. This chapter explains the iteration of the solutions to fulfil the requirements, its evaluation and analysis. Lastly, the final product called FooDi is concluded. FooDi is special storage to keep fruits and half-cut vegetables only for 24-48 hours. The product aims to encourage consumers to display those commodities and eat them in time.

# 3.1 CONCEPT DEVELOPMENT

## FOOD DISPLAY CABINET

### What is it?

Food Display Cabinet is special storage to show fruits and partly used vegetables usually hidden and forgotten in the fridge (e.g. half onion, half paprika or other cut vegetables). The product encourages the consumers to eat food they purchase in a daily portion and reuse the ingredient leftovers to prevent food waste at home.

### Why is it?

The Early Interview reveals that low food visibility in the storage, especially refrigerators, leads the participants to produce more waste. The food is located in the corner, out of sight and finally never been used until becoming rotten. Moreover, a messy arrangement, i.e. mixing and stacking fruits and vegetables in one opaque bowl or fridge container, also contribute to food waste. The consumers unintentionally put older food under the new one. As the older food is out of sight, people tend to forget it until it gets bad (the photo diary result).

### How?

Food Display Cabinet has the main function to enhance the visibility of those commodities. The user is expected to consume the fruits or half-cuts vegetables regularly, i.e. finish the targetted portion in time, then refill it again. Despite, the food is stored only for 24-48 hours, designing a room for ideal storage is necessary. Several factors could threaten food quality, specifically when keeping half-cut ingredients. Additionally, this product is aimed to support the users improve knowledge of the proper storage method of perishable food.

### Requirements to meet:

*Ideal storage for 24-48 hours*

There are four factors to manage to build ideal storage for the fruits and vegetables: ethylene gas presence, respiration rate, relative humidity, and temperature (Hardenburg, R.E, et al., 1986). Therefore, a designed room can maintain the food quality kept inside for 1-2 days by considering those aspects.

### 1) Ethylene gas

Ethylene is a substance in the plant tissue that regulates the growing and senescence process (FAO, 2004). Several fruits and vegetables produce ethylene, and a few others are sensitive to this gas. Many people do not know about this information. They often mix the ethylene producers and absorbers in one place, which triggers undesirable reactions such as premature ripening, quick wilting, and green colour loss. Adding a simple partition to separate those two items can help the commodities fresh longer to avoid these effects. The example of ethylene producers is apple, pear and ripe banana. Meanwhile, fruits and veggies susceptible to this gas are avocados, grapes, cucumber, and broccoli. Furthermore, there are "neutral" types, i.e. they neither produce nor absorb ethylene gas, for instance, orange, carrot, and onion (FAO, 2004).

| ROOM 1 | ROOM 2 |
|---|---|
| Ethylene producers | Ethylene absorbers |

"Neutral" items can be placed in any room

Figure 32. Simple illustration to split gas producer and absorber

*Iteration 1: use a fixed separator*

The simplest way to separate two different items is by constructing a wall. The border has a certain height to block ethylene gas flowing from the producer's room to the absorber's. However, a fixed separator was criticized during a user test (see Appendix C to read the complete test). Furthermore, a permanent wall limits the storage flexibility when they have more homogeneous fruits or vegetables, e.g. only the gas producer group. In this case, one room can be overcrowded while the other is empty.



Figure 33. A food cabinet with fixed separator (1)

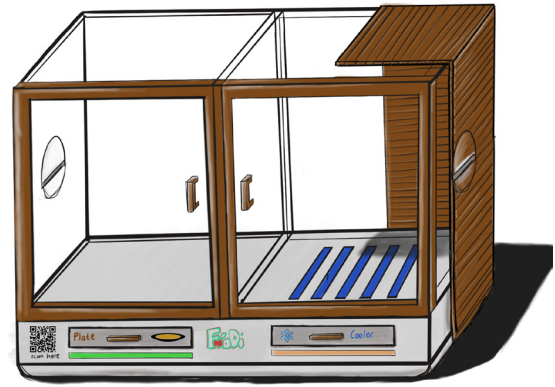Figure 34. A food cabinet with a fixed separator (2)
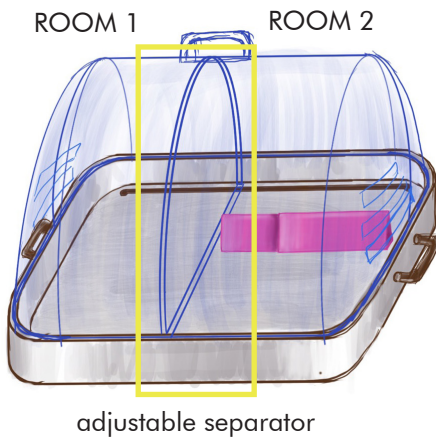
*Iteration 2: use an adjustable separator*


Figure 35. A food cabinet with an adjustable separator

A movable partition is applied to adjust the room's size to improve storing flexibility, to solve the previous issue.

When the user only has one typical fruits or vegetables, they can shift the separator to enlarge one room. The height and shape of the wall perfectly fits the lid to completely prevent ethylene gas entering the absorber's room when the cabinet is closed.

## 2) Respiration rate

Respiration (breathing) is a chemical process that uses oxygen to break down stored sugar in the fruits and vegetables into $CO_2$ and water. This process causes ageing called senescence, which makes the fruits wrinkled or the vegetables withered, less fresh and eventually died (FAO, 1989). Therefore, $O_2$ exposure should be reduced by building an enclosed chamber to decelerate these effects from happening.

However, if the concentration of oxygen is too low, fermentation will occur. Fermentation converts carbohydrates to $CO_2$ and alcohol, which also promotes premature decay and yields unpleasant flavour. Proper control of the oxygen and carbon dioxide amount surrounding the food can slow down the respiration rate (Becker et al, 2002). In this case, regular opening-closing the door during food taking-refilling becomes important to help manage the gas balance (a small experiment was conducted to test this, see Appendix D to read the full investigation).


Figure 36. Air tight food cabinet

In the experiment, fruits were stored in two different conditions: opened container (bowl) and enclosed chamber (a food container) (see Figure 36).
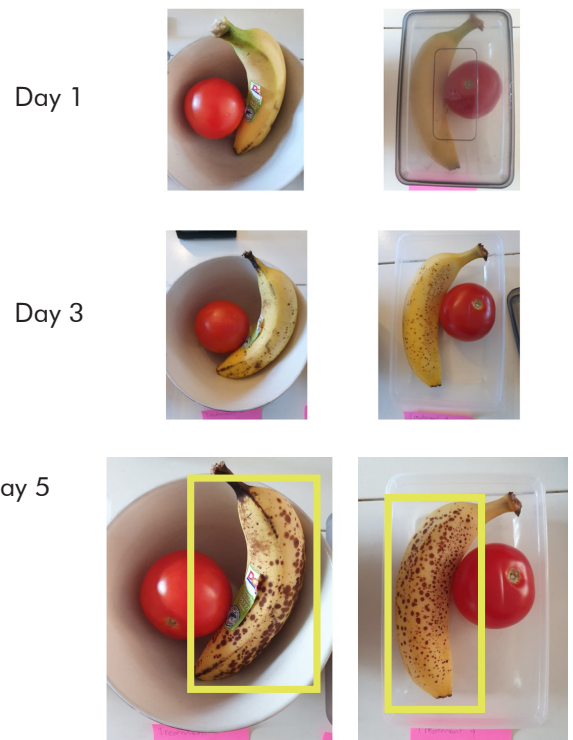

Figure 37. Experiment to retard respiration rate

Twice a day, the container was opened and closed to replicate the action of consuming the fruits. When the container is closed, the breathing gets slower due to the limited oxygen concentration to react. Whereas, when the lid is opened, $O_2$ enters the container and replaces $CO_2$. This treatment keeps $O_2$ and $CO_2$ at a proper level, which decelerates the respiration rate, yet does not start the fermentation reaction.

Figure 37 shows that the banana in the bowl has more and larger brown spots than the banana stored in the ait tight container. Moreover, the banana's tip in the bowl became dark as well.

This phenomenon proves that the lid worked quite well to fulfil its job.

## 3) Relative humidity (RH %)

The optimal relative humidity for a room to store most fruits and vegetables is between 80% - 95% (Engineering ToolBox, 2004). The average annual percentage of moisture in the Netherlands is 83% (outdoor) (Weather & Climate, 2021). Commonly, indoor humidity is much lower than outside, although it also depends on the room's ventilation system. Figure 38 depicts the RH percentage measured in two houses.
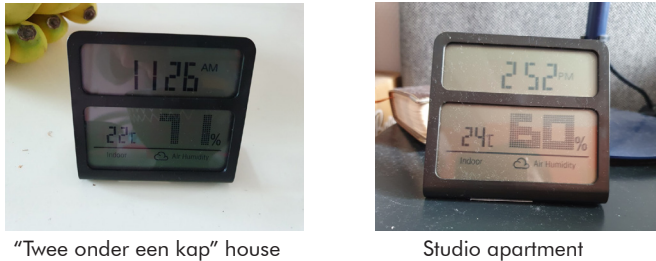


| "Twee onder een kap" house | Studio apartment |

Figure 38. RH % of two different houses

Since fruits and veggies are displayed in an open space at home, the number shown by the hygrometer is the environment that consumer provides for these commodities. An environment with a relative humidity lower than recommended can give a bad consequence for the food. The fruits and vegetables may get dehydrated due to losing moisture content, resulting in wilting and must be trashed (Smart Fog, 2015). RH value around the food should be intensified to avoid this circumstance occurring. However, overly humid surroundings also can ruin the quality of certain fruits and vegetables. Due to mould growth, the product may become soggy, soft, and spoilt (Smart Fog, 2015). Therefore, ideally, the cabinet should reach the suggested RH range was mentioned above.

Using the same mechanism to slow down respiration rate, an enclosed room is also expected to regulate Relative Humidity percentage in the food display cabinet. Underlying on a result of an experiment held during the project (see Appendix E for the complete experiment), it showed that a tight chamber successfully increased the RH value in the cabinet (see Figure 40). However, relative humidity became high, reaching 99% and damaging the stored food (see Figure 41). Mould grew on the limes, cabbage and the surface of half-cut tomato (see Figure 41).



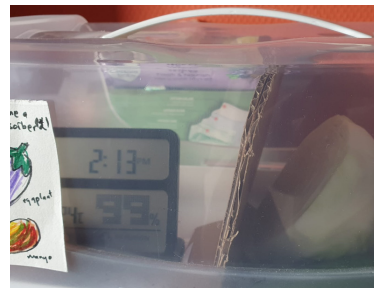Figure 39. Experiment to test effectiveness of enclosed chamber to manage RH



Figure 40. RH % inside an air tight room



Figure 41. Mould emerged on the food

Even though the same treatment (opening-closing the cabinet twice a day) was applied to this experiment, it was inadequate to create the recommended environment. Therefore, a further investigation was done to tackle this issue. As a result, an opening was made to allow some water vapour out of the cabinet to decrease saturated moisture (see Figure 42).

Figure 42 shows that adding this feature can drop chamber RH from 99% to 83%, which now the room reaches the optimal range for fruits and vegetable storage. Moreover, in the correlation with designing a food display cabinet, this small opening was translated as natural ventilation, i.e. a few holes to let air exchange happens (see Figure 43).



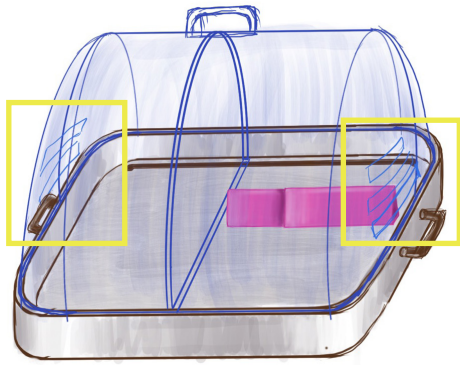Figure 42. A small opening to reduce RH %

Figure 43. Holes as natural ventilation

## 4) Temperature

Most fruits and vegetables should be kept in the fridge to prolong shelf life and maintain their flavour, except for a few items like banana, paprika, and cucumber (FAO, 2004). Exposing these commodities to higher temperatures for a quite long time could damage their quality. The food display cabinet is aimed to store food only for 24-48 hours. In the first iteration, a cooling system was implemented to keep the food (specifically half-cuts) standing for this period without significant impact.

*Temperature regulation*

Temperature regulation is done by inserting provided cooling elements in a special compartment under the main room. A cooling element called eutectic plate or "cold pack" takes a role as the cooler. It is a special bag that contains a reusable liquid coolant (see Figure 44). The pack must be frozen until completely solidified before use. The eutectic plate is frequently used as a chiller of a food buffet presentation (see Figure 45). Generally, the cold pack will stay frozen 24-36 hours in an insulated container (Ice Pack Store, 2021). From a durability test using a poor insulation room prototype, the cold pack lasted for 10 hours (see Appendix C to read the full experiment).



Figure 44. Cold pack

Figure 45. Cold pack in a buffet presentation

The cooling element is placed under the floor in the cooler drawer to cool down the chamber (see Figure 46). A ventilation system in the form of holes is built to let heat exchange happen. Direct contact between the skin of fruits and vegetables and the cooling element makes the cooling process faster. Moreover, another benefit of putting the cold pack underneath the food is that the cold air stays around the food, i.e. at the bottom part of the chamber, as cold air is heavier than warm air. Although the cold will distribute to the whole room at some point, the coolest points constantly surround the food. To understand how the cooling mechanism works, see Figure 47.
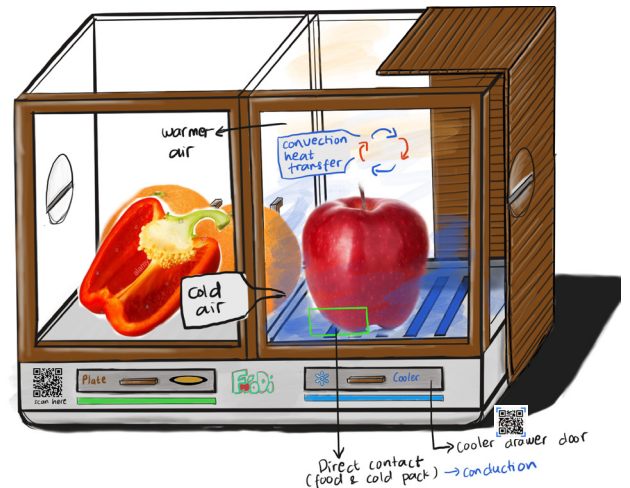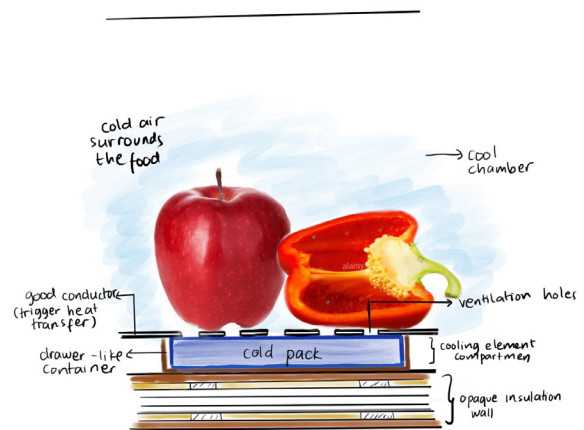


Figure 46. Heat exchange process



Figure 47. Cooling mechanism

Thermal insulation must be implemented in the cooling element compartment to have effective and long-lasting cooling (block external heat to interfere). The whole boundary wall protecting the cold pack from outside is opaque insulation, including the door panel (see Figure 48). Moreover, the same sealing method as the chamber door, i.e. using a gasket to prevent heat exchange, is also applied to this door (see Figure 48). Further, the drawer that contains the cold pack is made of a poor conductor (wood). The goal remains the same to reduce heat loss.
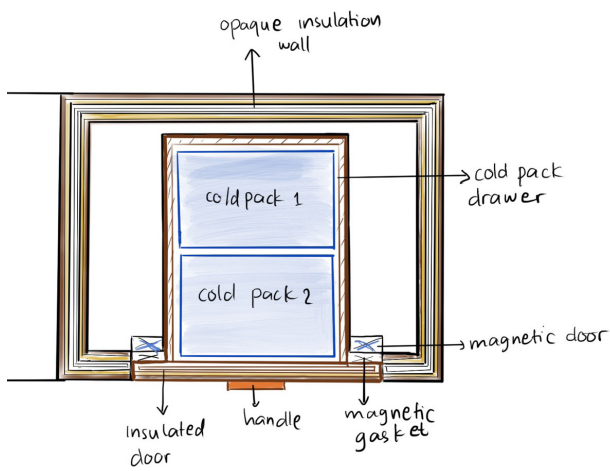
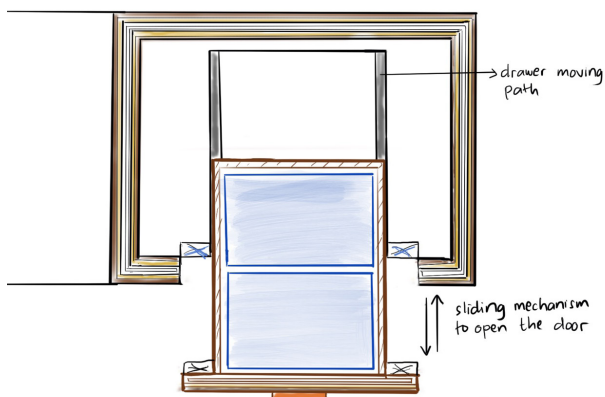Figure 48. Cooling element compartment (top view cross-section)



Figure 49. Opening-closing the drawer (top view cross-section)

*Thermally insulated storing room*

An insulated room is necessary to block heat transfer from external surroundings with higher temperatures to the cool chamber. If the heat loss is reduced, the cool section can last longer. There are three types of heat transfer involved in the cool room. Conduction happens when heat travels via direct contact or touch, usually in solid material. Convection occurs if heat transmits without direct contact, e.g. air and liquid. Lastly is radiation. This type does not need any medium to transfer, e.g. heat from sunlight. These three issues must be handled well to build a good insulation system.

Cabinet's body was half opaque-transparent to fulfil two requirements at once to achieve good insulation. The transparent wall is for food visibility, and the opaque wall is to create a properly insulated room. The principle to build the insulated chamber was inspired by a thermos flask which has multiple layers of poor heat conductors to suppress heat transfer from the external environment to the liquid tube (Woodford, 2021). Figure 50 depicts layers to build the opaque insulation.

1. Casing (e.g. plastic, wood, stainless steel)

The casing is the outermost layer made of any hard material. The main function of the case is to give an artistic or esthetic appearance to the product. In terms of insulation, it does not need to do a lot. But, using poor conductors like plastic or wood can help retard the heat transfer process.

2. Additional insulator

Additional insulation reduces conduction heat losses. A cushion type of material like foam was chosen against possible impacts.

3. Main insulator

This innermost layer is called a vacuum container. It is a double-wall polycarbonate with a vacuum gap in between. Polycarbonate is known as a good insulation material. It is commonly implemented as windows in the building sector. Its benefit is that thermal insulation helps heat during winter or keep the cold of the air conditioner in the summer, retaining inside the building (Tuflite, 2021). Moreover, polycarbonate is transparent and has an FDA-approved version frequently used for food utensils (Acplastic, 2021). In addition, It is half lighter than glass in the sense of frequent material used to build an insulation system (Horesh, 2018). Hence, the end product can be more lightweight as well. Doubled-wall polycarbonate minimizes conduction heat loss. Meanwhile, since the vacuum gap contains zero material inside, conduction and convection, which need a medium to transfer heat, are tackled (Wedgwood, 2021). Furthermore, the radiation is handled by applying a silver coating on the outer polycarbonate layer (see Figure 50). A shiny surface is a poor emitter so that it will reflect the heat back to the surrounding.

4. Support

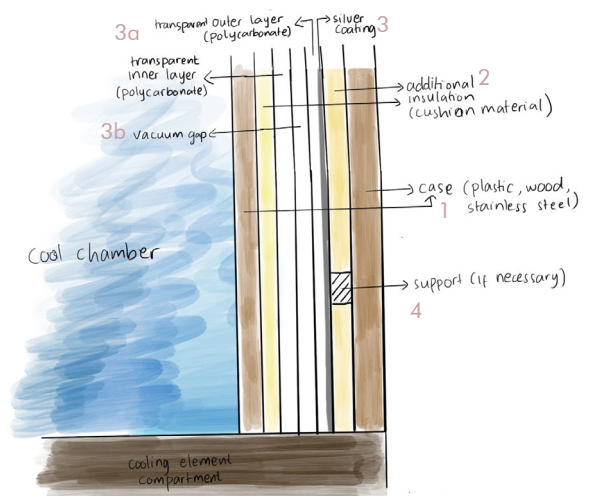This is a small block to support the vacuum container in place.



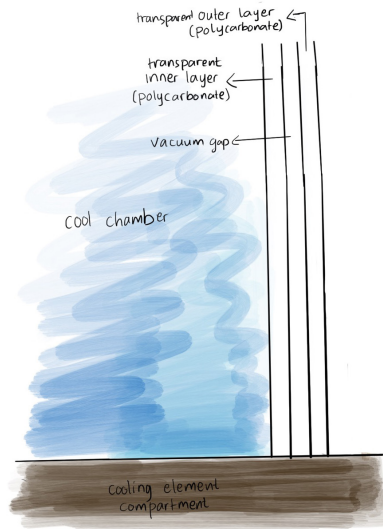Figure 50. Illustration of opaque insulation wall

Figure 51. Illustration of transparent insulation wall

Transparent insulation has the same main insulator. The difference is only the removal of the opaque material and silver coating (see Figure 51). As this wall lacks additional insulation, blocking heat transfer is poorer than the opaque wall.

As with other cooler products, insulation wall only is not satisfactory. The biggest heat loss arises in the door. When the user opens the door, heat transfer exists. However, commonly it is a short time occurrence and unavoidable. Thus this contribution is neglected. Then, there is a little gap between the main body and the door, which potentially lets the external heat enter through it. The door should be equipped with a sealing system to solve this matter.

Figure 52 shows the sealing system of the door. The main door remains transparent, made from polycarbonate. A magnetic gasket is a prominent component to create a proper seal. It is a flexible elastic strip attached to the edge around the door (Thomas, 2021). It forms an air-tight seal to act as a barrier between the cool chamber and the external environment.
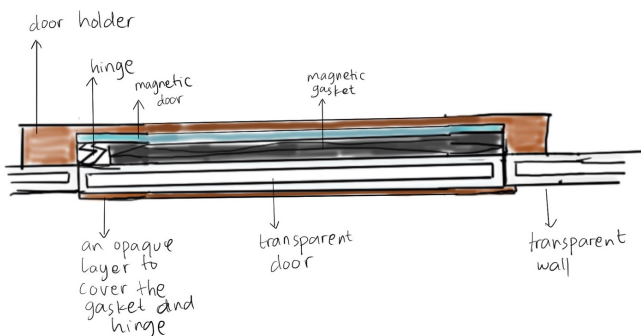


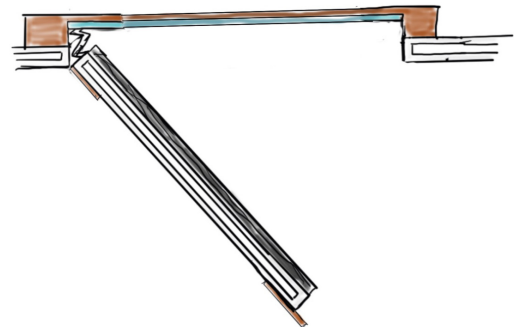Figure 52. Door insulation (top view, door closed)



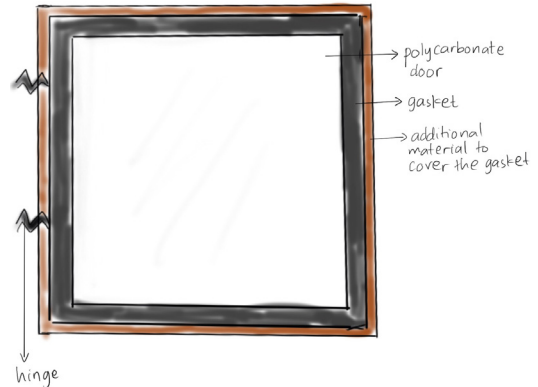Figure 53. Door insulation (top view, door opened)



Figure 54. Door insulation (door opened)

*Evaluation of the cooling system*

Adding a feature to maintain food shelf life in the cabinet is practically good to prevent food waste at home. However, this action contradicts the first intention of the food cabinet that encourages the user to consume the displayed produce as soon as possible. Moreover, as stated above that the cold pack only lasts for about 10 hours to maintain the targeted temperature. Therefore, the user should replace the cold pack more than once a day. Or even though the cooling element stands frozen for more than a day, its capability to cool down the cabinet eventually decreases.

A user test was conducted to understand people's feelings about having a temporary cooling chamber in their house (see Appendix C). The result revealed that it might be useful to store a few perishable food items quickly, but they pointed out the replacement frequency. Changing the cooling element is perceived as a bit cumbersome. One participant said, *"I will not use it if I have to replace it more than once a day because I have another priority to take care of"*. Another respondent stated, *"Since I am often not at home, I may use it when I just feel need it, so I do not have to change the cooling element every day"*.

Furthermore, putting fruits and veggies (whole or partly used) at room temperature for 1-2 days does not change its taste and texture. Although a few do deteriorate within two days, such as half-cutting potatoes, avocado and onion (Gena, 2015). Hence, an encouragement to eat them sooner is more reasonable than giving consumers a chance to postpone the consumption by applying a temporary cooling system. Based on those reasons, finally, the cooling system was removed.

## Increase visibility

There are two approaches to improve the visibility of forgotten fruits and vegetables in the fridge.

The first is by applying the scenario of displaying a daily portion. This way, the user is subtly "forced" to check their fridge more frequently. By doing so, people may become more aware of what food they purchase and store. Suppose the consumer could see inside the refrigerator better. In that case, there is a potential that practising this habit would help reduce fruits and vegetable waste and other kinds (e.g. meal leftovers or half-used products). A few participants from the user research admitted that they would have less food to waste when they check their refrigerator regularly (see Chapter 1).

Additionally, showing only a daily portion and a few half-cuts will limit the number of items to keep. This method prevents the user from stacking fruits and vegetables at once. One insight from the user research said that piling up too many things like the participants usually do can reduce food visibility, specifically one that is trapped in the middle or the bottom. As a result, they are typically overlooked, got rotten and discarded. In other words, implementing this restriction could save the edible fruits and veggies from being wasted.

Secondly, transparency was utilized to support consumers see the cabinet's content easily. Creating a transparent cabinet with a door came as the first idea (see Figure 55).

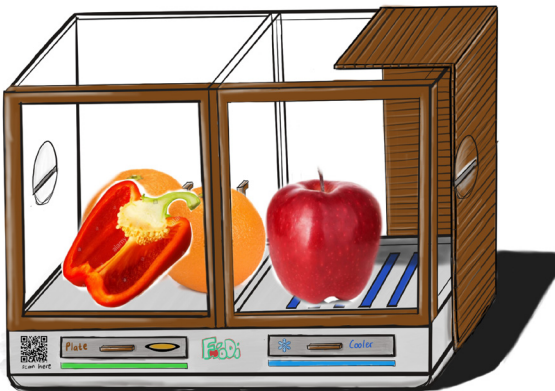*Iteration 1: transparent body*
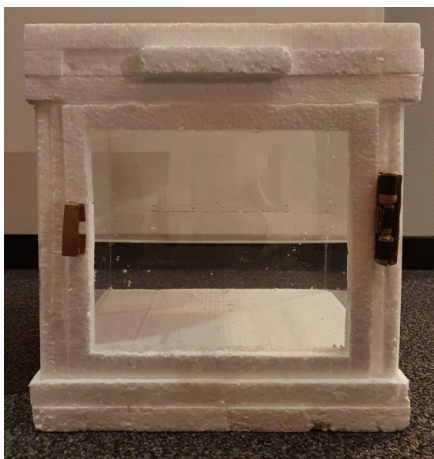


Figure 55. Transparent cabinet with front doors



Figure 56. Prototype of transparent cabinet with front doors

Having a fully transparent body is beneficial to improve food visibility in the cabinet. There is almost no hindrance to seeing the fruits or half-cuts vegetables from any angle. However, designing a front door to access the food looks troublesome for certain people, especially for tall people. The food display cabinet is envisioned to be placed on the kitchen counter, shelf or dining table. These locations make the cabinet position quite low. The user may need to bend down a bit to take the fruits or vegetables. Moreover, the user may have to bend lower to reach food items at a deeper level using this design.

In addition, in cleaning the product, accessing the inner wall through the front door is rather inconvenient. The user should bend over and rotate their hands up and down to reach and ensure all sides and corners are clean.

Furthermore, the front door type was designed to support constructing good insulation for the cooling system. However, that feature was taken out; this special form may not be necessary anymore. Instead, focusing on satisfying the ergonomic requirement (i.e. convenient accessibility) becomes more prominent.

The cabinet's shape was redesigned and turned into Figure 57 to resolve the door problem.

*Iteration 2: transparent lid*



Figure 57. Food cabinet with a transparent lid

Instead of a transparent body with the front door, building a flat tray with a fully transparent lid seems more promising. It does not affect the effectiveness of using transparency to improve food visibility. Also, since the product position will be slightly low, opening the cabinet from the top is easier and commonly applied for serving bowls or plates. Consumers do not have to bend down to take the fruits and vegetables. They only need to lift the lid using the handle and grab the food (see Figure 58).

In the context of cleaning, this approach is more convenient. The user does not have a depth level which complicates the cleaning process. After removing the lid, they just wipe the flat floor with fabric or tissue. Afterwards, to clean all sides of the transparent cover, the consumer can flip it (see Figure 59).

In conclusion, a transparent lid was chosen to support providing visible food in the cabinet.
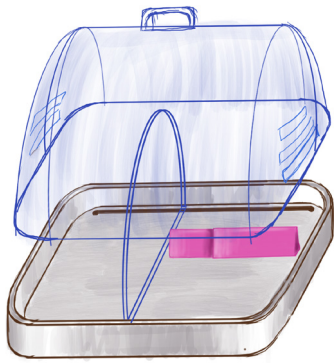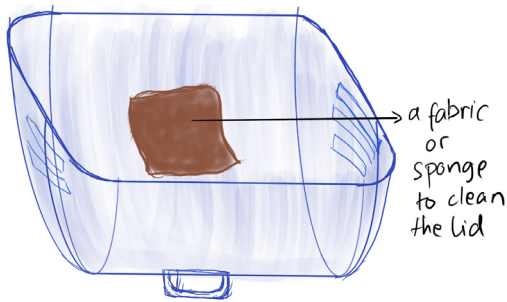
Figure 58. Lift up transparent lid


Figure 59. Cleaning the inner part of the lid

## Enhance knowledge of proper storage

So that the food display cabinet can support preventing household food waste effectively, the user should utilize the cabinet correctly. They should separate fruits and vegetables as suggested by the product and follow the rule of displaying only a few foods to consume for a day. The first idea was a guidebook on the product to communicate this information because it is the most common way to tell the user about a new product.

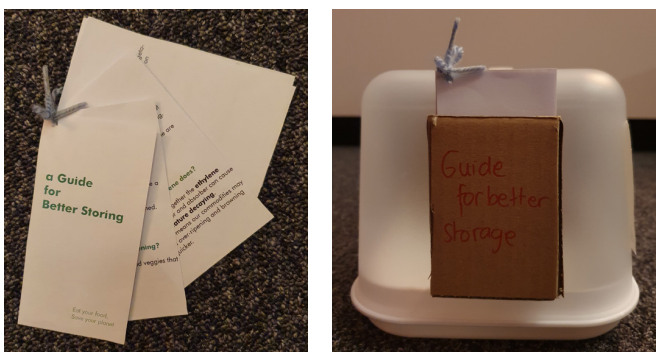*Iteration 1: a guide book on the side of the cabinet*


Figure 60. Manual book attached on the cabinet

The guidebook covers the info about the urgency of splitting certain fruits and veggies due to ethylene presence. It also tells a short story of how these commodities are thrown away and result in food waste (see Figure 61). The guide book was attached to the cabinet side body to engage the user to read it (see Figure 60). Moreover, to guide the user to put the food product correctly, images of ethylene producers and absorbers are sticked on the front face (see Figure 62). Finally, through a user test (see Appendix C), the effectiveness of delivering storing messages was evaluated.



**a Guide for Better Storing**

Eat your food,
Save your planet

**1 Let's separate our food!**

Most fruits and vegetables have a short shelf life. They are often wasted due to getting rotten quickly before being consumed.

**Why this happening?**

We mix fruits and veggies that should not be

**What is ethylene?**

Ethylene is a plant hormone that regulates growing and ripening. A few fruits and vegetables produce ethylene, and some are sensitive to it (absorbers)

**What ethylene does?**

Putting together the **ethylene** producer and absorber can cause **premature decaying**. This means our commodities may get over-ripening and browning quicker.

**How to separate?**

1) Put away your fruits and vegetables by following the stickers on the cabinet.
2) Always close the lid.

Figure 61. Manual book information


Figure 62. Sticker to tell where to store the food (left is ethylene absorbers and right is the producers)

Based on observation during the test, no respondents took and read the guidebook. One participant said, "I noticed the book, but as it says 'A Guide for Better Storing' I ignored it. I know how to open this cabinet and just put the fruits". After showing the guidebook content, she stated that the content does not match the name "guide for better storage". The info is new for her, but she missed it due to the title.

Furthermore, regarding the stickers, a respondent felt that images on the sticker do not represent all fruits and veggies that they usually purchase. The user might get confused if they have commodities other than in the sticker. Lastly, the stickers are a bit large, which obstructs the visibility of the cabinet content.

A second iteration was done to deal with the feedbacks. An app was designed to provide all required information about the cabinet and storage system. Further, a simple pamphlet was added to introduce the food display cabinet briefly.

## Iteration 2: A pamflet and an app
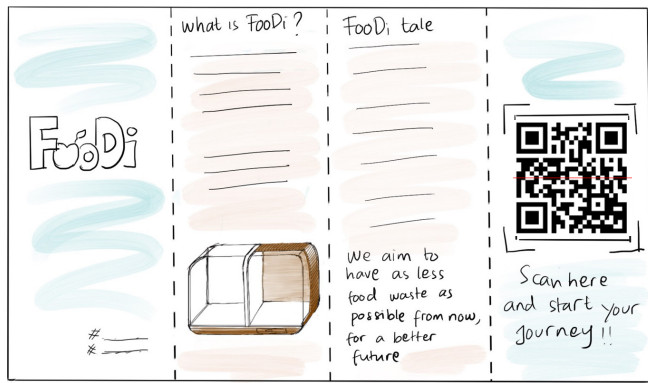


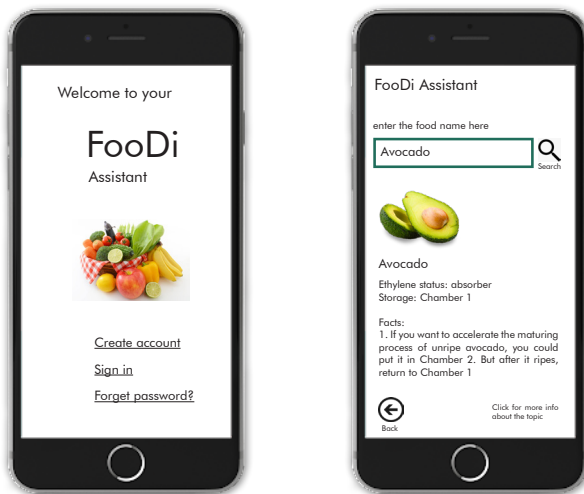Figure 63. Food display cabinet pamflet



Figure 64. Food display cabinet app

All product stories and description information are available in a pamphlet included in the package (see Figure 63). Meanwhile, to access other info like food storing guidance, the user should download an app by scanning a QR code on the pamphlet (see Figure 63).

Despite accommodating complete information, there are downsides to implementing an app in the case of consumers forgetting to bring their phones to the kitchen. They will not be able to access the information. Consequently, they may store fruits and vegetables mistakenly, which could shorten the shelf life. Moreover, gathering essential information only in the app is not preferable. Suppose the app is an error, but the user needs to access it to store something. They might end up mixing the ethylene producer and the susceptible commodity. This incident could ruin the food quality quicker. The requirements from the previous chapter say that the product should be simple and use low technology to become inclusive and affordable for as many as people. Offering an app to support the food display cabinet seems to contradict that intention. Instead of perceiving the cabinet as a simple product, people may think it is part of smart home appliances.

In the third iteration, a brochure and sticker are developed again to bring back the simplicity.

## Iteration 3: A brochure and sticker on the product



Figure 65. Food cabinet brochure
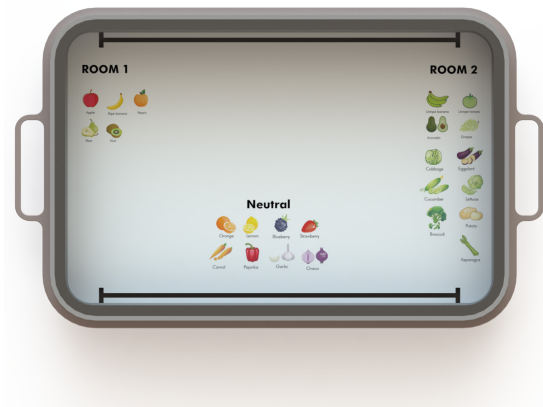


Figure 66. Storing guide sticker

The information shown in the brochure is product description, background story and storage guide (see Figure 65). A poster-like brochure and permanent stickers inside the cabinet guide the user in separating fruits and vegetables. The brochure is put on the cabinet during the packaging to make the user read it. The user should take it off before using the food cabinet. This way, the probability of noticing and reading the information becomes higher. The sticker attached to the product is meant to remind the user to store the commodities correctly continuously.

# Conclusion

Through some iterations that have been explained above, the solution for each requirement was finally determined.

## Ideal storage for 24-48 hours

1) Reduce ethylene gas impact: use an adjustable separator to split the ethylene producers and the absorbers.

2) Retard respiration rate: design an enclosed room to reduce the respiration rate and avoid starting the fermentation process

3) Regulate relative humidity: natural ventilation in the form of holes on the cabinet's wall. These holes become a way for saturated water vapour out of the cabinet to achieve optimal relative humidity levels to keep fruits and vegetables.

4) Manage temperature: remove the cooling system. as the food condition stored for 24-48 hours is still fine without the cooling system, and to create an "urgency" feeling to consume the food as soon as possible before getting bad, the temperature regulation is neglected.

## Increase visibility

Fruits and vegetables usually stored in the fridge are displayed in the open space to enhance food visibility, where eyes can spot them directly. The amount of the items to show is limited to prevent food stacking that could reduce visibility. The cabinet only accommodates a daily portion of fruits and partly-used vegetables. Moreover, a transparent lid is implemented to let the user see through the cabinet and not miss any food.

## Enhance knowledge of proper storage

The product will inform the user about separating some fruits and vegetables from others in the context of ethylene gas presence by utilizing a brochure. Furthermore, some information is delivered in the form of stickers on the product body. Hence, the user can always notice and read it.

# 3.2 FINAL PRODUCT

**FooDi**

*set your target, finish your portion*

FooDi is storage to display fruits and partly used vegetables usually hidden and forgotten in the fridge (e.g. half onion, half paprika or other cut vegetables). This product wants to prevent food waste at home by encouraging the user to eat food they purchase in a daily portion and reuse the ingredient leftovers as soon as possible.
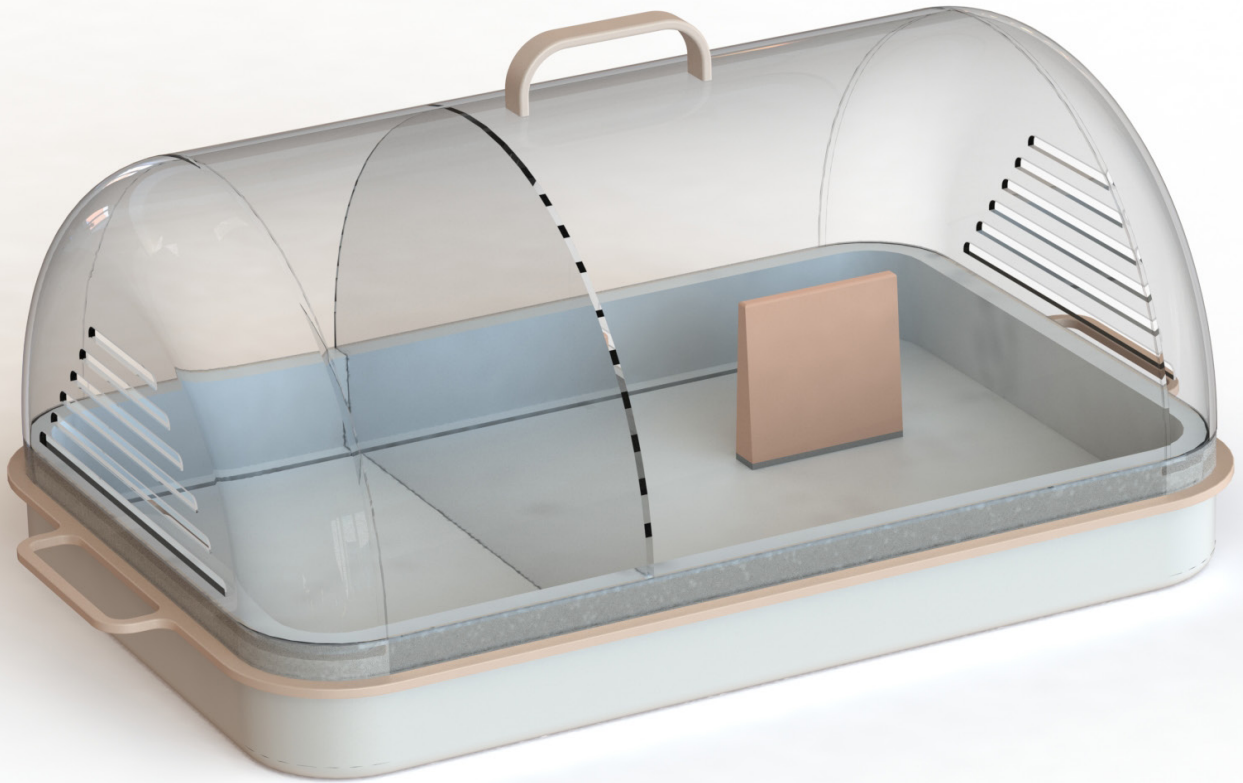


Figure 67. FooDi Cabinet
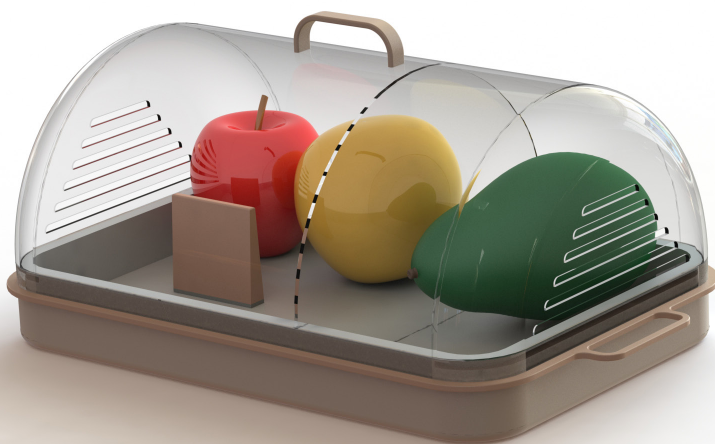


Figure 68. Storing fruits in FooDi

In the case of fruit, the user determines their consumption target for one day. They take the fruits from the fridge and move them to FooDi. The next day, they are expected to grab one by one the fruits and finish the target.

On the other hand, storing vegetables has a different scenario. FooDi is not supposed to keep a whole vegetable because it should be stored in the fridge. The product focuses on saving half-cut vegetables. It gives a second chance for small ingredient leftovers (e.g. half tomato or half onion) to be reused for the next day. By storing this food in FooDi, it becomes noticable.

# Features



(A) Lid handle

(B) Transparent lid

(C) Ventilation holes

(D) Movable separator

(E) Separator track

(F) Second separator

(G) Detachable tray

(H) Base

(I) Base handle

Figure 69. FooDi Cabinet Exploded View
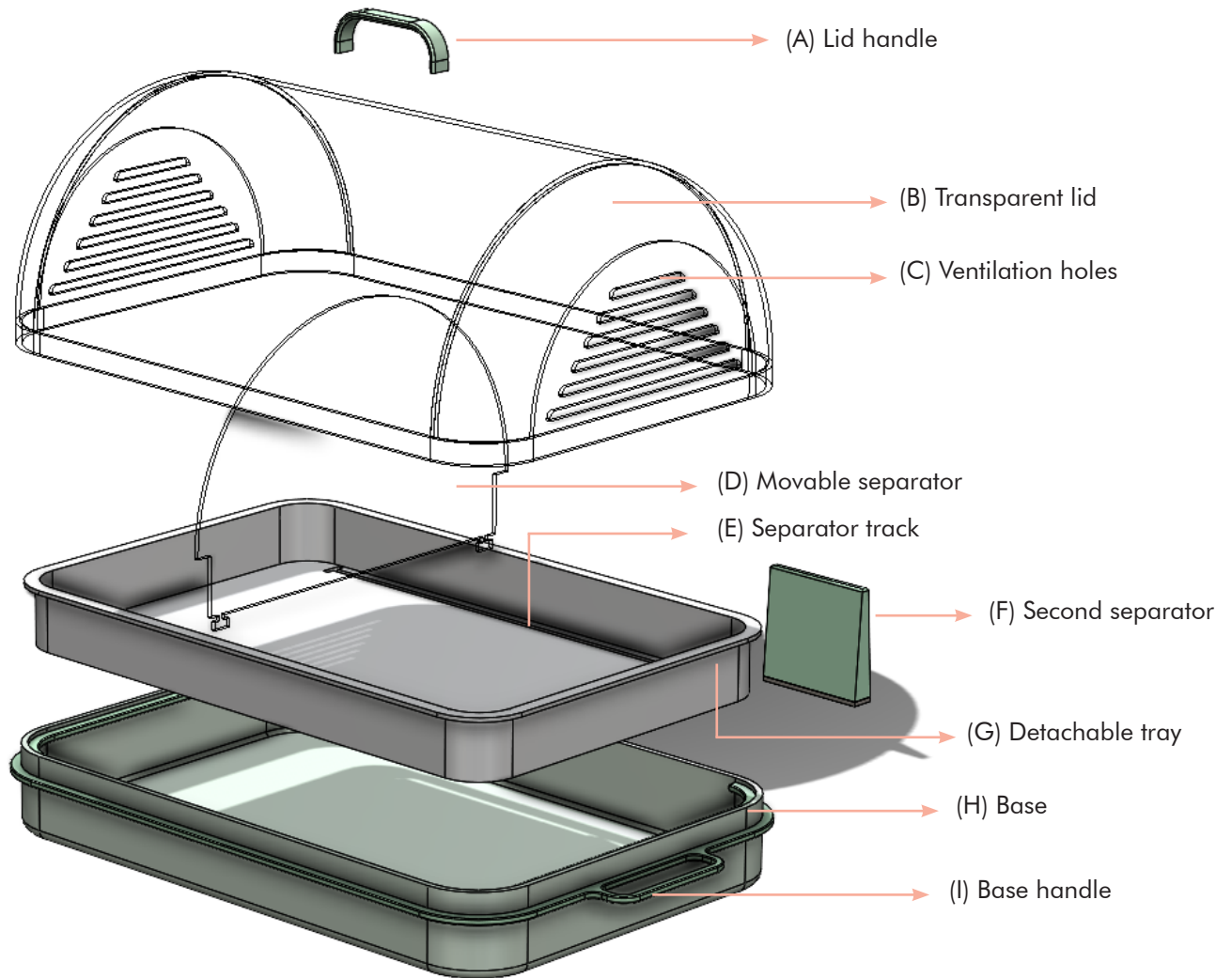
(A) Lid Handle: to remove the lid from the base and access the stored fruits and partly used vegetables.



Figure 70. Lid handle

(B) Transparent lid: the main function is to ease the user to see the cabinet's contents. Additionally, it helps build an ideal room for the stored food, i.e. low respiration rate and achieve the optimal relative humidity.



Figure 71. Transparent lid

(C) Ventilation holes: a way for air exchange when the cabinet is closed. Saturated water vapour trapped in the FooDi will be released to the surroundings and new fresh air replaces it through these holes. This occurrence will manage the relative humidity inside the cabinet to reach its optimal level.



fresh air in

saturated air out

Figure 72. Natural ventilation

(D) Movable separator: a partition to fully split the producers of the ethylene gas and the absorbers. Shifting the separator will adjust the room size and give the user freedom to divide the room.
A sliding mechanism with a track was selected to make the separator move smoothly.
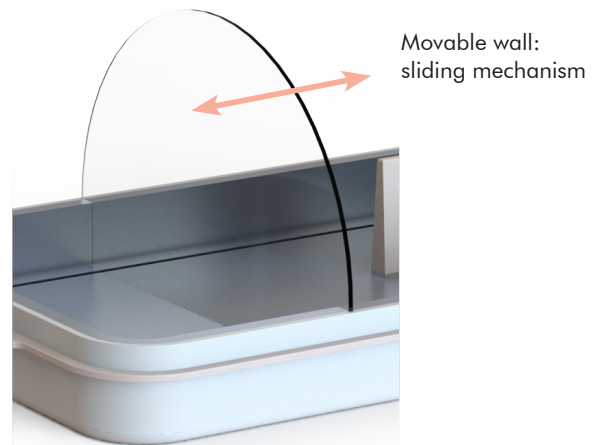


Movable wall: sliding mechanism

Figure 73. Movable separator

Separator body: the shape is designed so that it perfectly fits the lid's curve to suppress the ethylene gas movement





separator track

Separator feet

A gap between tray and base: space for the separator feet moves
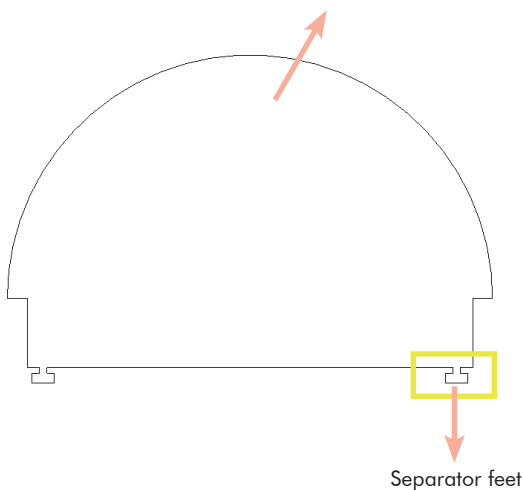
Separator feet

Figure 74. Movable separator shape
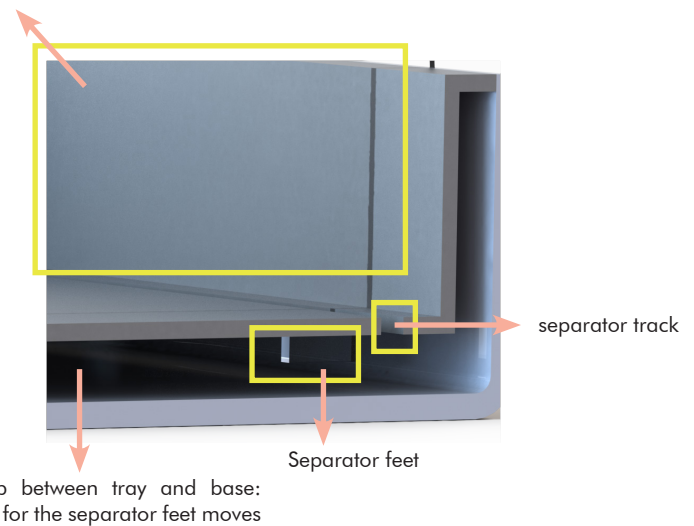
Figure 75. Cross-section view

(E) Separator track: this track creates a long hole as a path to move the separator horizontally. The separator track is two long holes in the detached tray. At the start of the track, there is a larger hole (see the yellow square in Figure 76) to insert the movable separator's feet into a gap between the tray and base. As a result, the separator body and feet clamp the tray and make it stand firmly along the track. This position is perfect for blocking the gas glow.



Figure 76. Movable separator track (top view)

(F) Second separator: it is a wall to separate the whole and half-cuts fruits or vegetables. This separation is required to avoid contamination possibility from the half-cuts to the whole and vice versa. Partly used items have a shorter shelf life and are more vulnerable to getting spoilt. In addition, when the user does not reuse it in time until it becomes mouldy, it could harm the whole item quickly if they make direct contact



Figure 77. Second separator

(G) Detachable tray: a main place to lay the fruits and partly-used vegetables. It can be detached from the base to support the user carrying a few stored ingredients leftover to the cooking area. Moreover, the tray has two holes for the separator track.



Figure 78. Detachable tray

(H) Base: the main body of FooDi where the tray is located.



Figure 79. Base
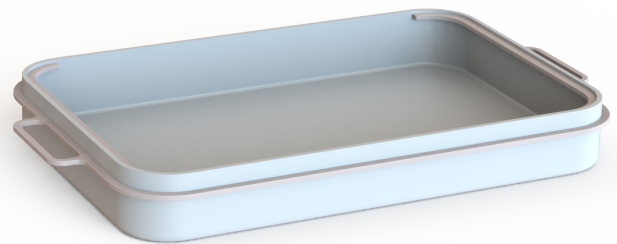
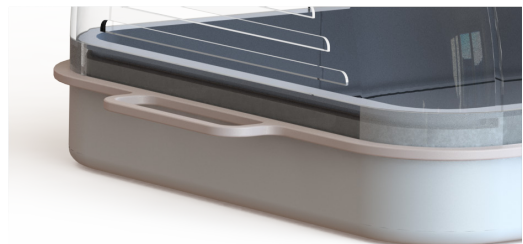(I) Base handle: to help the user lifts the FooDi Cabinet.



Figure 80. Base handle

(J) Two chambers: to separate fruits and vegetables that release ethylene gas and those that are susceptible. Room 1 is for the producers, and Room 2 stores the absorbers. The size of these rooms is adjustable following the type of commodities that the user has.
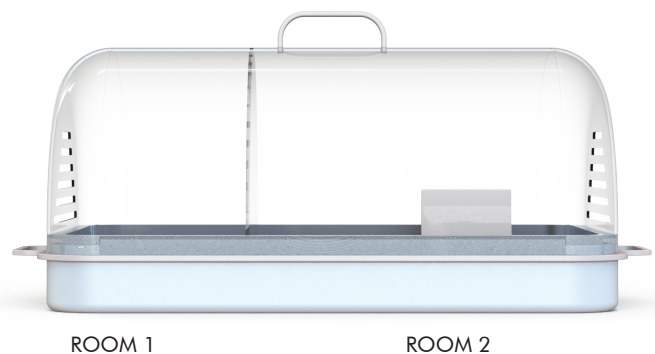


ROOM 1          ROOM 2

Figure 81. Two rooms

## Information Resource

A brochure and stickers are used to inform the user about the product story and how to use FooDi correctly, including how to distinguish the ethylene producers and absorbers.

(1) Food description: tell a short definition of FooDi (FooDi's function in brief)

(2) Background story: explain to the user what FooDi is designed for (why). Also, fact about food waste -> make the user aware

(3) Do(s) and Don't(s): rules to guide the user to store fruits and vegetables correctly and keep FooDi clean and safe to store food. This information is the key of FooDi to effectively accomplish its function to support preventing food waste at home. If the user reads and follows it, some fruits and veggies can be saved.

(4) Tagline and several motivation words: encourage and remind the user to obey FooDi rules.

(5) Your contribution: many people feel unmotivated to reduce food waste because they perceive the benefits are distant and non-personal. Hence, showing a direct return like saved money is essential to keep them motivated (van Geffen, L., et al., 2020).
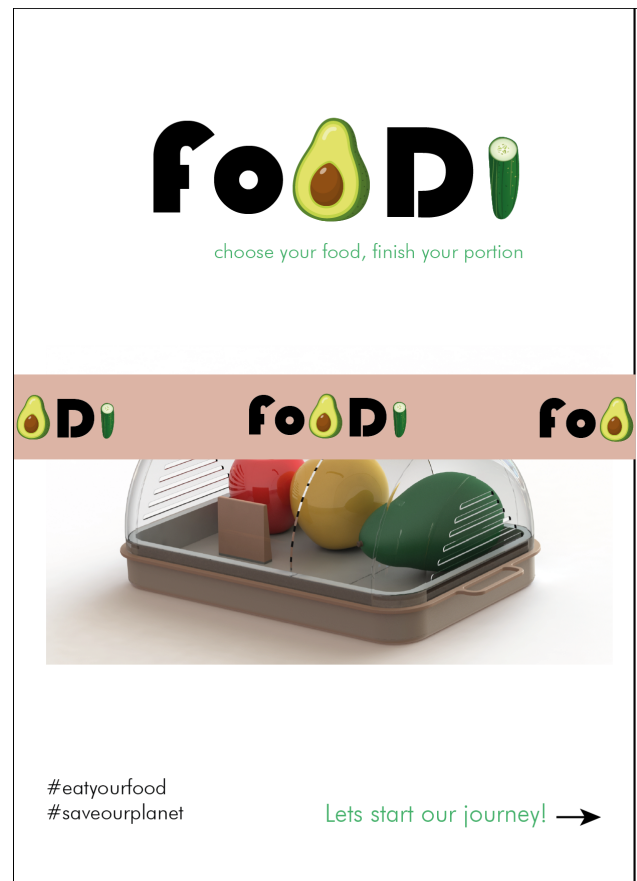


Figure 82. A bundle of folded brochure (front page)



choose your food, finish your portion

#eatyourfood
#saveourplanet

Lets start our journey! ⟶

## What is FooDi?

A special storage to display your daily portion fruits and partly used vegetables that are usually hidden and forgotten in the fridge (e.g. half onion, half paprika or other cut vegetables).

### FooDi Story

FooDi was designed to support people and the environment to deal with food waste at home. Annually, we throw away 13% of food we purchased. 28% is contributed by fruits and vegetables, which get rotten due to being hidden and are not consumed in time.

Being stand out in your kitchen, FooDi exists to help you remember to eat your healthy fruits every day in your daily portion and reuse half-cuts veggies to prevent food waste.

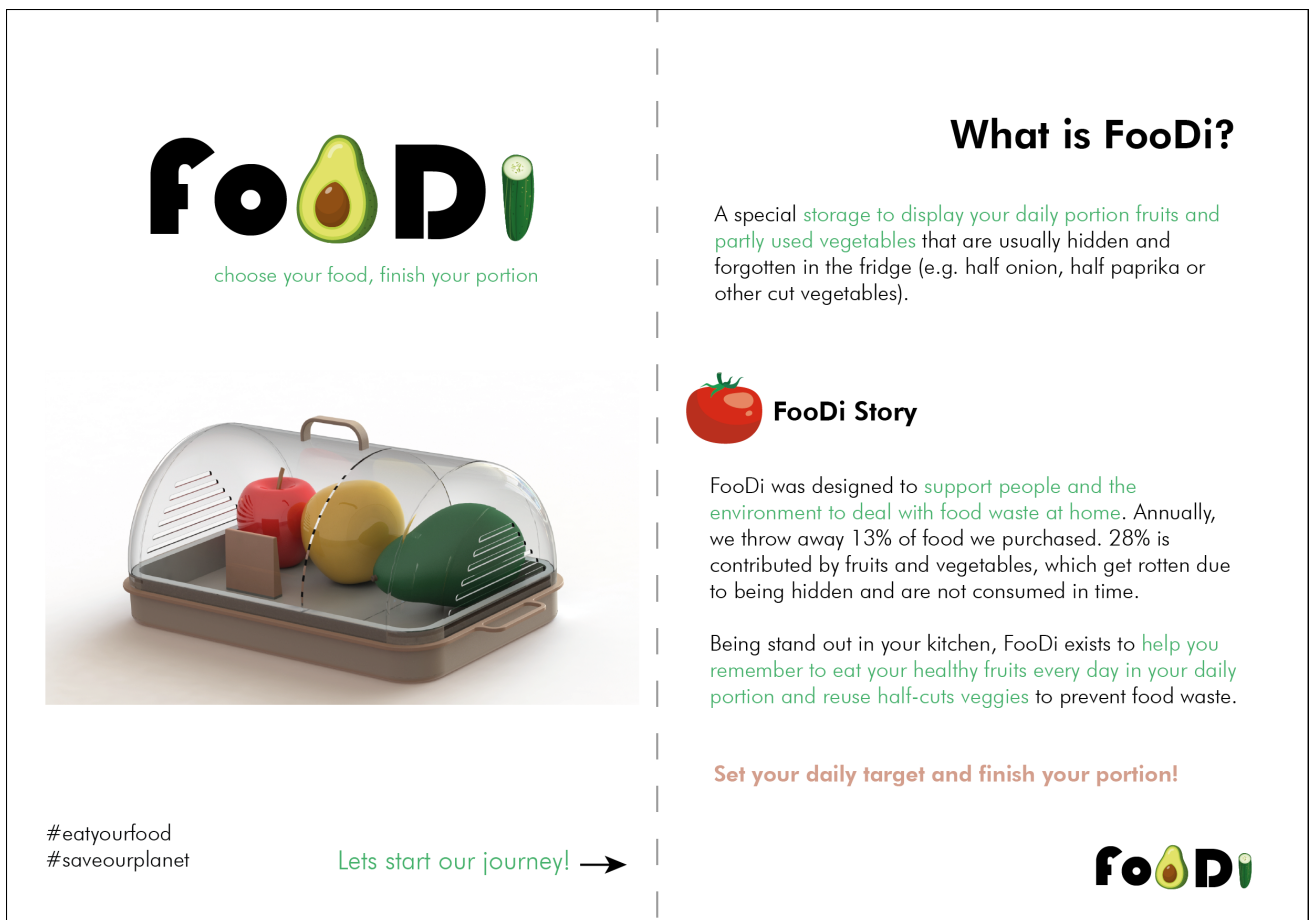**Set your daily target and finish your portion!**

Figure 83. Foldable brochure (1)

# Get acquainted with FooDi

## DO(s):

### Separate your fruits and veggies!

FooDi provides two rooms to separate fruits and veggies that are not supposed to make a direct contact. Some of them produce certain gas which accelerates ageing process and reduce freshness for the absorbers. Check the "Separation Info" paper to know the producers and absorbers.

### Only store your food max 48 hours!

Fact: most fruits and veggies should be stored in the fridge to keep them fresh and flavourful longer. FooDi will only take care of your daily portion of fruits and half-cuts for today's dinner.

### Regular cleaning!

Clean the cabinet at least once a week to prevent mold and bactery growth. Wipe inner part of the lid and body utilizing wet fabric or tissue and let it fully dry before use. Supposed you spot a rotten food, immediately clean it following the procedure.

## DON'T(s):

### Pile up fruits and veggies

Stacking fruits and vegetables can lower their visibility from you. Once you do not see them, you might miss it. Moreover, piling up could increase the possibility of contamination from a rotten item as they always touch each other.

### Store more than 2 days

Keep your fruits and vegetables in FooDi NO more than 2 days. Otherwise, it could start rotting, moldy, and become distasteful.

**EAT your food IN TIME to save your body, your money, and your planet**

to continue →

Figure 84. Foldable brochure (2)

## Your Contribution

By using FooDi at home, you have saved edible food worths **€120**

What you can do with **€120**?

**€120 =** 

add one movie to watch in the cinema each month

or

help to cover holiday expense

or

support you to stay alive for 3 weeks more per year

**The planet thank you**

FooDi

## Want to know more about FooDi?

Visit our website to know more about FooDi and saving food agenda

FooDi

Figure 85. Foldable brochure (3)

**foODi**

choose your food, finish your portion

## SEPARATION INFO

We separate to save.
Splitting gas producers and the absorbers is crucial to slow down over-ripening process in the fruits and vegetables storage

## ROOM 1
(Ethylene Gas Producers)

### Fruits

Apple    Ripe banana    Peach

Pear    Kiwi
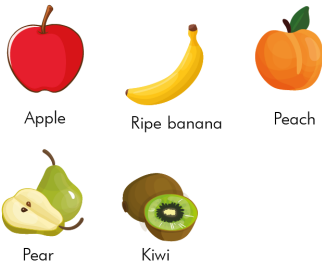
**Neutral**

Neither produce nor absorb the gas.
**You can put it anywhere**

### Fruits

Orange    Lemon    Blueberry    Strawberry

### Vegetables

Carrot    Paprika    Garlic    Onion
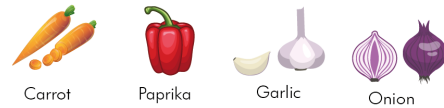
## ROOM 2
(Ethylene Gas Absorbers)

### Fruits

Unripe banana    Unripe tomato

Avocado    Grapes

### Vegetables

Potato    Cabbage    Eggplant

Broccoli    Cucumber    Lettuce

Radish    Asparagus    Mushroom
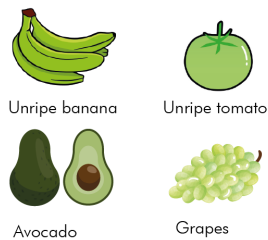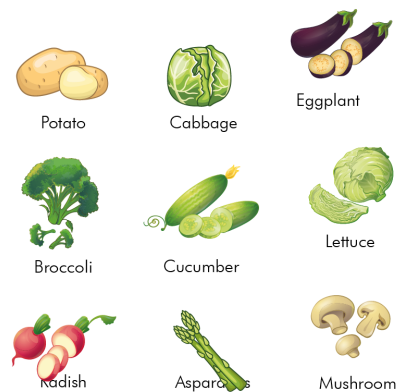
**NOTE: If you cannot find the items here, please go to our website to see the complete version**

Figure 86. Storing guide brochure

(6) Barcode: connect to FooDi website. The website contains further information on FooDi and its company's plan in contributing to sustainability. Unfortunately, in this project, the website is not designed due to time limitations.

(7) Separation info: a poster-like brochure that shows fruits and veggies that belong to the ethylene producers group, the absorbers or neutral (i.e. neither release nor susceptible to the gas).

(8) A permanent sticker on the tray is created as a daily storing guide for the user. After opening the FooDi package and reading the brochure, people will often put the brochure either in the original package or in a drawer or somewhere in the house. Although a few consumers may keep it near FooDi as a reminder. In that case, people may forget how to store fruits and vegetables correctly. To deal with that issue, the existence of a permanent poster that displays separation info becomes crucial.



Figure 87. Fruits and vegetables stickers



Figure 88. Final product top view



Figure 89. Final product

## Specifications

### Shape

FooDi is a supporting product. The product wants to be perceived as an accompaniment that helps the user reduce food waste at home. As support, FooDi form should elicit a "friendly" perception. On the other hand, since FooDi is also responsible as a reminder, there should be a little sense of seriousness. Therefore, a rounded edge square shape was chosen to express that emotion. Square is typically associated with reliability and seriousness (Levanier, J. 2021). Meanwhile, a circle gives an impression of being friendly (Levanier, J. 2021). Therefore, combining both shapes is supposed to evoke a feeling of being supported.

Furthermore, the base form was designed to be flatter than the usual fruit bowl. The objective was to prevent the user from piling up fruits and veggies inside FooDi. This way, the number of stored food products can be limited. The participants of the Photo Diary admitted when they stack many items in one bowl, they usually miss a few and get them spoilt or mouldy. This casualty happens due to low air flow at the bottom part of the bowl, which enhance mould growth (the more crowded the fruit, the less room for air to circulate each piece (which can lead to rotting) (Mifflin, 2019). Hence, showing only a daily portion of fruits and veggies and consuming it in time becomes important.

Go to Appendix F to see other form exploration.

### Size

In 2019, on average, each person in the Netherlands ate fruit 37.5 kg (van Dooren, 2020). This means people eat ~0.102 kgs or 102 grams or one or two fruits per day. Meanwhile, vegetable consumption (including potato) is 61.81 kg per person per year (van Dooren, 2020), which means people eat ~0.169 kgs or 169 grams per day.

The cabinet is supposed to store daily portion fruits and a few half-cuts of fruit and vegetables, which creates a possible combination:

1) whole fruits + half-cuts veggies

2) whole fruit + half-cut fruit + half-cut veggies

3) Half-cut fruits + half-cut veggies

*Product size was determined based on approximation of the amount of fruits and vegetables stored for one day.*

For a single household:
Assumed someone has two fruits a day (banana/avocado and an apple). The average length of these fruits are:
- Apple: 7–8.5 cm in diameter

- Avocado: 7–20 cm long

- Banana: 15–20 cm long (medium size)

(Bjarnadottir, A. (2021))

Then, the minimum length should be ~20 cm. However, the cabinet should have two compartments to separate the ethylene producer and absorber. But, it does not need to double the length (20 cm) because depending on the fruits and vegetable type, these fruits might be separated (i.e. one fruit in one compartment. Therefore, if the shape is rectangular, the size is stretched to 30 cm, depth is 20 cm, and height is 15 cm. Other space is used to store half-cuts veggies. If the shape is a circle, the diameter is 20 cm.

For couple households (2 persons):
Supposed fruits per day: 3-4
partly-used veggies: similar to 2 fruits size
then the size would be:
rectangular: LxDxH = 40 x 20 x 15 cm
circle: d=30cm

For family households (assumed for four persons):
fruits per day: 6-8 pieces
partly-used veggies: similar to 4 fruits size
As cooking for a family could be quite a  lot, the cabinet size should be double of couples. But, it would be oversize and difficult to keep on the kitchen counter or shelf. A possible resolution is a family household type using the couple size but refilling more frequently or creating a vertical compartment. During this project, FooDi form for family households was not explored.

Simple prototyping was done to get a sense of how big above dimension in a real product:



Figure 90. Prototype single households version (circle)



Figure 91. Prototype single households version (rounded square)

Figure 92. Single household size (circle)



Figure 93. Single household size (rounded square)



Figure 94. Couple household size

*Result and Evaluation*

A single household circle (d=20cm) was enough to store two apples and a few half-cuts vegetables (cucumber and lime). Nevertheless, it seems quite small to build two compartments.

A rounded square could accommodate about three fruits and 3-4 small half-cut veggies. Therefore, this size is suitable for a single household. However, the prototype's height was ~20 cm (5 cm taller than the design) due to material limitations. Therefore, the product looks slightly not proportional using this dimension due to its over height. Thus, in the 3D model of the final product, the height number used was around 15 cm.

The prototype of couple household size was able to contain 3-4 fruits and 4-5 half-cuts. Therefore, implementing this dimension is sufficient to accomplish a couple's consumption need.

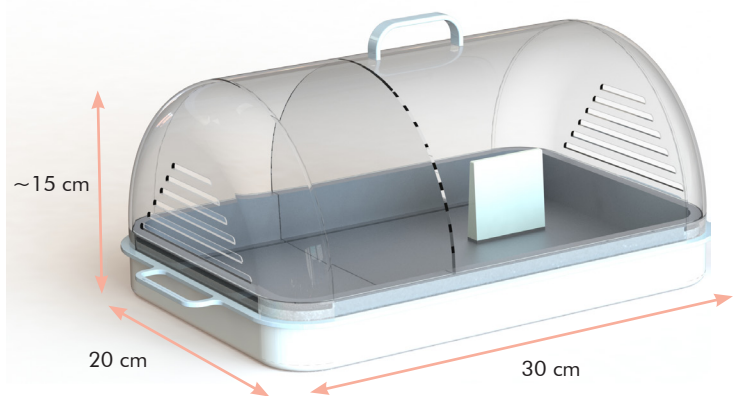The 3D model depicted as the final product represents a single household version.



~15 cm

20 cm

30 cm

Figure 95. FooDi dimension (single household version)

## Material

*Transparent lid: polycarbonate*

FDA grade polycarbonate was selected as it is transparent and safe for food storage (Acplastic, 2021). This material is commonly used for the lid of a buffet display.

*Detachable tray: aluminium alloy*

There are several material options for a product with a similar function as a fruit bowl & basket. The best material to preserve fruits and vegetable longer is ceramic. However, most ceramic applied for food ware is not transparent. Plastic is generally cheaper, yet it can ruin the quality of fruits and vegetables quicker by making them sweat. Lastly, metal and wood or bamboo-based bowl is known as the most durable and also help keep the food in good condition (Hilton, 2020). Hence, a metal type was chosen, specifically aluminium, because it is broadly used in kitchenware.

*Base and handle: polypropylene*

PP is lightweight, moldable, quite strong to be a base of FooDi, and an excellent FDA food-grade plastic (Fast Radius, 2021). In addition, polypropylene is the safest for reuse. Hence its general usage is for food containers (Stieger, 2015).

## Colour

Suitable colour for a food storage product like FooDi highly depends on the type of stored food. The container should be contrasting and harmonizing with the food colour to make the food stand out. But, as fruits and vegetables kept in the cabinet may vary, the best choice would be a monochrome or subdued colour to create a minimalistic perception (Hilton, 2020). This way, any fruits or veggies which have strong colours can stand out and look appealing. Moreover, pastel or white tone colour feels neutral, which is nicely applicable for various kitchen interiors.

In this report, the final product in this chapter displays slightly different colours. That diversity represents various versions of FooDi offered to the consumer.

## Weight

As a wish, a food display cabinet should be light enough to lift. The 3D model in this report was built by implementing the material explained above. Then, utilizing a measurement tool in Solidworks, the weight of FooDi was measured.

FooDi weight is approximately 1089.39 grams or 1.089 kg. This weight is not heavy to carry by an adult who will use the product.

# Cleaning FooDi

The cabinet should be washed at least once a week or more often if there are quite a lot of half-cuts to store to keep FooDi clean and reduce the risk of creating a perfect place for fungus growth. The water content of partly used fruits or vegetables is easier to evaporate than the whole one. This condition will rise relative humidity in the cabinet, which could speed up spoilage (Mifflin, 2019). The user should dry it well, or the moisture will lead to the fruit deteriorating faster.

Furthermore, if the user spots rotten fruits or vegetables, they should remove and replace the decaying items to keep FooDi as fresh as possible. Finally, before reusing the cabinet, the user should clean the inner part of FooDi before the remaining mould or bacteria contaminates other stored food.

# 3.3 FooDi – USER JOURNEY

This subchapter depicts an interaction journey between FooDi and its user. Consumer's interaction with fruits and vegetables at home is different. Generally, people eat fruits during snack time or dinner. Then, they just grab it and go. Meanwhile, ingredient leftover from the vegetable is obtained from cooking and will be reused for cooking.

**1**  Consumer buys groceries



**2**  They store the fruits and vegetables in the fridge



**3**  The consumer takes  an apple and avocado to put in the FooDi for today's consumption
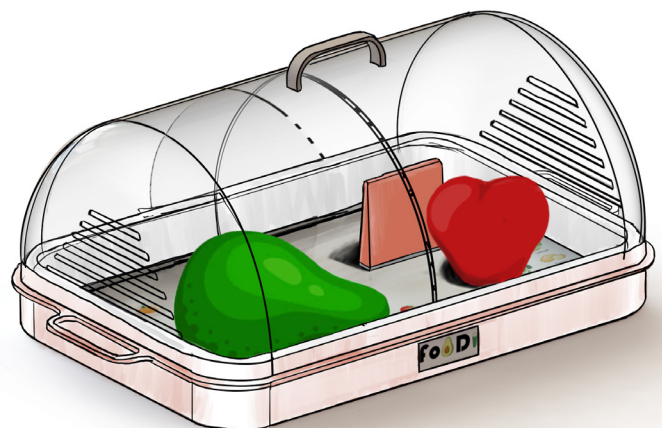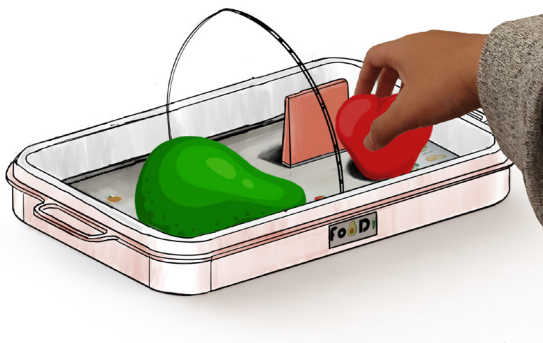
**4** In the afternoon, the person grabs the apple for a snack while working



**5** In the evening, the consumer uses the avocado to make a salad for dinner





**6** After cooking, half paprika and half cucumber left. The person keeps the partly used ingredients in FooDi and refills a few fruits for tomorrow.
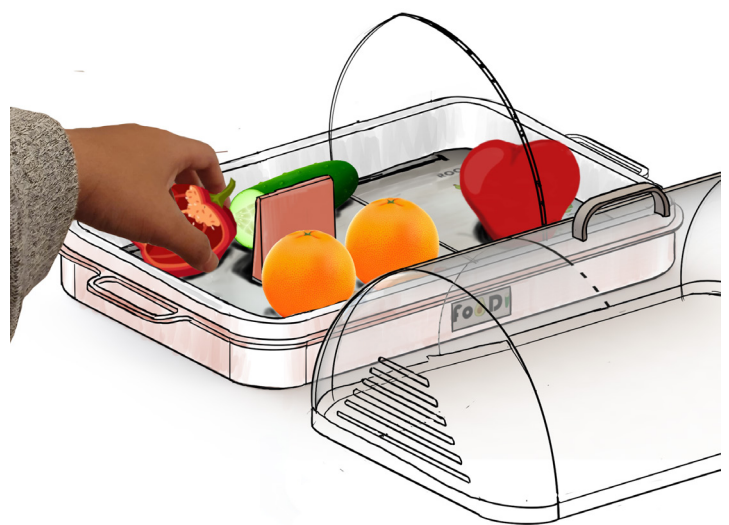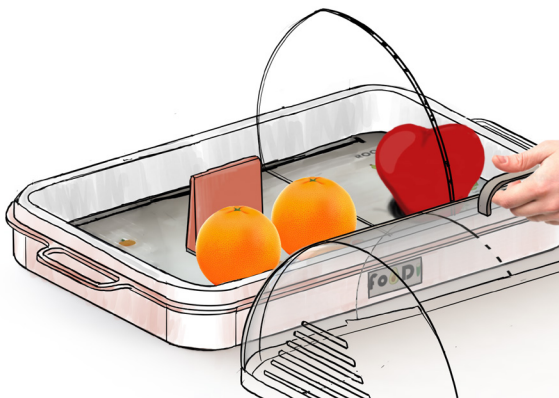
**7** The next day, the person consumes the oranges for lunch and afternoon snacks. The apple is eaten during dinner. Meanwhile, half-cut cucumber and paprika are reused to cook a soup.

# Chapter 4

# PROJECT CONCLUSION

Chapter 4 consists of the conclusion of the thesis project and estimation of the impact of FooDi usage at home in reducing food waste, project recommendations to develop this product, and further research in this field.

# 4.1 CONCLUSION

The project started with the goal of designing an intervention to support people in reducing food waste at home. Through several consecutive user research, the daily food practices of consumers and their relationship with food waste were investigated. Forgetting food stored in the fridge until it gets spoilt was found as the prominent struggle felt by almost all research participants. Furthermore, among all food that people consume, fruits and vegetables were known as food items that were overlooked the most, which highly contribute to food waste. The design statement, therefore, formulated as follows:

*"Design to improve food visibility to support households in the Netherlands in preventing food waste."*

and the problem statement:

*"How might we minimize forgotten and overlooked food at home for people who live in the Netherlands so that as to reduce food waste at the consumer level?"*

The problem statement was broken down into five specific to find the best solution to answer the question. Afterwards, the idea exploration phase was begun and ended up with four ideas. These initial concepts were analysed, and the most promising idea for each concept was combined. As a result, a particular design concept called FooDi emerged.

*FooDi is storage to display fruits and partly used vegetables usually hidden and forgotten in the fridge (e.g. half onion, half paprika or other cut vegetables).*

This product wants to prevent food waste at home by encouraging the user to eat food they purchase in a daily portion and reuse the ingredient leftovers as soon as possible.

Fruits and vegetables stored in the fridge are displayed in the open space to increase food visibility so that the consumer can see them. The amount of food to show is limited to prevent food stacking that could reduce visibility. Moreover, a transparent lid is implemented to let the user see through the cabinet and not miss any food.

FooDi is designed to keep the food only for 24-48 hours. Even though it is only short time storage, some possible risks were measured to retard food deterioration. FooDi prevents premature ageing by splitting ethylene gas producers and absorbers using a movable separator. Furthermore, a lid with natural ventilation was implemented to keep the stored fruits and vegetables fresh (avoid quick wilting).

Finally, a brochure and permanent sticker on the product was added to guide the user to use FooDi effectively to support reducing food waste.

# 4.1.1 Impact on Food Waste Reduction

According to the European Commission report about food waste estimation, 88 million tons of food waste are generated every year (FUSIONS, 2016). In the EU, households contribute around 53% of the total food waste (47 million tonnes).

In the Netherlands, it is approximately 2 million tons or 2 billion kgs. Among all food supply chain actors, households contribute to 37% of total food waste (Figure 6), which equals 0.74 million tons or 74 million kgs.

Avoidable waste from households is 68.6% (50.76 million kgs) of total household food waste or 25.38% of total food waste in the Netherlands.

The combination of avoidable fruits and vegetables is 28% (14.21 million kgs) of total avoidable waste households or 7.1% of total food waste in the Netherlands.

FooDi is designed to save avoidable waste from fruits and vegetables. If Netherlands consumers use FooDi, they could help prevent 14.21 million kgs of food wasted per year. Thus, reducing 7.1% of total food waste in the Netherlands.

This result is based on an optimistic assumption that FooDi is distributed to each household in the Netherlands.

## 1. Saved edible food

Using FooDi to support Dutch consumers in reducing food waste can decrease household food waste share in the supply chain.

Food waste shared by households:
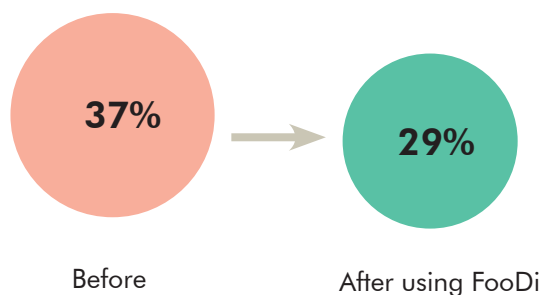


| 37% | 29% |
|---|---|
| Before | After using FooDi |

1.3 billion tons of food waste in 2011 is estimated could feed up to 868 million people worldwide (FAO, 2011). Therefore, based on a small calculation, saving 14.21 million kgs of fruits and vegetable commodities may help1000 hunger in the Netherlands every year.

## 2. Saved money

Each year, one Dutch consumer wastes approximately 50 kilos of solid waste (all types of food excluding beverages), which worths €145 money lost (an Dooren, C., & Mensink, F., 2018).

The main goal of developing FooDi is to support the user to reduce fruits and vegetable waste. Displaying this commodity outside the fridge also means increased visibility of other food in the refrigerator because less food will be stored. Moreover, encouraging the user to refill the cabinet every day may influence consumers to check the fridge more frequently and carefully. Consequently, the possbility to use or reuse food in the refrigerator will be higher and less food will be wasted.

Supposed that the user could reduce 80% of total food waste, they would save €120 per person per year. Depending on the consumer's financial situation, this amount of money could benefit them in different ways.

*Middle income, permanent Dutch residents:*



**€120 =**    or

add one movie to watch in the cinema each month

help to cover holiday expense

*Low income, permanent Dutch residents or comers like international students:*



**€120 =**

support to surviving for 3 weeks more in a year (average food expense for a single household is €200 (Teller Report, 2020)

## 3. Environmental benefit

CO2 is one of the greenhouse gases that cause global warming worldwide (Lindsey, 2021)—at the EU level, disposing of 88 million tons of food waste per year equal to 170 million tons of CO2 emission (FAO, 2013). Due to global warming, extreme climate change happens everywhere, including in the Netherlands. For example, last July was the wettest summer in Netherlands history (NL Times, 2021). NL Times reported that in mid-July, heavy showers caused severe flooding in Limburg. Moreover, as the average temperature in the Netherlands has increased by 1.7C during the last century, snow during the winter significantly decreases and even becomes rare.

Reducing food waste by 14.21 million kgs prevents 27.42 million kgs CO2 to release, thanks to FooDi. If CO2 reduction is expanded and successful, the temperature rising could be stopped, and summer and winter in the Netherlands could be stable again. Having a nice summer without a lot of rains and hurricanes is a dream for everyone. Also, if the Netherlands has snow in the winter again, people may experience annual ice skating on the frozen canal.

# 4.2 RECOMMENDATIONS

1. In doing user research, the questions should be prepared well to answer research questions so that the result can be inspirational. A pilot study should be conducted, and an early analysis should be done to evaluate and improve the user research before starting the user research with the real targetted user.

2. Build a fully functional prototype (embody the final product) for a user evaluation. The used materials do not have to be the same. Its substitute is acceptable as long as it can create a similar appearance. A suitable method for user evaluation is like a product diary. The participant utilizes FooDi for a few days at home and fills a booklet to capture their interaction with FooDi. At the end of the product diary, the following interview should be conducted. This way, people's experience and opinions about FooDi to support them reducing food waste at home could be revealed. The result of the user evaluation will be used for FooDi further development.

3. Redo the experiment of slowing down the respiration rate by using an enclosed room. As this experiment was done for five days, so it is not valid to represent a storing period for 1-2 days that FooDi promotes. If we see from the full experiment (Appendix D), after a day or two days, the effect of using the lid seemed unnoticeable. Therefore, it could be that for short-term storage, the respiration rate's influence is neglectable. However, the enclosed room is still useful to control relative humidity. So, this feature should not be removed totally.

4. Redesign the product's shape. For example, only one layer could be preferable instead of using two layers (movable tray and base). It will consume less material which will affect production cost reduction. The best impact is the selling price may be lower or more profit will gain by the manufacturer.

5. In this project, the comprehensive version FooDi is only suitable for a single household. Meanwhile, the product is intended to approach as many as the consumer to prevent food waste. Therefore, exploring form for the couple and family version is crucial.

6. An LCA analysis is required to know the real impact of FooDi from the environmental point of view. This measurement compares FooDi production impact to the environment and food waste reduction by using FooDi to how much $CO_2$ is released (all are calculated in the $CO_2$ emission unit).

# PERSONAL REFLECTION

Working on the first big design project and surviving from Covid 19 restriction were double challenges for me. During the user research, I expected to meet the participant and see their living environment directly to gain meaningful information for the thesis project. But due to Covid measurement, I could not. As a solution, a photo diary method was chosen to cope with that situation. It was my first time as well to use this method. I struggled to create a booklet to fill in by participants. But, I found it very helpful to collect someone's personal information without meeting them. However, I still felt that it would be perfect for doing the final interview in the participant's house after finishing the photo diary booklet. Thus, this project taught me how to adapt to harsh conditions yet obtain an optimal result.

Regarding the conceptualization phase, unfortunately, I could not build a fully functional product and test to people that I had hoped for beforehand due to time limitations. So it was a bit disappointing for me. But I learned another essential aspect of design: creating a good and reasonable story for my thesis project. While working on the project, I easily got distracted, not focusing on the project's design statement. Moreover, since I seemed to please anyone and tried to create an inclusive product that satisfied many people, I was prone to adding unnecessary features into my concept, complicating the design. But then my supervisors asked me to make one storyline that summarizes the content of my project (the decisions I made and the reasoning). Sticking to this line had guided me to focus and finally produced a final concept that I am proud of.

Moreover, I think I executed my graduation plan chaotically. I frequently did not meet the set deadline either from my supervisor or myself. I acknowledge that sometimes I underestimated the tasks a little bit, but I mostly miscalculated the required time to finish the work, specifically when writing a report. It always took more hours than I had planned to translate something in my head into text. This was also the reason I often sent my project progress postmidnight.

Furthermore, theoretically, I understand that design is an iterative and never-ending process. Therefore, the designer should quickly collect only sufficient supports for their reasonings, then decide. We do not have to show complete evidence to take the first decision. Through iterations, eventually, the reasoning will be comprehensive itself. However, in practice, it was not easy for me. I faced indecisiveness many times during this thesis project. Perhaps, I have just not gotten used to this way of working yet. But, I think understanding my weakness is a good start to keep moving forward. Hence, in the future, I would know what to anticipate and improve.

My final note for myself is I hope one day you could be an impactful designer who creates products that help people and the environment towards a better world to live in

# REFERENCES

Acplastic. (2021). Tuffak FD 0000 UF FDA Approved Polycarbonate -48 x 96 x .250in. Retrieved from https://www.acplasticsinc.com/products/0000-250-48x-96-tuffak-fd-uf [Accessed in August 2021]

Becker, B.R., & Fricke, B. (2002). Transpiration and Respiration of Fruits and Vegetables.

Beer, Tommy. (2021). More Than 1 Billion Tons Of Food Was Wasted In 2019, UN Report Finds. Retrieved from https://www.forbes.com/sites/tommybeer/2021/03/04/more-than-1-billion-tons-of-food-was-wasted-in-2019-un-report-finds/

Bjarnadottir, A. (2021). How Many Calories and Carbs Are in a Banana?. Retrieved from https://www.healthline.com/nutrition/bananas-calories-carbs?c=486077489992#TOC_TITLE_HDR_2 [Accessed in October 2021]

Bloom, J. (2011). American wasteland: How America throws away nearly half of its food (and what we can do about it). Da Capo Press.

Design Kit. (2021). Photojournal: Photos are a fantastic way to learn about a person's life, especially if they're the one taking them. IDEO.ORG. Retrieved from https://www.designkit.org/methods/photojournal [Accessed in October 2021]

Dott, J. (2020). Food Waste Prevention: a design intervention for Households [Master thesis, Delft University of Technology]. Delft University of Technology Repository. https://repository.tudelft.nl/islandora/object/uuid%3A9f7cceaf-9942-4fa4-aadf-7109d53f51e8

Engineering ToolBox, (2004). Fruits and Vegetables Optimal Storage Conditions. [online] Available at: https://www.engineeringtoolbox.com/fruits-vegetables-storage-conditions-d_710.html [Accessed August 2021].

European Union. (2021). Living in the EU. Retrieved from https://europa.eu/european-union/about-eu/figures/living_en [Accessed in September 2021]

Evans, D. (2012). Beyond the throwaway society: ordinary domestic practice and a sociological approach to household food waste. Sociology, 46(1), 41-56.

Eyal, N., & Hoover, R. (2014). Hooked: How to build habit-forming products.

Falk, P. (1994). The Consuming Body. London: Sage Publications

Farr-Wharton, Geremy & Foth, Marcus & Choi, Jaz. (2014). Identifying factors that promote consumer behaviours causing expired domestic waste. Journal of Consumer Behaviour. 13. 10.1002/cb.1488.

FAO. (1981). Food loss prevention in perishable crops. FAO Agricultural Services Bulletin 43, Rome, 72

FAO. (1989). Prevention of post-harvest food losses fruits, vegetables and root crops a training manual. FAO: Rome.

FAO. (2004). Manual for the preparation and sale of fruits and vegetables, from field to market. FAO: Rome.

FAO. (2013). Food Wastage Footprint; Impacts on Natural Resources. FAO: Rome.

FAO. (2015). Food loss or food waste? Anything but the same, says FAO expert. Retrieved from http://www.fao.org/europe/news/detail-news/en/c/277058/ [Accessed in May 2021]

FAO, I. WFP (2015), The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Food and Agriculture Organization Publications, Rome.

Fast Radius. (2021). Top 5 FDA-approved food-grade plastics. Fast Radius. Retrieved from https://www.fastradius.com/resources/top-five-food-grade-plastics/ [Accessed in October 2021]

Fusions. (2016). Estimates of European food waste levels. Retrieved from http://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf [Accessed in September 2021]

Gena. (2015). Reduce Food Waste For The Earth And Your Wallet {Free Food Storage Printables!}. Retrieved from https://gingercasa.com/reduce-food-waste/ [Accessed in October 2021]

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A., (2011). Global food losses and food waste. Extent, causes and prevention.

Hardenburg, R.E., A.E. Watada and C.Y. Wang. (1986). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA-ARS Agriculture Handbook Number 66 (revised) 136p.

Hartel, K. (2021) . How Colors Can Change Your Appetite and Eating Habits. Retrieved from https://www.fitday.com/fitness-articles/nutrition/how-color-can-change-your-appetite-and-eating-habits.html [Accessed in August 2021]

Hilton, E. (2020). How To Choose A Fruit Bowl & Basket. Foter. Retrieved from https://foter.com/how-to-choose-a-fruit-bowl-basket [Accessed in October 2021]

Horesh, T. (2018). Handy Comparison between Polycarbonate and Glass. Retrieved from https://blog.palram.com/construction-and-architecture/handy-comparison-between-polycarbonate-vs-glass [Accessed in September 2021]

Ice Pack Store. (2021). Frequently Asked Questions (FAQS). Retrieved from https://www.icepackstore.com/faqs [Accessed in August 2021]

Levanier, J. (2021). The meaning of shapes in design. Retrieved from https://en.99designs.nl/blog/tips/meaning-of-shapes/ [Accessed in October 2021]

Lindenberg, S., Steg, L. (2007). Normative, gain and hedonic goal frames guiding environmental behavior. J. Soc. Issues 63 (1), 117–137. https://doi.org/10.1111/j.1540-4560.2007.00499.x

Lindsey, R. (2021). Climate Change: Atmospheric Carbon Dioxide. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide [Accessed in October 2021]

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., & Searchinger, T. (2013). Reducing food loss and waste. World Resources Institute Working Paper, June

Lyndhurst, B. (2011). Consumer insight: date labels and storage guidance. WRAP, Banbury.

Mifflin, M. (2019). How to Keep Your Fruit Bowl Fresh. Retrieved from https://www.thespruceeats.com/keep-fruit-fresh-1908316 [Accessed in October 2021]

Moffatt, Mike. (2020). Farming Post World-War II. Retrieved from https://www.thoughtco.com/farming-post-world-war-ii-1146852

Netherlands Nutrition Centre. (2019). Synthesis Report on Food Waste in Dutch Households in 2019. Retrieved from https://www.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Professionals/Pers/Persmappen/Verspilling%202019/VC_Synthesis%20report%20on%20food%20waste%20in%20Dutch%20households%202019.pdf

Nielsen, K.S. (2017). From prediction to process: a self-regulation account of environmental behavior change. J. Environ. Psychol. 51, 189–198. https://doi.org/10.1016/j.jenvp.2017.04.002

NL Times. (2021). Wettest summer in Netherlands history. NL Times. Retrieved from https://nltimes.nl/2021/08/06/wettest-summer-netherlands-history [Accessed in October 2021]

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 3065–3081. https://doi.org/10.1098/rstb.2010.0126

PBL Netherlands. (2013). The effects of Climate Change in the Netherlands: 2012. Retrieved from https://www.pbl.nl/en/publications/the-effects-of-climate-change-in-the-netherlands-2012 [Accessed in October 2021]

Population Reference Bureau. (2000). 9 Billion World Population by 2050. Retrieved from https://www.prb.org/resources/9-billion-world-population-by-2050/ [Accessed in September 2021]

Scheviak, T. (2020). 9 Methods to Extend the Shelf Life of Fresh Produce. Retrieved from https://onethird.io/9-methods-to-extend-shelf-life-fresh-produce/ [Accessed in August 2021]

Smart Fog. (2015). How Humidity Affects Fruits and Vegetables. Retrieved from https://www.smartfog.com/how-humidity-affects-fruits-and-vegetables.html [Accessed in October 2021]

Smart Fog. (2015). How Humidity Affects Fruits and Vegetables. Retrieved from https://www.smartfog.com/how-humidity-affects-fruit-and-vegetables.html [Accessed in October 2021]

Stenmarck, Å., Jensen, C., Quested, T., & Moates, G. (2016). Estimates of European food waste levels. 10.13140/RG.2.1.4658.4721.

Stieger, G. (2015). Which plastic food containers are safe to reuse?. Retrieved from https://www.foodpackagingforum.org/news/which-plastic-food-containers-are-safe-to-reuse [Accessed October 2021]

Teller Report. (2020). The Dutch spend on average on groceries. Teller Report. Retrieved from https://www.tellerreport.com/post/2020-07-16-the-dutch-spend-on-average-on-groceries.Sk5dFKOTkv.html [Accessed in October 2021]

Temminghoff, M.B.M. (2019). Huishoudelijke aankopen voedingscategorieën 2019-2016-2013. edited by GfK [Household purchases of food categories 2019-2016-2013]. edited by GfK. Dongen.

Temminghoff, M.B.M. and N. Damen, Voedselverspilling 1-meting. (2013). GfK: Dongen.

Thomas. (2021). Tips for Replacing a Refrigerator Gasket. Retrieved from https://www.thomasnet.com/articles/hardware/refrigerator-gasket-replacement/ [Accessed in September 2021]

Tuflite. (2021). Benefits Of Using Multiwall Polycarbonate Sheets. Retrieved from https://www.tuflite.com/blog/benefits-using-multiwall-polycarbonate-sheets [Accessed in September 2021]

UN. (2020). The Sustainable Development Goals Report 2020. UN, New York. https://doi.org/10.18356/214e6642-en.

van Dooren, C. (2016). Oplegnotitie Voedselverspilling in Nederland in 2016, p22, Voedingscentrum, Den Haag.

van Dooren, C., & Knüppe, J. (2020). Consumer Food Waste Fact Sheet. Netherlands Nutrition Centre. Retrieved from https://www.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Service/English/Factsheet%20 Food%20waste.pdf

van Dooren, C., & Mensink, F. (2018). Consumer Food Waste Fact Sheet. Netherlands Nutrition Centre. Retrieved from https://www.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Service/English/Factsheet%20 Food%20waste.pdf

van Dooren, C. and V. Klostermann. (2013). Supermarkt laat kansen liggen; Ouderen, vrouwen en kleine huishoudens vaker ontevreden over portiegrootte. VMT. Nr.16/17 9 augustus: p. 26-26.

van Geffen, L., van Herpen, E., Sijtsema, S., & van Trijp, H. (2020). Food waste as the consequence of competing motivations, lack of opportunities, and insufficient abilities. Resources, Conservation & Recycling: X, 5, 100026. https://doi.org/10.1016/j.rcrx.2019.100026

VanHooker, B. (2019). The Psychological Effect of the Countdown Clock. Retrieved from https://melmagazine.com/en-us/story/the-psychological-effect-of-the-countdown-clock [Accessed in July 2021]

Voedingscentrum. (2021). The Netherlands Nutrition Centre. Retrieved from https://www.voedingscentrum.nl/nl/service/english.aspx [Accessed in August 2021]

Weather and Climate. (2021). Average Humidity In Amsterdam (Noord-Holland). Retrieved from https://weather-and-climate.com/average-monthly-Humidity-perc,Amsterdam,Netherlands [Accessed in September 2021]

Wedgwood, O. (2021). The design features in a Thermos Flask. Retrieved from https://gcsephysicsninja.com/lessons/thermal-physics/thermos-flask-design/ [Accessed in September 2021]

Woodford, C. (2021). Vacuum flasks. Retrieved from https://www.explainthatstuff.com/vacuumflasks.html [Accessed in September 2021]

WRAP. (2008). The Food We Waste. UK Waste Reduction Action Programme, United Kingdom.

WRAP, (2015) , Banbury, Strategies to achieve economic and environmental gains by reducing food waste. Retrieved from: http://newclimateeconomy.report/wpcontent/uploads/2015/02/WRAP-NCE_Economic-environmental-gains-food-waste.pdf