



ICT tools for food management and waste prevention at the consumer level

D1.5



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Executive Summary

This report examines and evaluates the availability and effectiveness of existing ICT-based tools and smart technologies for food management and waste reduction by consumers. It is part of the EU research project REFRESH, which aims to contribute to the goal of reducing food waste across Europe.

A literature search in 2018 resulted in only twelve papers that focus on the topic of apps in relation to consumers' sustainability behaviour. The scarce evidence indicates that apps can be effective in raising consumer awareness indicated, but not much is known about the effects of using apps on food waste behaviour of consumers. Therefore, two subtasks were executed within task 1.5: an inventory of available ICT tools and a consumer focus group study.

Inventory of ICT tools

Via an online search in 2016 & 2017, suggestions from REFRESH project partners and tools mentioned in publications, an inventory was made of existing ICT based tools for food management and waste reduction by consumers. The functionalities of these apps were analysed for the different phases of the household food logistics (as defined by WP1.1). The aim of this inventory was to give an overview of existing apps and examples of the diversity of functionality of the apps.

Numerous apps and websites were found that relate to food-waste related behaviour. Most apps cover the phases of planning, acquiring, and storing of food. They can be categorized as 'informative', 'reminder', 'food sharing', 'planning', 'recipes' and 'supermarket' apps. Supermarket apps (with only an indirect influence on food waste), the apps that remind consumers of the expiration date of a product, and apps that provide an infrastructure for food sharing are most frequently used. In the areas of preparation and consumption of food, fewer apps are available.

Inventory analysis results

Many apps available in the app stores were built by individuals, have limited functionality and are not updated frequently, whereas commercial apps built by companies are usually better maintained, have wider functionality and have more installs. The most important limitations of the currently available apps seem to be limited functionality, infrequent updates, incomplete information from unknown sources, and suboptimal usability (especially in apps with combined functionalities).

Focus groups

Based on the criteria of a high number of installations or novelty, three apps from this inventory were selected for use in the consumer focus group study. App 1 had the features: a meal planner, shopping list, inventory list and recipes. App 2 consisted of a shopping list that could be shared; and app 3 had a shopping list, which could be shared, an inventory list and monthly report journals.

Twenty eight consumers participated in our focus group study in May 2018 in the Netherlands. Their mean age was 45 ± 15 years old (range 22-65 years), with 68% female and 38% male. Almost 80% had a higher or university education. The

majority (39%) had an above-average income and lived in a 1-2 person household (50%). The participants were divided over three groups, for each app one group. They were asked to use the app for three weeks, in order to figure out the functionality and usability of the app. Subsequently, each group participated in one 90-minute semi-structured focus group discussion where the app was evaluated. The aim of the focus group discussion was to gain insight in how consumers experienced the use of the app and to what extent using the app led to a change in self-reported behaviour. One day after the focus group discussion, participants completed an online questionnaire to get insight into the demographic characteristics of the sample and to get quantitative information about the use and effects of the three apps in relation to self-reported food waste behaviour.

Focus group results

The focus group study showed that consumers seem to be open and interested in apps that help in reducing food waste. However, many participants indicated that they did not perceive a clear need to use such an app, because they thought that they did not waste much food. The focus group discussions also showed that the tested apps lacked clear incentives that reward and reinforce positive behaviour, nor did they engage a lot with the user. Furthermore, two of the three apps scored very low on user-friendliness and were time consuming to use. All three received an overall score below 5.5 (on a 10-point scale), and would not be recommended to friends or family. One app showed small, positive changes in awareness and motivation (app 3), but none of the apps showed an effect on self-reported food-waste related behaviour (meal planning and groceries shopping). Whereas the added value of app 2 (shopping list) was not recognized, participants perceived that the functionalities in app 1 and 3 could be positive and potentially useful to influence food-waste related behaviour, on condition that the app was easy to understand and easy to use. Overall, respondents felt that they had to invest much more (in time, energy and stamina), than what they got out of the app (convenience, insights and engagement).

Conclusions for development of ICT tools to reduce consumer food waste

The results of our study indicate that **user-friendliness is a key component**, meaning minimal usage time and little cognitive effort in working with the app. As soon as the app is not user-friendly, consumers will stop using it. Consequently, a change in food waste behaviour will not be achieved via the use of a user-unfriendly app. Because our participants felt a low intrinsic need to use food-waste related apps, we recommend that apps in this area should be extremely easy to use, with an intuitive navigation, an easy app structure, and not too many notifications. Consumers preferred no ads and banners, but this will be difficult with a free app. Entering products manually is too time-consuming and should be automated, by for example scanning food products. A well-maintained and up-to-date database of food products is needed in order to achieve a functionality that makes the entry of products easier, and provides accurate information about expected remaining shelf life of the products. However, such a database is very hard to achieve, since these databases are most of the times only suitable for one country and not complete.

In order to achieve a change in food waste behaviour, the results of our study indicate that including a direct insight or showing the economic and/or ecological effects of consumers' food-waste related behaviours in an app could work as a reward. By including direct feedback or incentives in apps, consumers can set goals and see the effects of their behaviour. In addition, they can compare themselves to other consumers. This could enhance motivation and make consequent usage of such an app on the long term more likely. This will enlarge the likelihood of changes in food-waste related behaviours.

Our study is one of the very few studies that focus on apps (ICT-tools) in relation to consumers' food waste behaviour, looking from the perspective of which tools are currently available for consumers, as well as evaluating three different apps by consumers, who actually used these tools for a period of three weeks in their everyday life. Although the inventory is not exhaustive, the overview provides good insight in the type of apps that are available for consumers in relation to food-waste related behaviours. In addition, the focus group study provided interesting and additional insights on top of the currently available literature. Nevertheless, the sample in our study was small and relatively highly educated. Because the evaluation questionnaire was completed after the focus group discussion, the group discussion may have influenced the individual answers of the respondents. Therefore, the results have to be interpreted with some caution and the results may not be representative for the average Dutch consumer.

Future research is recommended to obtain a comprehensive picture of the effects of apps (ICT tools) on consumers' awareness, motivation and behaviour in relation to food waste.

Because user-friendliness is a key point, it is recommended to include users in an early stage of the development. After various cycles of pre-testing, the full-functioning apps should be tested in longer-term studies that are sufficiently powered, and measure actual food-waste related behaviour of the consumers. Larger studies also provide the opportunity to investigate whether certain groups (segments) of consumers are more susceptible for behavioural change.

Apps and ICT tools form an interesting tool for policy makers in order to reach consumers from all parts of society. Policy makers should support further research that investigates the effects of apps and ICT tools on actual food waste behaviour of consumers, as the research so far indicates that apps and ICT tools can raise awareness. Because consumers do not perceive a clear need to use apps for food waste reduction, policy makers could also take actions that bring forth a feeling of urgency among consumers to change their own behaviour. Finally, policy should support the development and maintenance of an up-to-date data source for food products, define data standards for the exchange of data from primary sources and from other apps, and provide quality guidelines that support the development of user-friendly apps.

1. General Introduction

1.1 Background

This report is part of the EU project REFRESH (Resource Efficient Food and dRink for the Entire Supply cHain), under project number 641933. REFRESH addresses both waste prevention and creates new options to prevent material becoming waste. The project aims to contribute significantly towards the objective of reducing food waste across the EU and maximise the value from unavoidable food waste and packaging materials. A central ambition of the REFRESH project is to develop and demonstrate a 'Framework for Action' (FA) model that is based on: strategic agreements across all stages of the supply chain; underpinned by robust policy; delivered through collaborative working; supported by science and evidence-based tools, which will allow targeted cost effective interventions and support transformation towards a more sustainable and secure EU food system.

The current report is part of the first work package of REFRESH, in which consumer understanding in relation to waste generation, handling, reuse and by-product valorisation is investigated. The current report focuses on ICT-based tools for food management and waste prevention at the consumer level.

1.2 Objective

This report is the deliverable of task 1.5. The objective of task 1.5 is to examine and evaluate the availability and effectiveness of existing ICT based tools and smart technologies for food management and waste reduction by consumers; thereby contributing to an iterative design cycle for new ICT tools in practice.

Industry has many initiatives in place to reduce and manage food waste. However, in many cases, these and similar interventions failed to meet expectations of consumer behavioural change (Hoem, 2017; Lim, Funk, Marcenaro, Regazzoni, & Rauterberg, 2017). Recent innovations in mobile application development have provided some new avenues for optimism to encourage food waste reduction (Farr-Wharton, 2015; G. Farr-Wharton, J. H. J. Choi, & M. Foth, 2014a).

The aim of this work is first to make an inventory of existing ICT tools for food management and waste reduction by consumers. We analyse the functionalities they have for the different phases of the household food logistics (as defined by WP1.1). Secondly, we evaluate the effectiveness of these tools and technologies for food management and waste reduction by consumers. We will identify missing, but promising functionalities, and propose suggestions for policy and further research.

1.3 Introduction: consumer food waste and apps

About one third of all produced food is wasted. This large amount of food waste leads to economic, social and environmental losses. A large part of wasted food is generated at the level of consumers (Stenmarck, Jensen, Quested, & Moates, 2016). Deliverable 1.1 and 1.2 have shown that consumers' food waste behaviour is a complex behaviour, that is influenced by many factors (determinants). In order to prevent and reduce the amount of generated food waste by consumers, it is necessary to understand and focus on these different determinants, as changing consumer food and waste behaviour is a challenging task (Aschemann-Witzel, 2015; Farr-Wharton et al., 2014a).

Apps seem to have great potential for changing consumer's food waste behaviour, because almost all consumers nowadays have a smartphone or tablet, and apps are often inexpensive, so a high number of consumers can be reached via interventions that use smartphone applications. Moreover, apps have potential to reach populations that previously had restricted access to interventions or information. In addition, different forms of communication can be applied: text, pictures, video and interactive ways of communication. Apps also provide the opportunity to personalize interventions at an individual level, which may enhance its success. Furthermore, notifications can be used to contact the consumer, even though the consumer is not using the device at that moment. Finally, apps make it possible to focus on the three key determinants of the Consumer Food Waste Model: opportunity, ability and motivation (Deliverable 1.1). For example, apps provide new technology that help consumers at the moment of shopping not to buy foods they already have in stock (opportunity), apps can increase consumers' knowledge about expiry times or help consumers with food planning (ability), and apps can motivate consumers by presenting feedback or compliments when desirable behaviour occurs (motivation). Taken together, apps may present a low-cost, scalable and effective approach to change consumer behaviour (Mummah et al., 2017).

Although apps have great potential to change consumers' food waste behaviour, not much is known about the effect of these tools on food management and food waste behaviour of the consumer. A literature search in 2018 focussing on the effectiveness of apps (search terms: apps, smartphone applications, computer technology, mobile phone, mobile technology) to improve food-waste related behaviour of consumers, resulted in twelve papers. The majority of these papers were conference papers presenting the design of a study, or a design research paper, asking consumers how the app or smartphone application should look like.

The strategies that have been described in these papers were the following:

- 1) Social recipes (Lim et al., 2017; Lim, Yalvac, Funk, Hu, & Rauterberg, 2014; Yalvaç, Funk, Lim, Rauterberg, & Hu, 2014), which refers to a community-based system of food sharing.
- 2) Eco-feedback (Lim et al., 2017), which refers to comparing one's own food waste behaviour to others.

- 3) Apps and wearables (Farr-Wharton et al., 2014a; Farr-Wharton, Foth, & Choi, 2013; Hoem, 2017; Ng, Shipp, Skatova, & Bedwell, 2015), where different apps and – in one study - a wearable camera, were tested by consumers.
- 4) Interactive or smart fridge (G. Farr-Wharton, J.H.J. Choi, & M. Foth, 2014b; Nguyen, Nguyen, Huynh, Nguyen, & Stigberg, 2015; Rouillard, 2012), which aimed to help consumers organizing the food in their fridge.
- 5) Indirect and direct persuasion (Aleahmad, Balakrishnan, Wong, Fussell, & Kiesler, 2008), where two variants of a recipe website were investigated in relation to consumer's environmental attitudes and their recipe choice.

The results show that apps and ICT tools can be effective in raising consumer awareness (Farr-Wharton et al., 2014a; Farr-Wharton et al., 2014b; Lim et al., 2017; Nguyen et al., 2015). Consumers who used an app with the aim to encourage sustainability behaviour, felt that the application positively impacted awareness on their food supply (availability), food location and their knowledge and understanding of how to use and store food (food literacy) (Farr-Wharton et al., 2014a). Another study showed that a social recipe system raised awareness of in-home availability of food and triggered food-related conversations among participants, resulting in knowledge gain (Lim et al., 2017). After using a prototype smart fridge, consumers indicated (self-reported) that the fridge increased their awareness of the available food items in their fridge, it motivated them to group food, and it encouraged them to use food before the expiration date (Nguyen et al., 2015). Another study with 'smart fridges' indicated that using FridgeCam (photos of fridge interior) led to an improvement in food supply knowledge and the Colour Code Project (paper-based colour scheme in the fridge) improved food location awareness; participants mentioned that these tools were helpful in reducing domestic food waste (Farr-Wharton et al., 2014b).

The food waste studies also showed that consumers like to get feedback on their behaviour, for example eco-feedback (Lim et al., 2017), where their own behaviour is compared to others (social comparison). Consumers perceived this component as being effective in reducing food waste and experienced it as an important motivating factor. Also goal-setting has been suggested to enhance compliance (Aleahmad et al., 2008). Finding ways to keep consumers interested and engaged is important, as it seems difficult to maintain high retention rates (Farr-Wharton et al., 2014a; Zhao, Freeman, & Li, 2016).

A social recipe system suggests recipes to a group of people by combining available ingredients for effective and pleasurable food waste prevention. Although consumers seem to be positive about such a system, it was also shown that the suggestions of the Social Recipe system were not used by the participants. They used the recipes to plan and make their own meals, not a shared meal. Therefore, social recipes alone was not perceived as being effective in directly reducing food waste (Lim et al., 2017). Another study also indicates that food sharing is a controversial action for consumers (Farr-Wharton et al., 2014a) due to issues of trust (related to the person to share with and the food item to share). In their study, none of the participants used this feature of the application.

Hoem (2017) tested whether an app with targeted content about reducing food waste can be a useful tool to prevent consumer food waste. Three versions were

tested (full app, light app and paper version). Although some participants found the app useful on several points and a few positive changes were reported in some participants' behaviour (i.e. use of food before expiry date), the overall usefulness of the app was scored very low. Technical problems, too much text, a lack of new content (boring), and the absence of figures and pictures contributed to this low score. Based on the results, the authors conclude that the app tested in this study could not help consumers in wasting less food.

More research has been done about the use of apps (ICT tools) for changing health behaviour (43 papers). The health behaviour mostly targeted was physical activity. Other health behaviours were also studied, such as dietary behaviour (for example vegetable intake), weight management, mental health, alcohol addiction, smoking behaviour, self-regulation of diabetes and sedentary behaviour. Several interventions showed significant effects in the direction of the targeted health behaviour (40 – 66% of studies in (Schoeppe et al., 2016); 74% of studies in (Zhao et al., 2016)). However, the apps were often used in multi-component interventions, and therefore it was impossible to know the effect of the stand-alone-app. It was also not known which feature of the app was effective in changing the health behaviour. Furthermore, the studies were often small, and thus lack statistical power. Many studies did not use a control group, making it difficult to know the real effects. Overall, it was concluded that apps can be promising for health behaviour change, but rigorous research to test their effectiveness is lacking (Hoem, 2017; Schoeppe et al., 2016; Zhao et al., 2016).

A study that reviewed 115 habit formation apps (not specifically focused on food waste) for their functionality showed that most of these apps use self-monitoring as behavioural change technique (tracking own behaviour and receiving feedback). The apps also provided features that help to maintain motivation, such as positive reinforcement, goal setting, rewards and incentives, positive self-talk. The authors argue that self-monitoring can be effective for behaviour change, but that other techniques - that support event-based cues and the development of automaticity - may be required for behaviour maintenance (Stawarz, Cox, & Blandford, 2015).

The research that has been done regarding apps and behaviour change provides insights into the desired characteristics of apps and ICT tools for food management and food waste reduction. The applications should use clear uncomplicated systems, such as smileys and colour coding for organizing food (Hoem, 2017; Nguyen et al., 2015). Furthermore, time and effort are important aspects for using the application. Apps should be user-friendly resulting in minimal cognitive effort and usage time (Hoem, 2017; Lim et al., 2017). Also fun facts about food waste, an overview of discounted food with short shelf life in grocery stores, different colouring systems to support systematic storage of food, an up-to-date inventory list or photo of fridge interior, action-oriented guidance on the desired food waste behaviour change, and flexibility for users in the nature of information they receive, have been suggested as promising and desirable characteristics for food-waste related apps (Farr-Wharton et al., 2014a; Hoem, 2017; Lim et al., 2017; Lim et al., 2014; Nguyen et al., 2015).

The research regarding health behaviour & apps provides comparable and additional insights. Information should be up-to-date, presented via pictures and video's, the applications should use a positive focus, be easy to use, personally

pleasant, having a social aspect (contact/ connection), and provide reminders (Teo, 2017). Gamification has also been mentioned to keep consumers interested (Hamari, Koivisto, & Sarsa, 2014). One review explored which features would enhance the effectiveness of apps, and concluded that less time consumption, user-friendly design, real-time feedback, individualized elements, detailed information, and health professional involvement may improve effectiveness of health behaviour apps (Zhao et al., 2016).

Although the current literature gives some indication that apps can be helpful in changing consumers' food waste behaviour and provides suggestions for desired features of these tools, research about the effectiveness on actual consumer food waste behaviour is very scarce. In order to extend the current findings and to get insight in whether apps (ICT tools) can effectively change consumers' food waste behaviour, two subtasks were executed for this task 1.5. First, an overview was created of existing ICT based tools and smart technologies for food management and waste reduction by consumers. These tools were examined for the functionalities they have for the different phases of the household food logistics (as defined by WP1.1). Based on this overview, three applications were selected and evaluated in a consumer study. The aim of this consumer study was to gain insight in how consumers experienced the use of the app and to what extent using the app led to changes in food waste behaviour.

1.4 Relation to other tasks

This research¹ makes use of the results of the work from WP1.1 "Consolidating existing pan-European consumer understanding". In this research, we make use of the phases described in the theoretical framework on Consumer Food Management WP1.1 to categorize the different apps at which stage in the process they might have influence.

The stages defined in WP1.1 that will be used in the inventory:

- **Planning stage:**
Planning refers both to the planning before food enters the household and when the food is in stock.
List making, meal planning, stock checking.
- **Provisioning stage:**
Provisioning refers to all ways in which food can enter the household.
Intelligent use of offers, decision making in store, response to promotions, pack sizes.
- **Storing stage:**
Storing refers to the storing of food, either as single items or as a combination of

¹ WP1.5 of the REFRESH Project: "ICT tools for food management and waste prevention at the consumer level"

foods (e.g. leftovers from a meal).

Keep / remove things from original packaging, labelling what goods in the freezer, wrapping 'open' items

- **Preparing stage:**
Preparing relates to the handling (cooking or preparation in other ways) of food products to enhance edibility.
Decisions about what to prepare, proportioning to cook the right amount, batch cooking (on purpose) for future consumption.
- **Consuming stage:**
Consuming refers to the moments when the food products or meals are being consumed and leftovers are being handled.
What happens during eating and directly afterwards, how much gets served / put on the plate, who does the serving, use of 'buffet' style, storage of leftovers, finding an opportunity to eat the leftovers.
- **Disposal stage:**
From other stages, food or a surplus of food can be moved to the disposal stage.
Decisions can be made about how to dispose of the food. Throw it out in the bin or give it another destination like donate it or share it with other people.

We will also make use of the Consumers Food Waste Model described in WP1.1. In the inventory we indicate which of the waste model elements the tools / apps contributes to.

- **Motivation:**
Motivation to prevent food waste equates to a person's willingness to perform actions that avoid generating food waste.
Awareness, Attitude, Social norm
- **Ability:**
Ability refers to a person's proficiency to solve the problems that he or she encounters when changing behaviour.
Skills, Knowledge
- **Opportunity:**
Opportunity refers to the availability and accessibility of materials and resources required to change behaviour.
Time & Schedule, Infrastructure, Technologies

2 Methodology

2.1 Inventory ICT tools

2.1.1 Introduction

It is impossible to review all available apps. Every day new apps pop up and many also disappear again. Therefore, the aim of this review is not to give a complete overview of existing apps, but to give an overview and examples of the diversity of functionality of the apps.

For this review, we made use of online search engines like Google and Bing to find relevant websites, tools and apps. As search strings we used: "food waste", "food waste reduction", and the equivalent terms in Dutch: "voedselverspilling", "voedselverspilling voorkomen" and the suggestions Google came up with. In Google Play, we also looked at the suggestions Google Play gave us. In addition to these sources of information, also apps and tools mentioned in publications and suggestions of other project partners were used to complete the inventory.

Not all apps are available in other countries or regions than specified by the producers. So, our review is based on apps and tools available in Western Europe and specially The Netherlands. Although some of the apps and websites in this inventory are in French or Spanish, we had to focus on apps and websites available in English or Dutch. A possibly important app not being mentioned in our list does not mean the app is irrelevant, but that it's not available in The Netherlands, or that it was not available at all at the time of the review.

For apps we focused on tools available for Android and Apple IOS devices (smartphones and tablets). We did not search for apps useable on Windows Phone devices or other mobile platforms. Since Google Play provides more information on the installed base of the apps, more information is available about how often an app has been installed on Android devices. Apple App Store does not give any information on usage or installed base of its apps. Therefore much of our information is based on the Android version of an app.

Google only provides an estimate on how many times an app is installed on a device. Most likely an app that has a higher installed base will be used more often. But it is not a guarantee that a higher installed base automatically means that an app is used more often.

2.1.2 App selection for use in the focus group study

To get more information about how consumers make use of food planner apps, we selected three apps for evaluation by consumers in the focus group study, as discussed below.

The first app is an integrated app with inventory and reminder functionality, a shopping list, meal planning and recipes. At the time of selection, this app had the highest installed base according to Google Play and is therefore most likely the best used app related to food waste that is available.

We chose a second app that just focussed on one functionality: a shopping list. For this app, we also selected the app with the highest installed base according to Google Play.

The third app was new in The Netherlands and introduced only one week before the start of the focus groups. This is also an integrated app with inventory, shopping list and reminder functionality. As an extra feature, this app can generate journals of finished and uneaten foods.

In this report, we will refer to the apps as number 1, 2 and 3 respectively.

2.2 Focus group study

2.2.1 Recruitment of participants

A total of 30 consumers were recruited to test (*i.e.* use) the three selected applications for three weeks and to discuss their experiences in a focus group session. They were recruited from the consumer panel of Wageningen Food and Biobased Research by e-mail (see annex 1 for the recruitment text). Most consumers in this panel live in and around the city of Wageningen. Inclusion criteria were: aged between 18 and 65 years old, owning a smartphone and sufficient knowledge of the English language, since the apps were only available in English. The consumers were divided into group one, two and three and each app was tested by 10 consumers in total. Group three consisted of only iPhone-users, since this app was solely available for iOS. Group one and two consisted of both Android as iOS users. For further details on the participants of the focus group study, see table 1.

2.2.2 Home-use test

All 30 consumers were invited to come to our research facilities in Wageningen on the 7th and 8th of May 2018 for a short introduction. For each of the three groups, there was a separate introduction session of 30 minutes. The participants were given a short general introduction on food waste (what is it, numbers, solutions and goals) and on the research consortium. After the presentation, the name and features of the app that they would test and use was shown to them. They were asked to install this application on their smartphone (help was provided when needed) and to use it for a period of three weeks. No further instructions on *how* or *how often* they should use the app were provided. The purpose of the home-use test was that participants would figure out the app themselves, instead of following certain instructions. In case of any questions or problems during the three-week period, they could contact the research team by phone or e-mail. One consumer in group three dropped out before the start, so a total of 29 consumers were present at the introduction session and started with the home-use test.

2.2.3 Focus group discussion

After having used the app for three weeks, the participants came back to our research facilities for a focus group session of ninety minutes. For each group, there was a separate group discussion, led by an independent professional discussion leader (*Rob Drent, Canvas Concepting*). The aim of the focus group was to gain

insight in how consumers experienced the use of the app and to what extent using the app led to a perceived change in behaviour.

The group discussion was semi-structured, meaning the topics and questions were determined beforehand in a topic guide. In summary, the outline of the discussion was as follows:

- **Introduction.** The discussion leader gave a short introduction on the outline of the discussion. He explained that the purpose of the discussion was to gain insight in opinions about using the app and that there were no right or wrong answers. The participants were informed that the session would be audio-recorded. After that, the participants introduced themselves and explained their family situation and composition of household. See table 1 below for details of the participants in each group.
- **Current app-use in context of health, exercise and food planning.** The discussion leader asked about what type of apps the consumers were already using. For what purpose did they use them? And were they familiar with using apps to change a certain type of (health) behaviour?
- **Evaluation of experiences with specific app.** For this part the discussion leader focussed on the app that the consumers tested over the past three weeks. How did participants experience using the app? What were positives and negatives? The discussion leader encouraged consumers to give their opinion, even when they were the only person having that opinion. In what situations did they mainly use it? Did they use the app during the full period of three weeks? Would they recommend the app to their friends and family?
- **Effects on behaviour.** The last part of the discussion was about the effect of the app on behaviour. Did features of the app help participants in planning their groceries and meals? Did usage of the app become part of their daily routine? In the end, did they feel like they wasted less food? And if not, what features should the app have in order to achieve this?

In table 1, details on gender, age, family situation and household composition of the participants in each group are displayed. Two more participants dropped out in the period between the introduction session and the group discussion and unfortunately, they were both in group three. Therefore, the focus group discussion for app 3 consisted of seven consumers only. One of these drop-outs did fill out the evaluation questionnaire in the end (see chapter 2.3). So, the study had 28 participants, with N=27 during the focus group discussion.

Table 1. Participants in each focus group

Focus group Date Place	Gender	Age	Family Situation	Household composition
App 1 May 30 th 2018	F	65 years old	Widow, children	One-person
	M	42 years old	Engaged, children	Multi-person

11:30 – 13:00 Campus Wageningen 10 participants	F	65 years old	Married, children	Multi-person
	F	21 years old	Student	Multi-person (student house)
	F	50 years old	Married, children	Multi-person
	F	57 years old	Married, children	Multi-person
	M	31 years old	Living together, one child	Multi-person
	F	51 years old	Married, children	Multi-person
	F	42 years old	Married, children	Multi-person
	F	56 years old	Married, children	Multi-person
App 2 May 30 th 2018 13:30 – 15:00 Campus Wageningen 10 participants	M	59 years old	Married, children	Multi-person
	F	59 years old	Married, children	Multi-person
	F	56 years old	Married, children	Multi-person
	F	25 years old	Student	Multi-person (student house)
	M	42 years old	Single	One-person
	F	29 years old	Student	Multi-person (student house)
	F	50 years old	Married, children	Multi-person
	F	25 years old	Living together, one child	Multi-person
	M	52 years old	Married, children	Multi-person
App 3 May 30 th 2018 17:15 – 18:45 Campus Wageningen 7 participants	M	22 years old	Student, single	Multi-person (student house)
	F	57 years old	Married	Multi-person
	F	42 years old	Single	One-person
	F	59 years old	Married, children	Multi-person
	M	62 years old	Living together	Multi-person
		M	64 years old	Widower
	F	25 years old	Student	One-person

2.2.4 Questionnaire

In order to also retrieve quantitative data on the usage of the app, an evaluation questionnaire was designed and programmed in EyeQuestion software (Logic8). This questionnaire was sent out one day after the focus group sessions, to make sure the questions would not influence the consumers before the discussion. Participants received the questionnaire by e-mail and could access it through a unique link.

2.2.4.1 Content of the questionnaire

The questionnaire contained questions on the following topics:

- **Demographics** - education, income and composition of household. In addition, some data on the consumer's sustainable behaviour was collected according to Laureati et al (Laureati, Jabes, Russo, & Pagliarini, 2013). Consumers were asked to indicate how often (1=never, 2=rarely, 3=sometimes, 4=often, 5=always) they performed a series of sustainable and non-sustainable actions, for example to separate their waste, use public transport or consume exotic foods.
- **Evaluation of features** – Participants could indicate on 7 point scales, ranging from not at all interesting to very interesting, what they thought of the specific features per app. The answer categories per feature were as follows: 1=Not at all interesting; 2=Not interesting; 3=Slightly uninteresting; 4=Neither uninteresting, nor interesting; 5=Slightly interesting; 6=Interesting; 7=Very interesting. In case participants did not use the feature, they could pick option 8=Not used. Median ratings were calculated to summarise the outcomes for each statement. Participants were also asked to give an overall grade (score between 1-10) to the app and to give suggestions for improving the app.
- **Details on usage** – Participants could indicate whether they used the app alone, or together with more members of their household, on how many days during the test period and for how long per day (in minutes). Average scores were calculated per app to summarise the outcomes for the three apps.
- **Statements about the app** – To get insight into participants' experiences and how using the app changed behaviour, 12 statements were provided. Four statements were about participants' user experiences, four about the effect the app had on groceries and meals, and four about awareness in relation to food waste. Example statements are: *'I enjoyed using the app'*, *'Using the app cost me a lot of time'* and *'Using the app influenced the planning of my meals and groceries'*. Per statement participants could indicate whether they agreed on a 7-point scale: 1=Completely disagree; 2=Disagree; 3=Slightly disagree; 4=Neither disagree, nor agree 5=Slightly agree; 6=Agree; 7=Completely agree. To summarise the outcome for each statement, median ratings were calculated.

3 Results

3.1 Inventory ICT tools

One of the definitions of 'ICT Tools' is "A program that helps the user analyze or search for data. For example, query and report programs are often called query tools and report tools" (PC Magazine Encyclopedia). This is a very broad description. We have therefore focused on web-based tools, mobile apps and some smart devices.

The search for apps, websites and tools for this inventory has been done in 2016 and 2017. At that time, the apps were divided in different categories based on their main functionality. It is possible that the functionality of the app has changed in the meantime or that the app has even disappeared from the market. We indicate this where possible.

In the following list, the name of the producer of an application can be found behind the name of the app or website. The number in brackets refers to additional information in the document 'Inventory of Existing ICT Tools and Smart Technologies' (annex 2). This file provides more information about an app or tool. Finally, each line shows the platforms that support the app. In the following paragraph, we provide a link to the tool and a short description of its functionality.

In September 2017, a short search for Chinese apps and tools has been done together with a Chinese colleague. We found out that most food related apps and tools in China are about food safety and food security. We did not find any Chinese food waste related apps at that time.

3.1.1 Informative apps and websites

A large amount of apps and websites focus on informing the consumer on several aspects that can help reducing food waste. Most of these apps are more or less useful in the Storage phase. They focus on providing the consumer with information and advice on shelf life of perishable fresh products, on methods of preservation of fresh produce. Some of these apps are provided by research organisations, but most of these apps are developed by concerned consumers themselves. The source of the information and the correctness and completeness is in most cases neither clear nor guaranteed. As most of these tools are websites, we do not have accurate information of the usage of these tools.

- A Good Opportunity (Pensativa) [26] *Website, Android*
www.unabuonaoccasione.it/en
To avoid food waste, to save money, to produce less waste. An app where you can find – for more than 500 food - tips on where and how store food, the recommended portions, how to use leftovers, fruit and vegetable seasonality, how to shop.

- Bewaarwijzer (Voedingscentrum) [11] Website
www.voedingscentrum.nl/nl/mijn-boodschappen/eten-bewaren.aspx
Select a food item from a list and the tool shows how long it can be stored safely in a fridge, refrigerator or outside a fridge/refrigerator.
- Food Tank-The Think Tank For Food (Food Tank) [21] Website
foodtank.com/, foodtank.com/news/category/food-waste/
Global community for safe, healthy, nourished eaters
- Food Waste Calculator (Rhinososauruses) [34] Website
play.google.com/store/apps/details?id=appinventor.ai_jcforsy.FoodWasteCalculator
Gives insight in the cost of food spoilage.
- Koelkast in orde (ContentMoon) [69] Website
koelkastinorde.be/
In Flanders, the Roadmap Food Loss has been defined with numerous actions to reduce food loss by 15% by 2020. The possibilities to avoid food loss through the optimal use of the refrigerator is one of those actions. The site provides lots of tips to reduce food waste and recipes for leftovers.
- Stop verspilling (Unilever Inc.) [35] Android
play.google.com/store/apps/details?id=uk.co.torchb2b.waste.nl
With the application 'Stop wasting' professional chefs to the foodservice follow their waste production and analysis. The app shows you where and when you generate the most waste. Based on that you can save money and the environment.
- USDA Food Keeper (USDA Food Safety and Inspection Service) [22] Website
www.fsis.usda.gov/wps/portal/fsis/home
Gives storage advice about more than 400 food and beverage items. Find specific storage timelines for the refrigerator, freezer, and pantry, depending on the nature of the product. Gives cooking tips for cooking methods of meat, poultry and seafood products.

We also found websites of (government driven) organisations that inform people about food waste and try to motivate them to change their behaviour. Some provide the visitors with tools to test the consumer's behaviour or give helpful links.

- Dagboek Voedselverspilling (Milieu Centraal) [7] Website
www.milieucentraal.nl/media/2594/dagboek-voedselverspilling.pdf
Diary to measure food waste for 14 days
- FoodBattle (Milieu Centraal) [73] Website
foodbattle.nl/
*An online game to battle food waste together with friends, colleges, family of neighbours.
The website also contains recipes and information about food waste. Dutch only.*
- Milieu Centraal about food waste (MilieuCentraal) [5] Website
www.milieucentraal.nl/voedselverspilling
Website with information about food waste and food waste reduction. Dutch only

- Klieklopedia (SIRE / Voedingscentrum) [9] *Website*
www.klieklopedia.nl
Website with tips and recipes for left-overs. Dutch only
- Love Food Hate Waste (WRAP) [13] *Website*
www.lovefoodhatewaste.com/
Website with information about food waste and tips to prevent food waste.
- Voedingscentrum about food waste (Voedingscentrum) [10] *Website*
www.voedingscentrum.nl/minderverspillen
Website with information about food waste and tips to prevent food waste. Dutch only
- Weggooitest (Millieu Centraal) [6] *Website*
www.weggooitest.nl
Short test (several questions) to measure how much food you waste and what that costs in euro's and CO2. Tips about buying, cooking and storing food. Dutch only.

3.1.2 Reminder apps

A lot of apps focus on reminding the user on the expiry date of a food product, or on using a list of estimates of remaining shelf life of fresh produce to remind the user. Most of these apps have the possibility to show an inventory of the purchased products. Some let the user scan the barcode of the product, others let the consumer select food products from a list.

None of these apps seem to have a large installed base. Most of the times, the source of the information on the remaining shelf life used in these apps is unclear. Since the initial state of the food product is not known, we have doubts about the added value of these tools.

If an app with reminder function also has functionality for shopping lists or meal planning, you will find them in the sections for those apps. Some apps evolve over time, so it is also possible that an app that is listed below, now has become an app with more or less functionality.

- BEEP - Expiry Date Barcode Scanner (GPworks) [76] *Android*
www.beepscan.com
Scan the barcode of a food product, input the expiry date. The app will give a notification reminder a day, week or month prior to the expiry date. The database used for recognition is filled by the users of the app.
- Date Limite+ (Loïc SENCE) [28] *Apple IOS*
itunes.apple.com/fr/app/date-limite+/id504412027?mt=8
You can enter bought food by taking a picture and scanning the barcode, enter best before date. The app gives an alert near best before date. The apps also provides a shopping list and an inventory of bought food.

- Expired & Grocery Monitor (Y&A China) [54] *Android*
play.google.com/store/apps/details?id=com.material.management
This is an expired items housekeeper to help you. Integrated with a shopping list and statistics.
- Expiry Date App (EWK GmbH) [55] *Android*
play.google.com/store/apps/details?id=de.ewk.technologie.verfallsdatum
Keeps track of all your groceries, with reminder on which product will expire first.
- Expiry Reminder (CBWorkshop) [56] *Android*
play.google.com/store/apps/details?id=com.cbworkshop.expiryreminder
Keeps tracks of different types of items that has an expiry date such as food, medicine, documents.
- Expiration Alarm (MND Apps) [52] *Android*
play.google.com/store/apps/details?id=com.minudev.expiration
Expiration Alarm reminds you of the expiration dates of your products
- Food Expiration Track (TouchSi Co., Ltd.) [53] *Android*
play.google.com/store/apps/details?id=com.touchsi.keepemfresh
Food Expiration Track reminds you of the expiration dates of your products.
- Food Expiration Date (OcApps) [50] *Android*
play.google.com/store/apps/details?id=com.ocapps.nomorewastes
Information about expiration of foods with reminder function
- Food 'n Stuff (Sirius Cybernetics Corporation) [51] *Android*
play.google.com/store/apps/details?id=com.scc.stock
Inventory for foods with reminder function on expiration
- FoodLocker (Christian Ghelardoni) [29] *Apple IOS*
appadvice.com/app/foodlocker/659530548
The user can enter bought food with best before date and gives an alert near best before date.
Discontinued
- Food Saver (Salvatore Vivolo) [23] *Apple IOS*
itunes.apple.com/us/app/food-saver/id894059283?mt=8
Food Saver organizes your food and keep expiration dates under control, to save money and avoid any waste.
- Food Storage Helper (ybgallery) [57], *Android*
play.google.com/store/apps/details?id=com.ybgallery.yb.foodstoragehelper
Track amounts of food storage and lets you know where everything is and when it expires.
- Food Storage Assistant Pro (DzignStudio) [58] *Android*
play.google.com/store/apps/details?id=air.com.dzignstudio.FoodStorageAssistantPro
Helps you manage and track your family's food storage inventory.

3.1.3 Food sharing apps

3.1.3.1 Consumer to consumer

There are several initiatives for sharing leftovers and surplus of food between groups of consumers. These initiatives build communities of people in the same area, willing to share food and reduce waste.

We've seen several websites and apps active in England, Germany, Austria, Spain, India and the USA, building communities mostly in bigger cities. Some seem to be successful according to the number of installations.

- Foodsharing (Raphael Wintrich) [36] *Website, Android*
www.foodsharing.de
German website for sharing your surplus of food with people in your neighbourhood. Makes use of an android app.
- NO FOOD WASTE (Boomit Solutions) [38] *Website, Android*
www.nofoodwaste.in/
No Food Waste is a mission to end food waste and hunger to make the "World Hunger Free". No Food Waste recovers surplus food from weddings, parties and functions and donate it to needy and hungry people. Most of the activities are in India.
- OLIO - Food Sharing Revolution (OLIO) [40] *Apple IOS, Android*
olioex.com
Connect with neighbours and local shops so that surplus food can be shared. Supported by a website that gives some statistics on the amount of food shared.
- Ratatouille (Georgia Marena) [27] *Apple IOS*
www.ratatouille-app.com
Ratatouille helps you find someone who will be happy to take your extra food.

3.1.3.2 Retail to consumer

Some supermarkets in The Netherlands inform customers about food items that almost reach their 'Best before date' and give discounts on these products.

Some other apps are used to order takeaway meals from local restaurants, bakeries and collect food that would otherwise go to waste. These apps use the GPS of the mobile device to see if participating restaurants or bakeries are in the neighbourhood.

- Afgeprijd (Gemoro b.v.) [41] *Apple IOS, Android*
www.nofoodwasted.com
This app keeps you informed about foods on sale because of ending remaining shelf life, in your local supermarket
- Too Good To Go (Too Good To Go) [45] *Apple IOS, Android*
toogoodtogo.co.uk
Order takeaway meals from local restaurants, cafés and bakeries of food that would

otherwise go to waste.

- RedMaden (Martin Bay ApS) [46] *Apple IOS, Android*
www.redmaden.dk
Danish initiative to receive offers from restaurants in the local area when they have food left over at closing.
- Rekub (IntoApps) [71] *Apple IOS, Android*
www.rekub.be
Belgian initiative that keeps you informed about foods on sale in your local supermarket

3.1.3.3 Consumer and retail to charity

Many local charity initiatives are popping up to donate a surplus of food to a selected charity organisation.

- Foodcloud (Foodcloud) [66] *Website*
food.cloud/
Supermarkets, farms and food manufacturers can use FoodCloud to let charities know about surplus food available for donation. The organisations can see the exact volume and type of food being offered, and arrange a pick-up time. FoodCloud also acts as an intermediary, collecting food and storing it at one of its three Irish hubs, before redistributing the produce to homeless shelters and other groups
- Food Share (Mindnotix Software Solutions) [37] *Android*
play.google.com/store/apps/details?id=com.mindnotix.nofoodwaste
The user can share the food to available registered trusted Charity. User can find Charities near to the location and can deliver them self
- Food We (VZW Foodwe) [67] *Website*
www.foodwe.be
Belgian initiative to donate food or food items that cannot be traded by the traditional trading channels to charity institutions.
- Leket Israel (Leket Israel, the National Food Bank) [24] *Website*
www.leket.org/en/
The Leket Israel application enables you to find the nearest non-profit agency servicing the needy to bring your excess food from a party, conference, event etc. to be immediately distributed to those who need it most. Help prevent unnecessary waste as it's not only a good deed but it's good for the environment.
- Waste No Food (wastenofood.org) [14] *Apple IOS, Android*
www.wastenofood.org
Waste No Food is a registered non-profit that provides a web-based "marketplace" allowing excess food to be donated from the food service industry to qualified charities that work with the needy.

3.1.4 Planning apps

Many apps help consumers with some kind of planning. We found a lot of shopping list apps, often with functions like inventory, meal planning or recipes. It is likely that an app with more functionalities is more useful for consumers than single functionality apps, but the app may also become less user-friendly, because more input is needed. Most of these apps have a big installed base.

3.1.4.1 Shopping list apps

Apps helping the consumer with the daily planning of their shopping needs are among the most popular apps according to the number of installations. The range start with apps with a simple list functionality to apps with multiple shared shopping lists which you can use together with our family.

- Bring! Shopping List (Bring! Labs AG) [48] *Android, Apple IOS*
www.getbring.com
App that help with sharing of shopping lists and shopping planning.
- Grocereer (FJ) [62] *Android*
play.google.com/store/apps/details?id=fj.sssss
Save grocery items to your inventory. View grocery items in your pantry and see when they are expiring. Automatically generate your personalised grocery shopping list.
- Shopping List Voice Input (TK Solution) [47] *Android*
shopping-app.net
Manage and share shopping lists with voice control.
- Shopping List (Kiwi3) [61] *Android*
play.google.com/store/apps/details?id=com.shoppinglist
Multiple shareable shopping lists. Will give you suggestions as you type.

3.1.4.2 Integrated apps

These are the apps with the most comprehensive functionality. Beside a inventory with reminder function, they all have shopping list functionality, recipes and other planning tools like a meal planning. These apps seem to be popular according to the number of installations.

- CogZum (Ivo Dimitrov) [72] *Apple IOS*
cogzum.com
An assistant for optimal grocery shopping while helping to avoid food spoilage at the same time.
Smart shopping list, track bought food for end-of-life, 'game' for reducing food spoilage
- Eat This Much - Meal Planner (Eat This Much, Inc.) [60] *Apple IOS, Android*
www.eatthismuch.com
Manages diet goals and makes food planning with recipes based on your wishes. Also

makes use of shopping lists en a growing food database.

- Food Planner (MiniMobile) [49] *Apple IOS, Android*
www.foodplannerapp.com
Popular app for planning meals with shopping lists, recipes, inventory
- Fridgely (Jump Space Apps) [74] *Apple IOS*
fridgelyapp.com/
Reminds when food is going to expire. Shows recipes based on food you already have. Scan barcode to add food and estimate an expiration date. Put food items on a shopping list.
- Frigo App (Stephane Nguyen) [31] *Apple IOS*
www.friogoapp.com/
User can enter bought food with best before date. The app will alert near best before date. It has recipes based on content of fridge and can automatically generated shopping list based on recipe and content fridge.

3.1.5 Recipe sites and apps

There are numerous sites and apps which provide the consumer with all kinds of recipes. They are commercially driven or run by food loving consumers. We only list the ones that make use of leftovers or an inventory of what is already in your fridge to prevent food waste. The planning apps mentioned before often offer recipe services also.

- Empty The Fridge (Empty The Fridge) [65] *Website*
emptythefridge.be
A Belgian website with tips and recipes for perishable food ingredients
- Frigo Magic, recette facile (FrigoMagic.com) [68] *Website, Android, Apple IOS*
www.frigomagic.com/
This app provides consumers with recipe ideas for meal with ingredients already in your fridge.
- Home-Time (Jay Juillet) [33] *Website, Android, Apple IOS*
www.hometime-app.co.uk/
With Home-Time a user can keep track of what's in their kitchen, and have meals suggested based on what users have in stock
- Love Your Leftovers (Holroyd City Council) [25], *Apple IOS*
itunes.apple.com/au/app/love-your-leftovers/id654877641?mt=8
A community to share the best waste reduction recipes. Part of the love food hate waste program lovefoodhatewaste.nsw.gov.au.
- Slim Koken (Voedingscentrum) [59] *Android, Apple IOS*
play.google.com/store/apps/details?id=nl.voedingscentrum.slimkoken&hl=nl
This app gives recipes with right proportions and the ability to use left overs in the recipe

3.1.6 Supermarket apps

Especially in The Netherlands, supermarkets provide their customers with apps, with the intention to build a better customer relationship. Most of these apps combine recipes with a shopping list and other functionality. These are not specifically intended to be used as food waste reduction apps, but can function as such. Supermarket apps like 'Appie' and 'Jumbo' have a huge number of installations in The Netherlands; probably even more than the number of installations of all other apps together.

The apps with the largest installed base are:

- Appie (Albert Heijn) [63] *Website Android Apple IOS*
www.ah.nl/appie-app
App offered by a Dutch supermarket to help customers shopping in their shops or online. Included are a shopping list, special offers, best route in shop function and a comprehensive recipe database.
- Hallo Jumbo (Jumbo Supermarkten B.V.) [64] *Website, Android, Apple IOS*
www.jumbo.com/content/seizoen/jumbo-app
This app offers recipes, special offers, shopping list and online shopping for customers of Jumbo Supermarkets

3.1.7 Devices

Beside software solutions, also hardware devices can be used to reduce food waste or to help consumers with food planning related issues. For example, smart bins with weight sensors may form an interesting tool to measure actual food waste behaviour in households (Lim et al., 2017). The devices we found are very sophisticated, but this comes with a price. Whereas all software solutions are for free or at very low cost, these devices are pricy to very pricy. We do not have an indication of the use of these devices.

- Family Hub Refrigerator (Samsung) [3]
www.samsung.com/us/explore/family-hub-refrigerator/overview
*Display your calendar, notes, recipes, weather. Look inside remotely with a built-in interior camera. Create shopping lists and order groceries. Stream entertainment, including news, music, and TV.
Presented on the CES (consumer electrics show) 2016*
- Vacuvita Vacuum Storage (Vacuvita) [4]
www.vacuvita.com/
Vacuvita produces boxes and bags to store food and leftovers under vacuum. An Apple or Android app helps to keep track of the stored foods
- BinCam (Project, not available on the market) [75]
https://designandwellbeing.com/papers/bincam_INTERACT.pdf
BinCam is a social persuasive system to motivate reflection and behavioural change in the food waste and recycling habits of young adults. The system replaces an existing kitchen bin and automatically logs disposed of items through images captured by a smart phone installed on the underside of the bin lid. Captured images are uploaded to a BinCam application on Facebook where they can be explored by all

users of the BinCam system.

- Pervasive Fridge (prototype, not available on the market) [77]
<https://www.semanticscholar.org/paper/The-Pervasive-Fridge-A-Smart-Computer-System-Food-Rouillard/afb3be29288e835a4265bcd33244572ef0314363>
The "Pervasive Fridge" prototype allows users to be notified proactively, when a food arrives to its expiration date. Speech and image recognition are also integrated in the prototype. This system combines various resources in order to scan barcode, identify and store data related to products, with a smartphone. Later, notifications are sent to consumers by mail, SMS and pop-up, to avoid uneaten food loss.

3.2 Focus group study

In this chapter, the results of the focus group study will be described. First, the participant characteristics will be described, then the results from the focus group discussions, and lastly, the results of the evaluation questionnaire. The first part is about the whole study population (all three groups combined) and after that, the main results per group (*i.e.* per used app) will follow.

3.2.1 Demographics and sustainability behaviour of participants

Of the 28 study participants, 19 were female (68%) and 9 were male (32%). The mean age in the study sample was 45.1 ± 15.2 years old, ranging from 22 to 65 years old. A small part of the group (14%) had used a certain type of food-planning-app in the past. The largest part of the group had a higher or university education (78.6%). The majority (39.3%) had an above-average income and lived in a 1-2 person household (50%).

Group 1 consisted of 10 consumers (8 female; 2 male), with an average age of 48.8 years. Ten consumers (7 female; 3 male) tested app 2 (group 2). Their mean age was 43.1 years. A total of eight consumers used app 3 (5 female; 3 male). The mean age in this group was 43.1 years.

The results on sustainable behaviour of the consumers are reported in table 2. As shown, recycling was the most frequently reported sustainable action (71.4%), followed by 'buying seasonal products (57.1%)' and 'buying regional food (53.6%)'. The most frequently reported non-sustainable action was eating meat: 53.6% of the consumers indicated to perform this action often or always. The other unsustainable actions, were the least frequently reported actions (both 3.6%), except eating exotic foods: 35.7% of the participants reported to do this action often or always.

Table 2. Percentage of answers to the questions on sustainable actions of Laureati et al. In the last column, the sum of the percentages of answers "Often" and "Always" is reported. S = sustainable action; NS = non-sustainable action.

Action	Never	Rarely	Sometimes	Often	Always	Sum: Often+ Always
Eating meat (NS)	7.1	14.3	25	42.9	10.7	53.6
Buying local foods (S)	7.1	42.9	35.7	7.1	7.1	14.2
Buying seasonal products (S)	0	14.3	28.6	46.4	10.7	57.1
Recycling (S)	3.6	14.3	10.7	32.1	39.3	71.4
Saving electric energy (S)	14.3	17.9	21.4	7.1	39.3	46.4
Buying regional food (S)	14.3	39.3	25	17.9	3.6	21.5
Avoiding GMO's food (S)	57.1	17.9	3.6	10.7	10.7	21.4
Avoiding preservatives in food (S)	53.6	28.6	14.3	3.6	0	3.6
Using public transportation (S)	17.9	32.1	39.3	7.1	3.6	10.7
Eating organic food (S)	10.7	50	14.3	17.9	7.1	25
Leaving the lights on if you are not present (NS)	46.4	35.7	14.3	3.6	0	3.6
Mixing waste (NS)	75	7.1	14.3	0	3.6	3.6
Buying clothes from ethical fashion (S)	60.7	32.1	3.6	0	3.6	3.6
Buying Fair Trade products (S)	17.9	39.3	32.1	10.7	0	10.7

Eating exotic food (NS)	10.7	46.4	7.1	32.1	3.6	35.7
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3.2.2 Current use of apps (Focus group discussion)

At the beginning of each focus group session, the discussion leader made an inventory about current use of apps in the context of health, exercise and food planning per group. In each of the three groups, a number of respondents did use apps to help them change a specific personal behaviour, mainly around the topics of daily tasks such as cleaning, shopping lists, to-do lists, exercising, sports and movement, and food and liquid intake. From what was discussed, we can distinguish four motivational drivers of why consumers use these type of apps:

- To create more **awareness** about actual behaviour. The first step in wanting to change a habit, is to get insight into the current behaviour.

'It can be very confronting to see what you really eat.' (group 2)

- To serve as an **'external conscience'**. Monitoring food intake and activities, gently forces consumers to be honest to themselves, it is a sense of 'confessing'.
- To help them **remind** to complete certain tasks in an easy and fun way.
- For some, the quantification of personal behaviour is even **'addictive'**.

'It can be life-altering. My wife has a Fitbit. She gets out of bed earlier now, she walks to the store to get more points. She gets notifications when she needs to move.' (group 2)

3.2.3 Evaluation experiences with specific app (focus group discussion)

In each session, consumers were asked to write down a few positives and negatives about the app they had used during the three-week test period. The positives and negatives were discussed with the whole group and written down on a flip-over.

3.2.3.1 Group 1

Positives

In group one, it was rather difficult for the consumers to come up with positives about the app. They immediately wanted to name negatives, but the discussion leader encouraged them to first come up with some positives. Eventually the consumers mentioned the following :

- The app contains a functionality to repeat the week and therefore there are less choices to make.
- In the planning of meals, it creates an overview of necessary items to buy.
- The dashboard or home screen has a simple and clear lay out.
- The ability to enter the costs of a meal creates insight.
- The stock keeping option can help as a reminder - when you are in a store - to avoid buying products that are already in home.
- There is an ability to link products and prices to different supermarkets

'You can choose the butter from Albert Heijn but also from Aldi. It's good for your overall budget.'

Negatives

When the consumers could start mentioning their negatives, everyone started talking. It seemed like they were frustrated and wanted to get it off their chest. The following items were mentioned:

- The main issue was that the app was not user-friendly and not intuitive.
 - 'After 3 weeks, I still don't know how to use it.'*
- The consumers had to enter too much data and information for which they got too little in return.
- There were a lot of advertising banners, which annoyed the consumers.
- The menu structure was difficult and it was easy to get lost in the app.
 - 'Maybe it has a lot of options, but it is too much hassle to find out what they are.'*
- The use of the English language was complex for some.
- The recipes and ingredients were all based on American products and not tailored to the Dutch taste and product preferences.
- For access to recipes, a week plan and an ad-free version, a paid subscription was needed. This was a barrier for the consumers.
- Furthermore, the app contained no visuals.

'When I buy a cook book I get triggered by the images. You get the story behind the recipes. That's missing here.'

Effects on behaviour

The current performance and user interface of the app did not encourage any change in behaviour. Nevertheless, consumers could imagine that the current functionalities can increase the awareness and thus stimulate a different behaviour, if only they would be easy and intuitively to use. The functionality to plan could lead to less waste, and using and sticking to a shopping list can decrease impulse purchases. Finally, most consumers thought that listing expiry dates can lead to using products before they turn bad.

Overall conclusion of consumers

App number one scored extremely bad on user-friendliness, which led to a lot of frustration and confusion among the users. This creates an extremely high barrier for usage of this app, blocking any potential positive effect on behaviour. Although the functionalities in the app are seen as positive and can be useful, the execution made it impossible to have any influence on daily behaviour.

'It should be really easy to use, this app isn't.'

3.2.3.2 Group 2

Positives

Consumers came up with the following positives:

- The app looks complete and user-friendly.
- Products are depicted with icons, there is no need to read and that is time-saving.
- Making a shopping-list can help participants to buy less, because it is easier to stick to a list.

'If I don't make a list, I just grab stuff. Now you're more conscious about it.'

- There is a possibility to share with others that also have the app, this helps to avoid buying products double.
- The advantage of making multiple lists is to create overview and clarity.
- The app has a 'recently used' feature, this is a short cut to select frequently bought products.

Negatives

- Some participants were bothered by all the notifications. When lists are shared, users receive a notification each time a product is added to the list.
- The app is not intuitive enough, it takes time to understand how to fill everything in, especially the quantities.
- The app did not contain a stock list, so basically the app is just a shopping list.

'You do not see what you already have at home.'

- For some, the app did not fulfil a real manifested need as there are too many other ways to make a shopping list (pen/paper, blackboard, other note-taking apps on phone).

'I saw no need, there are so many ways to make a shopping list.'

Effects on behaviour

For the majority, the usage of the app had not resulted in a noticeable change in behaviour. As its main function is 'merely' a shopping list, it did not actively stimulate respondents to think about food planning on a broader scale.

'I used it the first few days, but then I forgot about it.'

'I got some insight into my shopping pattern, it made me more aware, but there's not a real change in what I do.'

'This app does nothing for reducing the wasting of food.'

Only a single respondent indicated that the raised awareness of what is bought, led to a change in behaviour.

'I noticed I buy less. I haven't used the app for a week now, but I only buy what I finished.'

Overall conclusion of consumers

App number two has a rather complex navigation, which decreases the user friendliness and thus the motivation to frequently use the app.

'It should be much easier, like with a scan or QR-code.'

Since there are so many other ways to make a shopping list, there was no perceived added value or need to use this application by most of the consumers.

3.2.3.3 Group 3

Positives

- The app registers stock and the shelf life of products and gives notifications of products that need to be finished. This way there is no need to think or worry about it.

'The app told me the grapes I bought needed to be eaten, very handy.'

- This was especially convenient for perishable products, to know when products need to be finished can reduce waste and spillage.
- The overview of stock gave participants a better insight for in the supermarket what to buy and what not.
- The app is very suitable for using your left-overs. The reminders help to diminish throwing products away.

Negatives

- A lot of information needs to be entered when starting to use the app. In addition, the app lacks a clear instruction (or at least it is difficult to find).

'The re-use function I didn't understand at all.'

- Some participants indicated that the use of the app was not very intuitive.

'In the beginning, I didn't understand what I needed to do.'

- There were too many notifications, this takes too much time and attention during the day.
- The entry of products was not easy and only possible by weight and not by quantity.

'How do I know how much 4 apples weigh? I want to put in: 4 apples, not xx grams.'

- The feature of creating reports on eaten and thrown-away food in the app was not seen or noticed by most consumers, it seemed to be too hidden within the app structure.

Effects on behaviour

This app did create an awareness of products in stock and their shelf life, which is the necessary first step to make a change in behaviour possible.

'It makes you aware of what products you have at home. It made me buy less, because I first wanted to finish my stock.'

'I recommended it to others, especially for left-overs. If you enter the date, you throw away less.'

'I throw away less, since I used the app and as such it also saves me money. It made me be more conscious about what I throw away.'

'I still use it to enter the shelf-life of the products I bought.'

Overall conclusion of consumers

Although the app is not very self-explanatory and has functions that are quite difficult to understand or use, the idea behind the app is appreciated. It creates insight and awareness in the food products bought and their shelf life. This information allows respondents to concretely undertake actions: finish products before their due-date. The added value is mainly found in the category of perishables. For ambient, long-lasting products, the app is considered less relevant.

'This is a useful tool to manage your stock and the shelf life of your products, so you don't have to throw anything away.'

3.2.4 Results of the evaluation questionnaire

Consumers rated the specific features per app on a 7-point scale ranging from 1=not at all interesting to 7=very interesting. Subsequently, they provided details about how and how often they used the app during the home-use test, and gave an overall score for the app. Finally, consumers gave suggestions for improving the app.

3.2.4.1 Evaluation of the features

Table 3 shows the results for the evaluation of the specific features of each app. App 1 had a meal planner, a shopping list, recipes and an inventory list. The meal planner feature was rated the highest (4 out of 7), with the shopping list following closely (3.5 out of 7) and the inventory list the lowest (1.5 out of 7). The recipes feature scored low (2 out of 7).

The main and only feature of app 2 was a shopping list, with the possibility to share this list with others. The regular shopping list features was rated higher (3.5 out of 7) than the shared shopping list (1 out of 7) feature. The majority of the consumers in this group (7 of the 10 participants) did not share their shopping list, so this median score is based only on the three consumers that did use it.

App 3 had the following features: a (shared) shopping list, inventory list, and journals on food eaten and food wasted. The inventory-list was rated the highest (5 out of 7) and the shared shopping list received the lowest score (1.5 out of 7; was used by only two participants). The journal feature received a 3 (out of 7).

Table 3: Median scores per app for interestingness of the app features on 7-point scale (1=not at all interesting, 7=very interesting).

Features	App 1 (N=10)	App 2 (N=10)	App 3 (N=8)
Meal planner	4.0	-	-
Shopping list	3.5	3.5	3.5
Shopping list (shared)	-	1.0 *	1.5 *
Inventory list	1.5	-	5.0
Recipes	2.0	-	-
Journals (monthly report)	-	-	3.0

* N=3 for app 2 and N=2 for app 3, because feature was not used by all participants of the group

Overall, the inventory list of app 3 is the only feature that is perceived as being interesting by the consumers, whereas this was not the case for the inventory list in app 1. A meal planner (app 2) and shopping list (all apps) are rated neutrally on interestingness. A shared shopping list (app 2 + 3) and recipes are not perceived as interesting by this group of consumers.

3.2.4.2 Details of usage per app

The details of how and how often the participants used the app during the home-use test, are shown in table 4. App 1 and app 3 were used on 13 to 15 days of the 21 days of the 3-week period. This was more often than app 2, which was used on 9 days of the 3-week period. The number of minutes spent per day was highest for app 1 (25 minutes), whereas participants used app 2 and 3 for 6 to 10 minutes per day respectively. For all three apps, most participants used the app alone (70-100%); two participants used app 1 with others and three participants used app 2 with others. The overall grade was highest for app 3, with an average grade of 5.4. App 2 was close to that with an average grade of 5.2, whereas app 1 received the lowest overall grade: 3.1.

Table 4: Usage details and overall grade per app (average)

	App 1 (N=10)	App 2 (N=10)	App 3 (N=8)
Days used (out of 21)	13.4	8.6	14.6
Time spent per day (minutes)	24.5	5.8	9.8
Alone or with others (such as partner or children)	8 participants alone, 2 with others	7 participants alone, 3 with others	8 participants alone, 0 with others
Grade (1-10)	3.1	5.2	5.4

3.2.4.3 Suggestions for improvement of the apps

Below are the most important suggestions that consumers gave for improvement of the app, listed per app:

- Entering data in the app should be less time-consuming (app 1).
- There should be suggestions for recipes with food-leftovers (app 1).
- Improve the user-friendliness. Navigating through the app is rather complicated (app 1).

- An inventory feature should be added (app 2).
- Add a feature that shows when products will expire (app 2).
- Sharing the shopping lists should be much easier (app 2).
- There should be clear start-up instructions (app 3).
- Entering products should be easier; barcode scanner for example (app 3).
- Use less notifications (app 3).

3.2.4.4 Statements per app

Participants rated the 12 statements about user experiences, effect on meals and groceries and effect on awareness on a 7-point scale, ranging from completely disagree (1) to completely agree (7). The results for each of these 12 statements are shown per app in table 5.

App 1 was rated extremely low on the user experiences items (median score 1.5 for user-friendliness, 1.5 for enjoying using the app and score 1 for recommending the app to friends). In addition, consumers thought using this app was time-consuming (6 out of 7). Compared to app 1, app 2 was rated higher on the user experience items. User-friendliness was rated 6 out of 7 and consumers experienced it as less time-consuming (2 out of 7). Still, they would not recommend the app to their friends or family (2 out of 7). App 3 received, just as app 1, low scores on user-friendliness (2 out of 7), enjoyment of using the app (3 out of 7) and recommending the app to friends or family (2 out of 7). Using app 3 was also perceived as time-consuming (5.5 out of 7).

The scores for effects on groceries and meals were low in all three groups, especially in group one. Highest scores were found for app 3, but these were still below the midpoint of 4. These data suggest that the respondents in this study did not perceive that the apps influenced their grocery or meal planning.

Using app 1 did not raise awareness for food waste (1.5 out of 7) or increase motivation to reduce food waste (1.5 out of 7). The same holds for app 2, using the app did not increase consumers' interest in food waste (1 out of 7), nor did it increase motivation to reduce food waste (1 out of 7). The use of app 3 seemed to slightly affect awareness and motivation amongst the participants. They indicated that using the app raised their interest about food waste (4.5 out of 7), that it made them more aware of food waste (5 out of 7) and that it increased their motivation to reduce food waste (4.5 out of 7).

Table 5: Median scores per app for the 12 statements on 7-point-Likert scales (1=completely disagree, 7 =completely agree)

	App 1 (N=10)	App 2 (N=10)	App 3 (N=8)
User experiences			
The app was user-friendly	1.5	6.0	2.0
I enjoyed using the app	1.5	4.0	3.0
Using the app was time-consuming	6.0	2.0	5.5
I would recommend the app to my friends and family	1.0	2.0	2.0
Effect on groceries and meals			
Using the app influenced my groceries planning	1.5	2.0	2.5
Using the app influenced the amount of groceries I purchased	1.0	1.0	3.0
Using the app influenced the type of groceries I purchased	1.0	2.0	3.0
Using the app influenced the type of meals I prepared	1.0	1.0	2.0
Awareness			
Using the app raised my interest about food waste	3.0	1.0	4.5
Using the app led to conversations about food waste in my household	1.5	1.0	3.5
Using the app made me more aware of food waste	1.5	1.0	5.0
Using the app increased my motivation to reduce food waste	1.0	1.0	4.5

4 Main findings

In this chapter, we combine the results from literature, our inventory of ICT tools, and the focus group study (discussions & questionnaire) to provide an answer to the question whether apps (ICT tools) can help to reduce food waste in consumers.

The limited amount of scientific research that is currently present gives some indications that apps can help in raising consumer awareness regarding food waste, but the effects on food waste behaviour are unknown.

A literature search resulted in twelve papers focusing on apps in relation to consumer food waste behaviour, mainly conference and design research papers. This indicates that the scientific research in this area is in an explorative stage. A few studies indicate that apps can help in raising consumer awareness for food waste (Farr-Wharton et al., 2014a; Farr-Wharton et al., 2014b; Lim et al., 2017; Nguyen et al., 2015), but actual effects on food waste behaviour were not found or not measured. Several studies focusing on apps in relation to health behaviour change have found significant effects in the direction of the targeted health behaviour (40 to 74% of studies in (Schoeppe et al., 2016) and (Zhao et al., 2016)). However, the studies were often small, many studies did not use a control group, and the sole effect of the app is unclear. So, apps seem to be promising for changing consumers' health behaviour and may have potential to change food waste behaviour of consumers, but rigorous research on the effectiveness of apps on changing consumer behaviour is lacking (Hoem, 2017; Schoeppe et al., 2016; Zhao et al., 2016)(Hoem, 2017; Schoeppe et al., 2016; Zhao et al., 2016). In order to draw conclusions about actual effectiveness, long-term, sufficiently powered trials that measure the direct effect of apps (ICT tools) on consumer's food-waste related behaviour are needed.

The inventory showed that most apps cover the areas of planning and storing of food, in particular on announcing product expiration; followed by apps in the areas of provisioning, preparation and disposal of food; fewer apps are available in the area consumption of food.

There are numerous apps designed to assist consumers with their everyday practices around handling food and food waste. From our inventory, we found that most apps cover the areas of Planning and Storing of food. In the areas of Provisioning, Preparation and Disposal of food also a wide range of apps is available. In the area of Consumption of food, fewer apps are available.

We found that a large group of apps give consumers a warning when food is about to reach its *expiration date*. The apps differ in the way they obtain product data, for example by scanning a barcode or by manual entry. Scanning the barcode of a product can only work in combination with a comprehensive and well-maintained database. The quality of this database is often a problem; usually it is only applicable for one country, not complete and depending on users to keep the data up-to-date. The reliability of the data is therefore not guaranteed. Determining the initial quality of fresh food

products at the time of purchase is another problem with the use of these apps. This initial quality is mostly not known and has to be estimated by the consumer. Reminding a consumer of the expiration date as the only functionality of an app we do not consider very useful.

There are also many *food sharing* apps. Often these are based on building communities, but sometimes donating to charity organizations is the goal. In some countries, these apps are quite popular. They can motivate a group of consumers and may help them to prevent food waste.

We only found a few apps and sites that focus on the use of *leftovers* in recipes. Keeping track of the inventory is always an issue. Usually it takes too much time for the consumer to enter all products correctly in the inventory and to keep track of the use of the food products. We did not find any app that can replace an ingredient in a recipe with an ingredient that is available in the inventory of a consumer.

Apps and websites with shopping list functionality only indirectly reduce food waste, but seem to be the most popular applications.

Although apps that offer *shopping list* functionality strictly do not count as food waste apps, they offer functionality that gives consumers an opportunity to better plan their purchases and therefore throw away less food. If this functionality is combined with meal planning and recipes, the app can be a good tool for reducing food waste. Although we do not have numbers about the use of the apps, we do see that apps that have a functionality for shopping lists or recipes are installed more often than apps with only functionality to remind people about product expiration or available left-overs. Although there are a lot of recipe apps, there are only a few recipes apps that use leftovers as a base or as ingredients in a recipe.

In The Netherlands, we see that every supermarket offers its own app for customer relationship purposes. Some of these apps can be seen as potentially helpful in reducing food waste, because they provide a good planning tool and a wide range of scalable recipes.

The most important limitations of current apps are: limited functionality, infrequent updates, incomplete information from unknown sources, and suboptimal usability. Interaction between apps and shared access to data would boost the usability of apps for food waste reduction.

Many apps available in the app stores have been created by tech-savvy individuals. These apps usually have limited functionality and are not updated frequently. The majority of these apps lack maintenance from the developers. The source of the data used is not clear and most of the time, the information is not complete and not kept up-to-date. Still, these apps can be useful for some consumers if they are aware of the shortcomings, and can work around them.

On the other hand, we see apps build by of for commercial companies. Most of the times these apps are better maintained, have a wider functionality and have more installs.

The more functionality an app offers, the more complex the app becomes. Usability is often a problem with apps with a lot of functionality. Combining information from different apps will be an enormous boost in providing better information and functionality to consumer (Bizer, 2009). This would require interfaces between apps and shared access to data sources, all based on open standards. At this moment, we do not yet see initiatives in this direction.

Consumers seem to be open and interested in apps that help in reducing food waste behaviour, but many did not perceive a clear need to use such an app and the gains from using the app did not outweigh the investment.

The focus group discussions showed that the respondents are open to, and interested in, apps that make them more aware of their food purchase, planning and usage. They agreed that such apps could make their daily tasks of grocery shopping, stock-keeping and usage of their purchased foods easier. However, at the same time, the majority indicates they do not perceive a clear manifest need to use these apps. Many say they are not wasting much food and, consequently, lack the intrinsic motivation to use these apps for this purpose. In addition, the pain was bigger than the gain: Respondents felt that they had to invest much more (in time, energy and stamina), than what they got out of the app (convenience, insights and engagement).

The three apps used in the study scored rather low on user-friendliness, would not be recommended to friends or family, and showed no effect on reported food-waste related behaviour, although one app showed small increases in food-waste awareness.

The features of app 1 were a meal planner, shopping list, inventory list and recipes. The focus group discussion and evaluation questionnaire showed that this app scored extremely bad on user-friendliness and was perceived as time-consuming. This created a high barrier for use, and no effects were seen on awareness, motivation or participants' shopping behaviour, or meal planning. Nevertheless, they could imagine that the current functionalities can increase awareness and help to change food-waste related behaviour, on condition that the app was easy and intuitive to use.

App 2, with a shopping list that could be shared, scored relatively high on user-friendliness and was not time-consuming based on the evaluation questionnaire. Still, some participants found it not intuitive enough. Since the main function of the app is 'merely' a shopping list, the participants did not see the added value as there are other ways to make a shopping list. In general, no changes in awareness or shopping and meal planning behaviour were reported.

App 3 had a shopping list, which could be shared, an inventory list and monthly report journals. Participants perceived this app as not user-friendly

and time-consuming, as it had functions that were difficult to understand or difficult to use. Still, the idea behind the app was appreciated. Participants indicated that using the app created insight and awareness in the food products bought and the shelf life of products. This information was helpful to concretely undertake action: finishing products before their due-date. The respondents scored slightly positive regarding the statements that using the app improved their awareness and motivation to reduce food waste, but on a group level, no changes were seen in self-reported shopping and meal planning behaviour.

5 Discussion

5.1 Implications

The current available literature, the ICT tools inventory, and the focus group study all indicate that food waste apps can be accepted for use by consumers and have potential to change food-waste related behaviour on condition that the apps require minimum time and little cognitive effort (Farr-Wharton et al., 2014a; Farr-Wharton et al., 2013; Hoem, 2017; Lim et al., 2017). Our study also indicates that apps with various functionalities have a higher chance to be helpful in changing consumer behaviour (Schoeppe et al., 2016), but may be less user-friendly. User friendliness appears to be a key point (Farr-Wharton et al., 2014a; Farr-Wharton et al., 2013; Hoem, 2017; Lim et al., 2017), as this influences whether and how long consumers use an app. An app that is not used by the consumer in daily life, will not lead to behaviour change. Therefore, it is important to include users in an early stage of the development of apps and other ICT tools (Yalvaç et al., 2014).

In our study, the overall consumer evaluation of the three apps was scored relatively low (concerning user-friendliness, overall grade, time investment, and likeliness to recommended the app to friends or family). Nevertheless, in all three groups, there was always one participant who agreed with the statements that it changed their shopping or meal planning behaviour. This may indicate that certain consumers may be more susceptible or more open to change their food-waste related behaviour. This is something that should be taken into account for further study.

The focus group discussions showed that the tested apps lacked clear incentives that reward and reinforce positive behaviour, nor did they engage a lot with the user. This together with the finding that most participants perceived no intrinsic need for using food waste apps, implies that food waste apps need to be extremely user-friendly, as there is little intrinsic motivation to give 'difficult apps a second chance'.

In the inventory, we focused on software tools, but also found some devices that aim at a reduction of food waste, for example for vacuum storage of ingredients or meals. In general, these devices have a high gadget content, but are very pricey in relation to the functionality. It is not known how successful these devices are, and this may be explored in future studies. In line with this, the literature search focused specifically on smartphone applications (apps) as a tool to improve food-waste related behaviour. Social media (Facebook) interventions were not included, but may also be an interesting avenue for future research, especially because engagement with the user appears an important feature for consumers, and does not seem easy for the topic of food waste (Comber et al., 2013).

Our study provided interesting and additional insights on top of the current available literature. However, the small scientific literature basis that is currently available, implies that more research in this field is required. In order to obtain a comprehensive picture of the effects of apps on consumers'

awareness, motivation and behaviour in relation to food waste, longer-term, sufficiently powered trials are needed in which full-functioning real apps are used (no prototypes) and actual food-waste related behaviour of the consumers is measured. Larger studies also provide the opportunity to investigate whether certain groups (segments) of consumers are more susceptible for food-waste related behavioural change.

5.2 Strengths and limitations of the study

This is one of the very few studies that focus on apps (ICT-tools) in relation to consumers' food waste behaviour, looking from the perspective of which tools are currently available for consumers, as well as evaluating three different apps by consumers, who used these tools for a period of three weeks in their everyday life.

Although the inventory is not exhaustive, the overview provides good insight in the type of apps that are available for consumers in relation to food-waste related behaviours. From this overview, a varied range of currently available apps could be selected for the next phase of the project. This made it possible to test apps with different functionalities among consumers.

The focus group study adds to the scarce amount of literature about the use of apps in relation to food management and food waste and the effects of using such an app on consumers' awareness and food-waste related behaviours. A strength of this study is that three commercially available apps (instead of prototypes) were actually used by consumers for a period of three weeks; leading to insights into their actual experiences in daily life instead of imagined experiences. A second strength is that the consumers participated in a focus group discussion as well as an evaluation questionnaire. The combination of qualitative data and more quantitative data gives a more comprehensive picture about their experiences and their perceived effects on awareness, motivation and food-waste related behaviour.

Because the evaluation questionnaire was completed after the group discussion, it is possible that the group discussion influenced the responses of the individual consumer when completing the questionnaire. With hindsight, it would have been better that respondents first completed the questionnaire and then participated in the focus group discussion in order to first consider their own thoughts and experiences. The variation in the answers of the evaluation questionnaire suggests that the group discussion did not overrule all individual responses, but the influence of the group discussion cannot be ruled out.

Other limitations are the small sample size (~10 subjects per app), the recruitment of participants in the university city of Wageningen, and the relatively highly educated sample (~80% higher education). Therefore, the results have to be interpreted with some caution and the results may not be representative of the average Dutch or European consumer. The relatively low reported frequency of unsustainable actions in the questionnaire may for

example indicate that this sample of consumers is somewhat more involved in sustainable behaviour. It could also indicate some social desirability in the answers, but the fact that meat eating was reported relatively often (~50% of the sample) makes social desirability a less likely explanation.

6 Conclusion & recommendations

The aim of this deliverable was to give an overview of existing apps and examples of the diversity of functionality of the apps (inventory) and to gain insight in how consumers experienced the use of the app and to what extent using the app led to a change in self-reported behaviour (focus group study).

From our inventory, we expected that combining inventory and recipe features in apps would be the most promising tools in changing consumer's food planning behaviour. However, from the focus group study, we learned that combining these two features may lead to less user-friendly applications. Even though the consumers in our study were interested in using an app to make them more aware of their meal planning, shopping and stock-keeping, many participants did not perceive an intrinsic need to use such an app. In addition, as soon as the app is not user-friendly, they will stop using it and a change in food waste behaviour will not be achieved.

The respondents in our study felt that they had to invest much more (in time, energy and stamina), than what they got out of the app (convenience, insights and engagement). Nevertheless, for one app, respondents slightly agreed that using the app had increased their awareness and motivation, but none of the apps showed an effect on the reported behaviour.

It is recommended that food-waste related apps for consumers have intuitive navigation and convenience, for example by scanning food products instead of having to enter each product manually. A well-maintained and up-to-date data source for food products is needed in order to achieve the functionality that makes the entry of products easier and less time-consuming. Effort is needed to extend and combine data from primary sources and from other apps, using well-defined data standards.

In order to maintain motivation to use the app time after time, and increase the chance of food-waste related behaviour change, it is recommended that these apps are extremely user-friendly, that they show the effects of consumer actions, provide incentives for positive behaviours, and actively engage with the user.

6.1 Recommendations

On the basis of the outcomes of our study and the current literature, a list of recommendations is provided for optimizing apps for food-waste related behaviours of consumers. The recommendations are subdivided in improving reliability, functionality and optimal information for users (reliable app); desired features of apps (content: what consumers want and potentially effective elements); and recommendations for improving user friendliness (low time investment by consumers and low cognitive effort).

6.1.1 Recommendations to optimize reliability of apps, and provide better and functional information to the consumer

- Sufficient maintenance, regular updates and user support.
- Up-to-date and comprehensive data sources on products and storage in general.
- A good data source for fresh products, both in terms of shelf life and nutritional value. This would not only help making apps more user-friendly, but also to create much added value in the use of recipes that make use of the products that a consumer already has in-house.
- Standard data formats for shopping lists, recipes and other planning tools, so that data between tools can be exchanged, which may result in added value (Bizer, 2009). This exchange makes it possible to combine the functionality of different apps and thus give the consumer the opportunity to choose the best combined app for his situation and application.

6.1.2 Recommendations for desired features

- Consumers want to have insight into the economic and/or ecological effects of their food-waste related behaviours, for example money saved, footprint achievement, or health effects (our study and Hoem, 2017).
- Consumers like to receive incentives for positive behaviour, such as compliments, achieving goals, earning points (our study and Mummah et al., 2017). Interviews in Norway about the potential of apps in preventing household food waste, identified three personal gains from not wasting food (Hoem, 2017): saving money, making a difference to the environment and to get a 'good feeling'. These personal incentives could be used in apps to motivate consumers in preventing and reducing food waste.
- Consumers appreciate social interaction; apps need to engage much more with the user, apps should be dynamic and intelligent. Our study indicated that users like a sense of community, and want to inspire and get inspired by others. Also an element of competition was valued, for example food waste reduction games. Also other studies indicate that social elements are desirable, such as peer support (Cardi, Clarke, & Treasure, 2013), competition and collaboration (Hoem, 2017; Lim et al., 2017), internal and social comparisons (Mummah et al., 2017). Social interactions may also be used to enhance and maintain motivation.
- Recipe suggestions for leftovers or products past the best before date (our study and (Hoem, 2017))
- Information on shelf life, expiry dates and how to know whether a product is safe to consume (our study and Farr-Wharton et al., 2014a; Hoem, 2017) and reminders for using food products before they turn bad (Hoem, 2017)
- Fun facts about food waste (Hoem, 2017)

- An overview of discounted food with short shelf life in the grocery store (Hoem, 2017)
- Physical colour schemes, stickers, sliders or LCD screen with living creature to support systematic storage of food (Farr-Wharton et al., 2014a; Nguyen et al., 2015)
- Visual photo of interior fridge, up-to-date inventory list (Farr-Wharton et al., 2014a) in order to know which foods are in stock
- Real-time and personalized feedback (our study and Burke et al., 2011; Mummah et al., 2017; Zhao et al., 2016)
- Detailed information (Zhao et al., 2016); users should be given options and flexibility in the nature of information they receive (Lim et al., 2017)
- Expert consultation (Zhao et al., 2016)
- Guidance and suggestions for the intended behaviour change, action-oriented (Lim et al., 2017; Lim et al., 2014)

6.1.3 Recommendations to optimize user-friendliness to support continuous use

- Make it easy to enter information and prevent repetitive tasks entering information. So, instead of manual entry of food products – which is very time consuming and may limit continued use of the application– make use of barcode scanner or other automated processes for registering products (our study and Farr-Wharton et al., 2014a; Hoem, 2017; Rouillard, 2014)
- Use an easy app structure and simple interface (our study and Zhao et al., 2016)
- Intuitive navigation in the app (our study)
- As few ads and banners as possible in free apps (our study)
- Not too many notifications or the possibility to switch notifications off (our study)
- Easy recipes (Hoem, 2017)
- Include the most commonly used products (Farr-Wharton et al., 2014a; Farr-Wharton et al., 2013; Hoem, 2017)
- Not too much text, use pictures and figures (Hoem, 2017)
- New content in order not to become boring (Hoem, 2017)
- More integration between a food waste apps and tools that consumers already use in daily life (Farr-Wharton et al., 2014a)

An app that is user-friendly, has the right features and contains up-to-date, reliable information, has a higher chance of being used by consumers and may consequently lead to the ability, opportunity and motivation that is needed for behaviour change.

6.2 Policy recommendations

ICT tools and apps have the potential to reach a large public, and have the possibility to connect to persons who are not always reached in health or sustainability interventions. Therefore, apps and ICT tools may be powerful tools for policy in order to reach consumers from all parts of society. Even more, because apps and ICT tools make it possible to focus on the motivation, ability and opportunity of consumers, which are three key components for behaviour change.

The research that has been done so far indicates that apps can raise consumer awareness regarding food-waste related behaviour, such as awareness regarding which food products are already in stock at home or regarding shelf life of products, and this is a first step for behaviour change. However, more insight is needed whether and when these tools are effective in changing consumers' actual food waste. Furthermore, there are other ways to change behaviour than via apps and ICT tools, which need further exploration in relation to food waste behaviour, for example nudging strategies, financial incentives and education programmes etc.

Furthermore, as most consumers do not perceive a clear need to use an app for reducing food waste, policy should take actions to make consumers aware of this problem, so consumers feel at least a sense of urgency to change their behaviour. Because consumers appreciate to get feedback on their own behaviour, it may be important to include strategies such as providing feedback, having consumers actually measuring their own food waste, or including a competition element to make consumers aware of how much food they (possibly unconsciously) waste.

Many ICT tools and apps need improvement concerning user-friendliness. As soon as apps are not user-friendly, consumers will not use them and no behaviour change is possible. Policy could define standards or quality guidelines to support that apps on the market meet certain standards for user-friendliness, although this may not be easy to bring into practice. Furthermore, policy should support the development and maintenance of an up-to-date data source for food products, and define data standards for the exchange of data from primary sources and from other apps.

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8 Annex

8.1 Recruitment text



Uitnodiging voor onderzoek naar voedselverspilling en gebruik van een 'food-planning-app'

Graag nodigen we u uit om u in te schrijven voor een onderzoek naar voedselverspilling en de rol die een zogenaamde 'food-planning-app' op uw smartphone hierin kan hebben. In deze mail leggen we uit wat de aanleiding is van dit onderzoek, wat er van u wordt verwacht en wat er voor u tegenover staat.

Waarom?

Voedselverspilling is wereldwijd een groot probleem. In Nederlandse huishoudens wordt gemiddeld 41 kg vast voedsel (inclusief sauzen, vetten en zuivel) per persoon per jaar verspild. Voedsel weggooien is zonde, omdat er veel energie en grondstoffen gebruikt worden voor de productie. Daarom is het belangrijk om slimme oplossingen te bedenken die voedselverspilling tegen kunnen gaan. Met dit onderzoek willen we kijken of het gebruik van een 'food-planning-app' op uw mobiele telefoon hieraan kan bijdragen.

Hoe ziet het onderzoek eruit?

Het onderzoek duurt in totaal 3 weken. Aan het begin van het onderzoek komt u naar een informatiebijeenkomst op de Wageningen Campus, waarin u uitleg krijgt over de te gebruiken app. **Let op: de app is alleen beschikbaar in het Engels en daarom is één van de vereisten om mee te kunnen doen een goede beheersing van de Engelse taal! Ook handigheid met uw smartphone en in het gebruik van apps in het algemeen is een vereiste.**

De app zal tijdens de bijeenkomst meteen geïnstalleerd worden op uw mobiele telefoon en u krijgt de gelegenheid om vragen te stellen aan de onderzoekers. Vervolgens gebruikt u de app drie weken. Na deze drie weken komt u weer naar de campus voor een groepsdiscussie van ongeveer 1.5 uur onder leiding van een discussieleider. In deze discussie vragen wij u om uw bevindingen over het gebruik van de app met ons delen.

Wanneer?

- **Informatiebijeenkomst** – Op maandag 7 of dinsdag 8 mei komt u naar een informatiebijeenkomst van ongeveer een uur. Tijdens de bijeenkomst wordt de app op uw telefoon geïnstalleerd en krijgt u uitleg van de onderzoekers over het gebruik van de app.
- **Gebruik app** - Na de informatiebijeenkomst neemt u de app in gebruik, t/m 30 mei.
- **Groepsdiscussie** – Op woensdag 30 mei vindt de groepsdiscussie van 1.5 uur plaats.

Waar?

De informatiebijeenkomst zal plaatsvinden in het Phenomea-gebouw op de Wageningen Campus, gebouwnummer 124, Bornse Weiland 9. Over de locatie van de groepsdiscussie informeren wij u nog, maar deze zal ook op de campus plaatsvinden. Het gebruiken van de app doet u gewoon thuis en tijdens het boodschappen doen.

Wij zoeken deelnemers die:

- Tussen de 18 en 65 jaar oud zijn
- Een goede beheersing van de Engelse taal hebben
- Het gewend zijn om apps te gebruiken op hun mobiele telefoon
- Bereid zijn om de food-waste app op hun smartphone te installeren en te gebruiken
- Een IOS (iPhone) óf Android besturingssysteem op hun mobiele telefoon hebben

Wat staat er voor u tegenover?

- Een financiële vergoeding van 45 euro bij voltooiing van het onderzoek
- U levert een belangrijke bijdrage aan wetenschappelijk onderzoek over het tegengaan van voedselverspilling

Hoe kunt u deelnemen?

Lijkt het u leuk om deel te nemen aan het onderzoek? Dan kunt u zich via [deze link](#) inschrijven.

Inschrijven kan t/m maandag 23 april 2018

U hoort zo spoedig mogelijk na sluiting van de inschrijving, of u geselecteerd bent om mee te doen. Als u geselecteerd bent, krijgt u dan ook de dag en het tijdstip van de informatiebijeenkomst waarop u bent ingedeeld te horen.

Wanneer u niet voldoet aan de criteria of wanneer wij teveel aanmeldingen ontvangen hebben, kan het zijn dat u een afwijzing ontvangt.

We stellen uw inschrijving erg op prijs!

Mocht u vragen hebben over dit onderzoek kunt u contact opnemen via smaakonderzoek@wur.nl of via telefoonnummer 0317 48 4034.

Vriendelijke groet,
Het onderzoeksteam van REFRESH!

8.2 Inventory of Existing ICT Tools and Smart Technologies



REFRESH - Frameworks of Action
Inventory of Existing ICT Tools and Smart Technologies (Task T1.5)
for food management and waste reduction by customers

Objectives

- * To create an inventory existing ICT tools and smart technologies for food management and waste reduction *by customers*
- * This will feed into T2.5 where DLO will undertake a gap analysis

Scope & definitions

We are focusing on existing ICT tools and smart technologies for food management and waste reduction by customers:

- * An ICT tool is an ICT software application or app
- * Smart technology is a smart combination of (new or existing) technologies and ICT, leading to new innovative processes, products or services
- * The tools and smart technologies are categorized in the phases of household food logistics:
Planning, Provisioning, Storing, Preparing, Consuming, Disposal
- * **NOT included** are tools and guidance which help the food industry

Completion of the inventory:

- * The inventory is formatted with a series of **13** questions running horizontally across the document.
- * Categorize the tools in the supported phases of household food logistics: Planning, Provisioning, Storing, Preparing, Consuming, Disposal
- * Describe the supported functionalities
- * Add comments if needed

#	Name of the tool	Developed / owned by	Installed (Android)	Rating (Android)	Contact Name	When was the tool created or updated	Link to the tool	Type of App	Used sensors (incl camera)	What format is it in?				Phase of household food logistics?						M/A/O			Which functionalities does the tool or smart technology implement?	Icon			
										Web tool	Mobile App	MS Excel, MS Word, Pdf	Other	Planning	Provisioning	Storing	Preparing	Consuming	Disposal	Motivation	Ability	Opportunity					
3	Family hub koelkast	Samsung	---			Presented on the CES (consumer electronics show) 2016	www.samsung.com/us/explore/family-hub-refrigerator/	Device	camera	x		x		x		x		x		x		x		<ul style="list-style-type: none"> *display your calendar, notes, recipes, weather, and more. *look inside remotely with a built-in interior camera. *create shopping lists and order groceries. *stream entertainment, including news, music, and TV. 			
4	Vacuvida Vacuum Storage	Vacuvida	100 - 500	3.9		06 December 2016	play.google.com/store/apps/details?id=com.vacuvida.vacuvida&hl=en	Device	camera	x		x		x		x		x		x		x		Vacuvida produces boxes and bags to store food and leftovers under vacuum. An Apple or Android app helps to keep track of the stored foods			
5	Milieu centraal about food waste	Milieu centraal	---				www.milieucentraal.nl/voeding/voorkom-voedselverspilling/	Informative	N	x										x		x		* website with information about food waste			
6	Weggooitest	Stichting Milieu centraal	---			19 May 2011	www.weggooitest.nl	Informative	N	x											x		x	* short test (several questions) to measure how much food you waste and what that costs in euro's and CO2* tips about buying, cooking and storing food			
7	Dagboek Voedselverspilling	Stichting Milieu centraal	---	---			https://www.milieucentraal.nl/media/2594/dagboek-voedselverspilling.pdf	Informative	N			x											x		* diary to measure food waste for 14 days		
8	Rekenmodel Voedselverspilling	Stichting Milieu centraal	---	---			www.milieucentraal.nl/voedselverspilling	Informative	N	x													x		* tool to calculate food waste on a yearly basis based on the numbers filled in Dagboek Voedselverspilling		
9	Kliekipedia	Sire / Voedingscentrum	---	---			www.kliekipedia.nl	Recipes	N	x													x		Website with recipes for left-overs. Part of a campaign against food waste.		
10	Voedingscentrum about food waste	Voedingscentrum	---	---			www.voedingscentrum.nl/minder-verspillen	Informative	N	x					x		x						x		* website with information about food waste and tips to prevent food waste		
11	Bewaarwijzer	Voedingscentrum	---	---			www.voedingscentrum.nl/nl/mijn-boodschappen/eten-bewaren.aspx	Informative	N	x							x						x		* you can select a food item from a list and the tool shows how long it can be stored safely in a fridge, refrigerator or outside a fridge/refrigerator.		
12	Love Food Hate Waste	WRAP	10.000 - 50.000	2.6		24 June 2015	play.google.com/store/apps/details?id=com.lovefoodhatewaste		N		x				x	x	x	x					x		x	* recipes * portion planner *meal planner * MyKitchen (inventory of what you have at home in your fridge, cupboard and freezer) *shopping list * achievements (?). Discontinued.	
13	Love Food Hate Waste	WRAP	---	---			www.lovefoodhatewaste.com/	Informative	N	x					x		x						x		x	* website with information about food waste and tips to prevent food waste	

