

Article

Managing Household Food Waste with the FoodSaveShare Mobile Application

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Abstract: It is estimated that European households are responsible for 55% of food waste generation. Key factors contributing to household food waste generation include food spoilage, confusion over expiration dates, overbuying, and inadequate shopping planning. Thus, food waste prevention at the household level depends heavily on food supplies monitoring and management. To this end, during the last decade, several consumer-oriented digital tools have been designed and launched. A literature review showed that currently accessible digital tools are scarce and cover a narrow range of functionalities. Here, we address these issues by designing and launching a decision support tool implemented in a smart mobile phone application (app), the FoodSaveShare Mobile App. The application development followed a traditional client–server architecture using state-of-the-art software and hardware technologies. Additionally, a survey of 340 individuals was conducted to better understand end-user motivation for and barriers against adopting this and similar apps. The developed application combines user-provided data with a retailer loyalty program to leverage the integrated features for tracking shopping activities. The app features a household shopping list populated by product barcode scanning and manual entry. Based on food and packaging type, food products are assigned approximate expiration dates to issue product expiration reminders. For products about to expire, suggestions for their utilization are provided, drawing from a list of over 7000 recipes. Additional functionality allows users to identify products that have either been consumed in time or that need to be discarded. Analytical tools, such as past purchase and resources discarded versus resources saved statistics, offer comprehensive insight and encourage improved shopping and consumption practices. The FoodSaveShare App was launched during the A2UFood Project, which allowed an organised campaign for its use. The app was tested under real customer data and conditions, and selected features have been adopted by the largest supermarket chain on the Island of Crete, Greece. The potential end-user survey results suggest that, provided personal data use issues are addressed, such apps can have a significant impact on reducing household food waste. Future work will focus on analysing the datasets produced by the application to assess its impact on household food waste management.

Keywords: household food waste; food waste behaviour; consumer support tool; retailer loyalty card; mobile app; recipes



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1. Introduction

Food waste generation has profound environmental implications related to waste management and CO₂ emissions, economic implications associated with market costs and consumer savings, and social implications connected to global food and water security and nutritional inequality [1–3]. It is indicative that global food loss and waste contribute 8% of the global greenhouse gas emissions, while leading to economic losses of USD 940 billion per year [4]. To address this threefold (i.e., environmental, economic, and social) challenge, in 2015, the United Nations General Assembly adopted food wastage reduction as one of the 17 Sustainable Development Goals (SDGs) for 2030 [5]. Specifically, the third target of the SDG 12 (Target 12.3) advances “halving per capita global food waste at the retail and consumer levels and reducing food losses along production and supply chains (including postharvest losses) by 2030” [5]. The same year, the European Commission launched the Circular Economy Package, through which the EU Member States are committed to contribute to the accomplishment of SDG 12.3 [6].

However, to tackle the issue of food waste and reach the target of SDG 12.3, the uncertainty is quite high, as a uniform, accurate, and a consistent food waste quantification and reporting methodology is still not available. The FUSION project estimated that in 2012, the EU-28 generated 88 (±14) million t of food waste, accounting for 173 (±27) kg/inhabitant or approximately 20% of total EU food production for 2011 [7]. The first dedicated statistical monitoring of food waste amounts in the European Union shows that in 2020, approximately 57 million t of food waste (fresh mass) were generated throughout the food supply chain, corresponding to “10% of food supplied to EU customers in the supply and consumption sectors” [8]. A closer look at the analysis of the results—by sector this time—confirms and highlights that households are responsible for the largest portion of food waste generation. More specifically, in 2020, households were responsible for up to a staggering 55% of total generated food waste (i.e., nearly 70 kg of food waste per inhabitant per year), while manufacturing of products and beverages accounted for 18%, primary production for 11%, restaurants and food services for 9%, and retail and other distribution of food for 7% [8]. In 2020, Greek households were responsible for approximately 45% of total food waste [8], accounting for 89.22 kg of food waste per capita.

Household food waste-related behaviour is typically assessed using survey questions about general food waste over an un-specified period of time, photo coding, kitchen caddies, pre-announced survey questions regarding a specific time period, and diaries with samples ranging from a few dozens to several thousand respondents [9], with respective limitations [10]. These studies have highlighted food provisioning and preparation-related routines, which are connected to the perceived capabilities of consumers to deal with household activities, as the main drivers of food waste generation [11]. Among these routines, meal and shopping planning, cupboard/fridge checking before going shopping, and understanding of expiration date labels might directly or indirectly have an impact on food waste generation [12]. For example, in a survey of 500 Greek households concerning the effects of shopping habits and eating preferences on food waste generation, Ponis et al. [13] concluded that unplanned shopping leads to overall higher amounts of food waste. Hence, food waste prevention at the household level is largely an issue of optimizing food supplies monitoring and management, to which end, during the last decade, several Information Communication Technology (ICT) tools for consumer use have been designed and launched. However, as pro-environmental behaviour is often based on choices beyond mere resource optimisation and rational decisions in general [14], these apps have the potential to achieve deeper and more lasting pro-environmental behaviour change in users than formal education or information sharing [15–17].

A review that took place in 2019 during the A2UFood Project [18] identified 13 such digital tools, of which seven were highlighted as examples of best practices. Their functionalities typically make use of information from one or more of the three actors involved in this food supply chain: the manufacturer, the retailer, and the consumer [19], to advise users on optimal foodstuff storage, notify them about expiration dates, and suggest recipes for leftovers and foodstuff

about to expire. Five of them, i.e., FoodKeeper [20], CozZo [21], Fridge Pal [22], No Waste [23], and StillTasty [24], were still available online in 2022, while others, i.e., Pantry [19] and Green Egg [25], are no longer available or maintained. It is worth mentioning that several apps are documented in the scientific literature as prototypes (e.g., EatChaFood [26], Pantry [19], MySus-Cof [27]), but nevertheless address many theoretical and practical aspects of the application design process. The five tools still available address food inventory management through one or more functionalities: (a) organising purchased products based on expiration date, (b) organising household food needs in shopping lists, and (c) suggestions for using up leftovers and products about to expire (Table 1).

Table 1. List of tools (applications, web platforms) focusing on food waste prevention at customer level, and their main functions relevant to the scope of this work.

Tool	Function			Country	Source
	Expiration Dates	Shopping List	Recipes		
FoodKeeper	×			USA	[20]
CozZo	×	×	×	Bulgaria; UK	[21]
Fridge Pal	×	×	×	Canada	[22]
No Waste	×	×		Denmark	[23]
Still Tasty	×			USA	[24]

In extracting information from manufacturers, retailers, and consumers for use with such tools, several actor-specific challenges arise. Regarding manufacturers, expiration dates are typically added in the final packaging step in a way that is not machine-readable (i.e., paper labels rather than barcodes). While numerous models exist to predict food shelf-life in terms of dehydration [28], oxidation [29], microbial activity [30–32], and possibly other degradation factors, their application is impractical at the level of a consumer-oriented application. Therefore, apps typically assume these dates based on product purchase date and typical shelf-life, or require the user/customer to enter them manually [21,23]. At the level of the retailer, purchased products information typically falls under general (customer) data protection regulations (GDPR), but can be accessed with the consent of the customer under the umbrella of a loyalty card scheme [19]. Finally, the customer needs to be actively involved in the use of the app and follow a daily routine of updating the inventory and interacting with the notifications provided. This final step is probably the most challenging, and one of the main reasons several of the reviewed applications are no longer maintained, as it calls for a more holistic and impactful approach.

In this context, the A2UFood Project designed and implemented a holistic management scheme, in which all aspects of reduction, reuse, and recycling of food waste are included. A2UFood implements the circular economy concept into the daily practice of the citizens of the Municipality of Heraklion (the main urban authority of this urban innovation action) in Crete, Greece [18,33]. Communication and prevention are integral parts of the A2UFood concept, designed to optimally inform, raise awareness, and educate the public to avoid food waste, with the use of (a) tailored, direct, in-person activities [34], (b) online tools (interactive website, social media), (c) a digital food waste monitoring and resources management tool for hospitality units [35], and (d) a mobile app to facilitate a shift in the food management routines of households [36]. Motivated by the results of our review, which did not identify existing mobile apps that could facilitate the goals set by the project, a new application called FoodSaveShare App was developed.

This work presents the development and implementations of the FoodSaveShare App, which combines data from user input, a retailer loyalty scheme, product databases, and recipes available online, as well as interdisciplinary knowhow from various fields, including information technologies, waste management, sustainable development, and social psychology, to provide consumers with an effective food inventory management tool as an innovative approach against the problem of food waste in households. Section 2 presents the methods used for software development, modelling the expiration dates,

and distributing the application to retailer customers. Section 4 presents the developed application framework, the working app, and preliminary results from its implementation during the testing phase. Section 5 presents the conclusions and outlook from this work.

2. Materials and Methods

2.1. Application Development

The application development followed the Agile Dynamic System Development Method (DSDM) [37], which is one of the most common software development methodologies and has been previously employed for food waste management apps [27]. Figure 1 shows the stages of the development process, starting before the project, undergoing a feasibility assessment, building a functional prototype and then undergoing an iterative testing and redevelopment process before the application is eventually deployed to incremental user bases. A final phase includes post-project feedback evaluation, leading to minor updates.

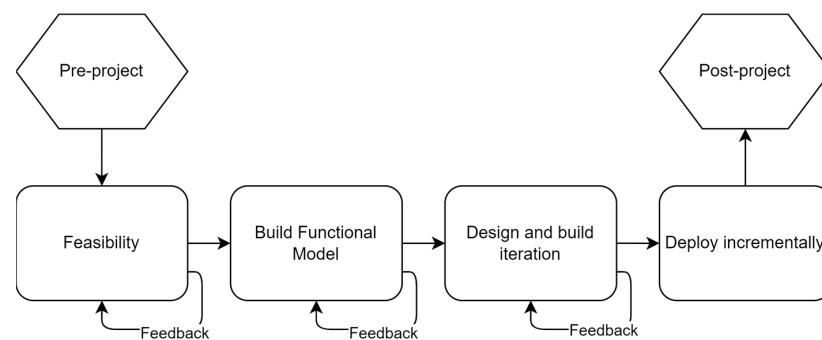


Figure 1. Dynamic System Development Method (DSDM) employed during the development of the FoodSaveShare App.

2.2. Software

The mobile app is based on the traditional client–server architecture where the backend consists of (1) the web server that hosts the cloud infrastructure, including (2) the database that stores all necessary data and (3) the search engine that performs product and recipe searches based on keywords, and the front-end is (4) the mobile application that acts as client and communicates.

2.2.1. Server Side

The server side of the application is built on the Node.js platform (OpenJS Foundation, San Francisco, CA, USA) [38], an open-source JavaScript runtime environment built on Google Chrome’s JavaScript engine, allowing the execution of JavaScript code outside of the web browser. Like other programming languages, such as Java, PHP, and Python, the Node.js runtime environment can serve documents and data to the clients, handle HTTP requests, and communicate with databases for data storage and retrieval, and web application programming interfaces (APIs) for data exchange. Node.js was chosen against other technologies because of (a) its capability of writing the server-side code with TypeScript; the same programming language for writing the mobile application’s code, (b) the availability of useful libraries (modules) that are offered through its huge codebase of useful libraries (modules) developed by the Node.js community and organisations, (c) the enhancement of productivity [39], and (d) the fast execution of the system functions [39,40].

The need for data storage was covered using a relational database management system (RDBMS). In the server, a PostgreSQL database instance was created to store all of the data required by the system. To gather, prepare, and insert the required data, an intermediate service was created, the Scheduler. This mechanism periodically searches and downloads all new/updated data in text format (TXT files) from Google’s file storage service “Google Drive”. These files are uploaded every morning—in some cases, twice per day—in private shared folders in Drive from the technical department of the supermarket through their

own scheduling mechanism. The entities (data) that are imported to FoodSaveShare's database are the customer records, the product records (including their categories and barcode tables), and the sales (purchases history) records.

To facilitate keyword-based searches in unstructured data, the Elasticsearch [41] distributed Big Data database system was used. Elasticsearch is an open-source system designed for efficient full-text searches and analytics, that was developed in Java and powered by Lucene, a cross-platform full-text search library developed by Apache Software Foundation (Forest Hill, MD, USA). Its functionalities are packed up in a stand-alone server that any application can talk to via a REpresentational State Transfer Application Programming Interface (RESTful API) for searching text by performing HTTP requests. Data from Elasticsearch come in JavaScript Object Notation (JSON) format and are organised in indexes, which can be thought of as analogous to databases from a relational perspective. The main advantages of Elasticsearch are its high scalability and efficiency due to the use of sharding [42].

2.2.2. Client Side

The client side of the mobile application was developed in Ionic [43], which is a powerful hybrid application development framework that is free and open-source. This framework allows the use of a combination of popular web programming technologies, like CSS, HTML5 and JavaScript/TypeScript language. The use of this combination will facilitate the creation of the best possible user interface for the targeted audience and the implementation of faster and easier features. Exploiting the capabilities of the Ionic framework, it is possible to build and deliver the software for both Apple iOS devices and the various Android devices through the same code base. In addition, the framework offers several plugins/modules developed, tested, and maintained by its community and allows one to write code for communicating with the device's components (e.g., storage, network access, camera) and operating system, as well as several third-party web services. Another helpful feature of the framework is the Ionic Creator [44], which is a custom web application developed by the Ionic team, allowing one to design the application mock-ups (the initial software designs for demonstration and design evaluation purposes).

2.3. Product Shelf-Life

To overcome the limitations described in the Introduction, products were classified in types (hereafter subgroups), for which approximate expiration dates were determined based on the literature, EU legislation, and market research. When sample shelf-life days were not in agreement, the average number of days was considered.

2.4. End-User Motivation and Barriers

To assess the motivation for, and the barriers against, using the app from the side of the user, an anonymous Google Forms [45] survey, including questions on (a) current use of food purchase organisation apps (including reasons for not using), (b) potential future use of apps with effectiveness in food waste reduction, (c) rating of the usefulness of various in-app tools (including suggestions for additional tools), (d) GDPR concerns, and (e) demographic parameters (gender and age), was prepared. The survey was administered between 15 January and 15 March 2024, via the largest social network [46], loosely following the guidelines of Neundorf and Öztürk [47], through four similar paid campaigns which targeted adult residents of Greece without audience exclusions or targeting. Demographic and gender gaps were filled with two additional targeted audience campaigns. Survey results were analysed and visualized in R [48]. Likert scale results are presented in diverging stacked bar charts, with Likert scale values normalized between -100 (strongly disagree) and 100 (strongly agree), as introduced by Robbins and Heiberger [49]. Depending on the question, scores were calculated to make comparisons between participant subgroups. The Wilcoxon signed-rank test was used to compare groups of individual Likert questions [50] in terms of mean normalized Likert value. The significance threshold was set at p -value 0.05. Data were analysed using the stats and *HH::likert* [51] packages in R.

3. Results

3.1. Pre-Proposal and Feasibility

The pre-project phase of the application development took place during the A2UFood Project proposal writing, where application concept, scope and context were outlined. After project funding, the feasibility stage heavily depended on the availability of at least one retailer who would provide real word information on products, customers, and loyalty scheme, and the way that this information would be integrated in the new application. Chalkiadakis S.A. (Gazi, Greece), a Greek retail chain based in Crete that operates 40 stores with over 1000 employees [52], came on board as part of its corporate social and environmental responsibility activities, and provided access to its product database and information from the loyalty scheme for those customers who gave informed consent for participating in the project. During the feasibility stage, it was established that, due to the existence of a Chalkiadakis loyalty mobile app, a completely new app would cause confusion to existing and new users/customers, and, therefore, deployment of FoodSaveShare to the full customer base would not be feasible. Nevertheless, it would be feasible for the existing Chalkiadakis loyalty app to adopt the most suitable features of FoodSaveShare and, therefore, achieve larger impact. According to our literature survey (Table 1), this the first app focusing on food waste prevention at the customer level developed and applied in Greece.

3.2. Product Shelf-Life

For the shelf-life database, 340 packaged food product types were established from combinations of (a) retail store department/corridor (b) product group (shelves, chillers, and freezers), and (c) product subgroup (Table 2). Therefore, for example, charcuterie items could be assigned different shelf-life periods depending on whether bought in slices or off the shelf, or from the department of the biological products. Regarding shelf-life estimates, 25 were based on the literature [53–55] and EU legislation [56], and 315 on a sampling campaign to five retailers. During sampling, multiple products (at least two) were sampled for each product type, and when variations among products in the same product type occurred (e.g., variations among brands), the midrange shelf-life was considered. The resulting product shelf-life database is retailer-specific.

Table 2. Tables used in the FoodSaveShare App.

Name	Description of Data Stored
users	User (supermarket customer) data (e.g., identifier, name, password)
stores	Retailer data (e.g., identifier, address, and city)
sales	Retailer sales records
products	Product data (e.g., identifier, description, price, categories, measurement unit)
barcodes	Product barcodes (associated with product table)
p_categories	Classification according to retail store department/corridor
p_subcategories	Classification to food and non-food products
p_groups	Classification of food products based on storage (shelves, chillers, or freezers)
p_subgroups	Classification of food products to 127 food subgroups
buylists	Customer shopping list data
buylist_products	Shopping products (associated with shopping lists)
recipes	Food recipes

3.3. FoodSaveShare App Architecture

The app was developed based on the architecture described in Sections 2.2 and 2.3. On the server side, the requirements of computing resources, data storage, and networking were fulfilled through the Okeanos [57] virtual compute and network service offered by the Greek Research and Technology Network (GRNET), in which a virtual machine was created to host the web server, the database and the search engine. Figure 2 depicts the system architecture, including the flow of information from the client request to the server response. The PostgreSQL database includes 10 tables, as listed in Table 2, which are related,

as shown in Figure 3. The database is updated in real time with information from the client, whereas information from the retailer (i.e., products, purchases) is updated nightly to avoid non-critical traffic during the peak hours. Elasticsearch was used to search for (a) products to be inserted in shopping lists based on keywords, and (b) recipes to use up leftovers based on ingredients. Recipes are ingested from the internet in batches (always maintaining source information) to increase search speed, avoid errors, and facilitate quality validation and curation [58].

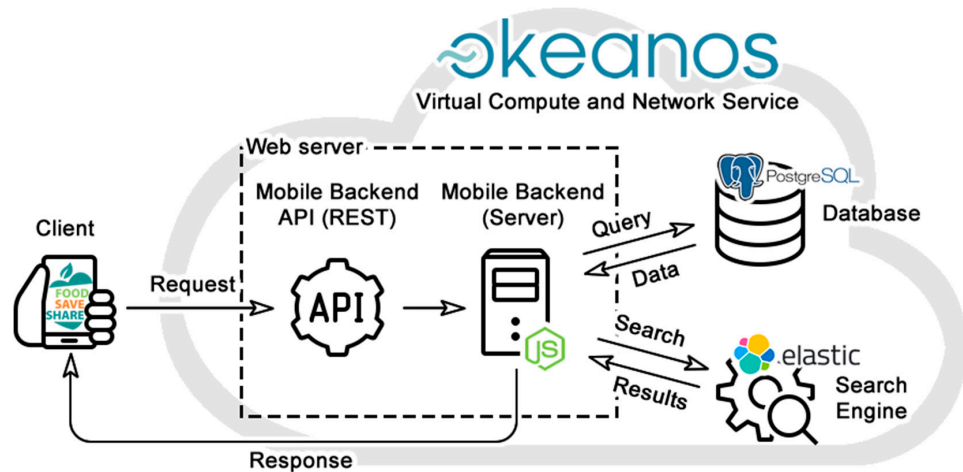


Figure 2. System architecture of the FoodSaveShare App, including the flow of information from the client request to the server response.

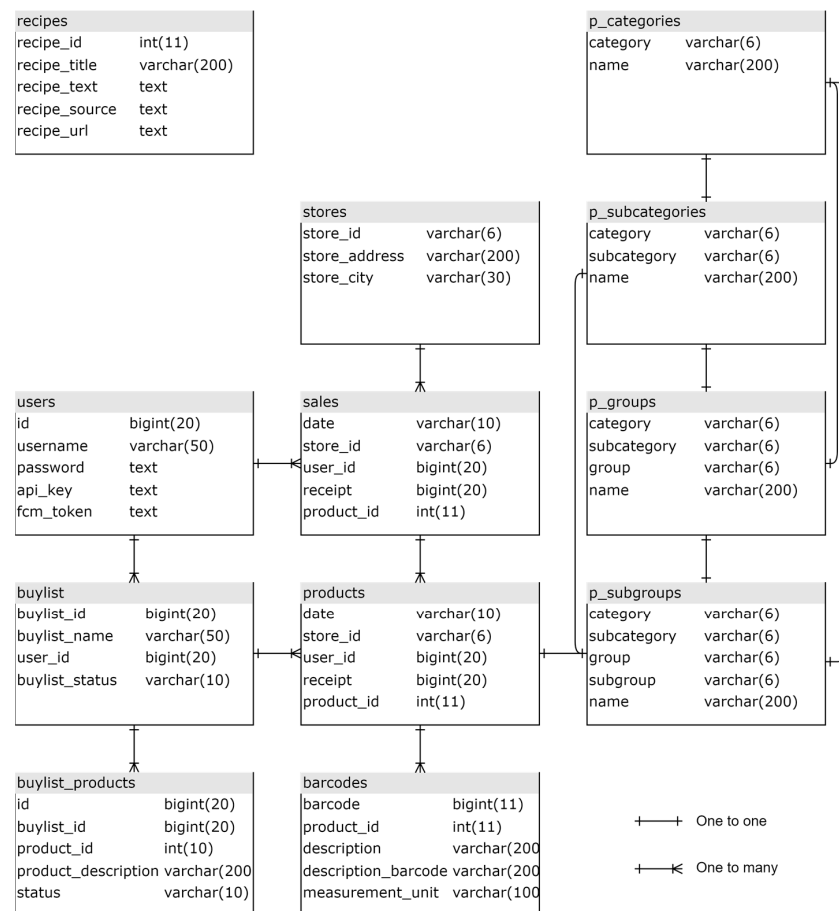


Figure 3. The Entity-Relationship Model of the FoodSaveShare App database.

3.4. Iterative Development and Deployment

Four main testing iteration stages were implemented, each including a wider testing user group from (a) the core development team ($n = 5$), (b) the A2UFood Project partner that undertook the specific task of app development (i.e., HMU, $n = 15$, Figure 4), (c) A2UFood Project Partners who were located in Crete and could, therefore, have access to a Chalkiadakis loyalty card, i.e., HMU, University of Crete, the Association of Solid Waste Management of Crete (ESDAK), and Municipality of Heraklion ($n = 50$), and (d) all employees of the entities from the third group ($n = 150$). As testing groups expanded, written consent for the use of the loyalty scheme information was also required. Testing periods lasted from 1 week to a few months, and feedback was collected via email and personal communication in the first three groups and via app analytics in the last group. After the fourth testing iteration, the final version of the FoodSaveShare app was made publicly available through Google Play and Apple Store [59], taking advantage of the features of the Ionic framework.

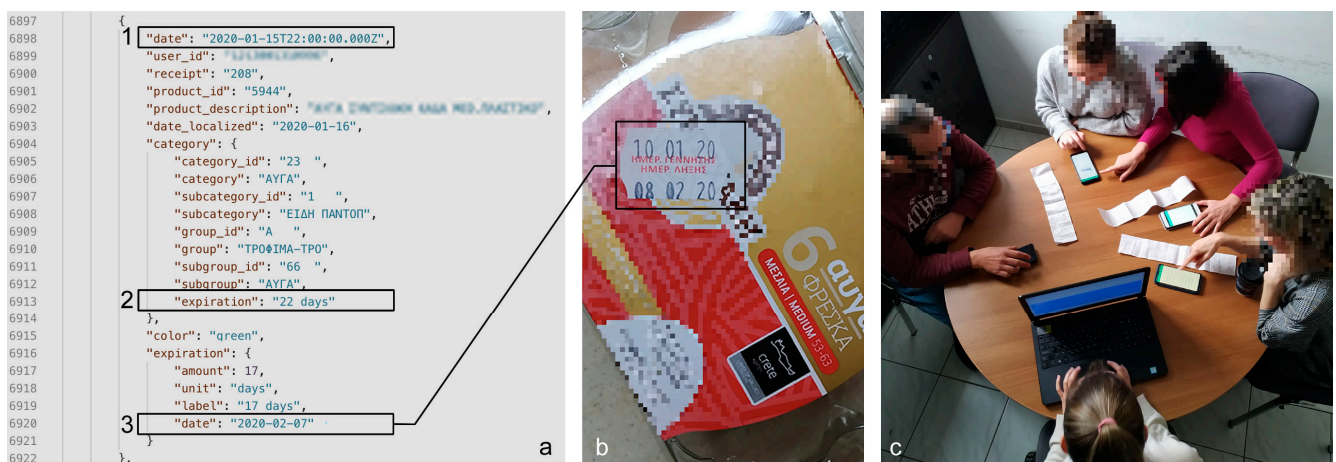


Figure 4. Example of (a) database section showing (1) purchase date, (2) estimated shelf-life, and (3) estimated expiration date, which approximately matches (b) actual expiration date. Group b testers (c), crosschecked shopping bills and actual expiration dates with application information. Photo (a) and (b) by J. Makridis, (c) by I. Daliakopoulos.

3.5. Application Implementation

The final version of the FoodSaveShare App (Figure 5) allows loyalty customers to create shopping lists (menu item Shopping Lists) of the products they plan to purchase, either by keyword search or by scanning product barcodes. The application searches from a database of over 14,000 products but also allows adding custom items to the list. Shopping lists are linked to the loyalty card account, thus allowing household members to create and share common shopping lists. During shopping, the customer can cross out products. Once purchased, the app draws the product list from the loyalty scheme and displays food inventory grouped by receipt (menu item Purchases) or by expected expiration (menu item Food Expirations). On the Food Expirations screen, products are further grouped into those already expired, those expiring soon (1–2 days), and those with longer remaining shelf-life (normal status), based on the framework described in Sections 2.2 and 3.2. The user can further define the status of each inventory product as consumed or wasted. This information feeds an infographic displayed on the home screen of the app, thus allowing the user to have a visual assessment of the percentage of food items consumed and wasted. Recipes can be retrieved by providing ingredients, either by selecting products from the inventory or directly by keywords (menu item Recipes). At the time of writing, a database of over 7000 recipes is available. The application issues push notifications for inventory products close to expiration, and user interaction with these notifications allows direct access to the Food Expirations and Recipes screens for further inventory management.

Finally, a Setting screen allows the user to manage application language and notification frequency, and the Profile screen shows customer and loyalty card information.

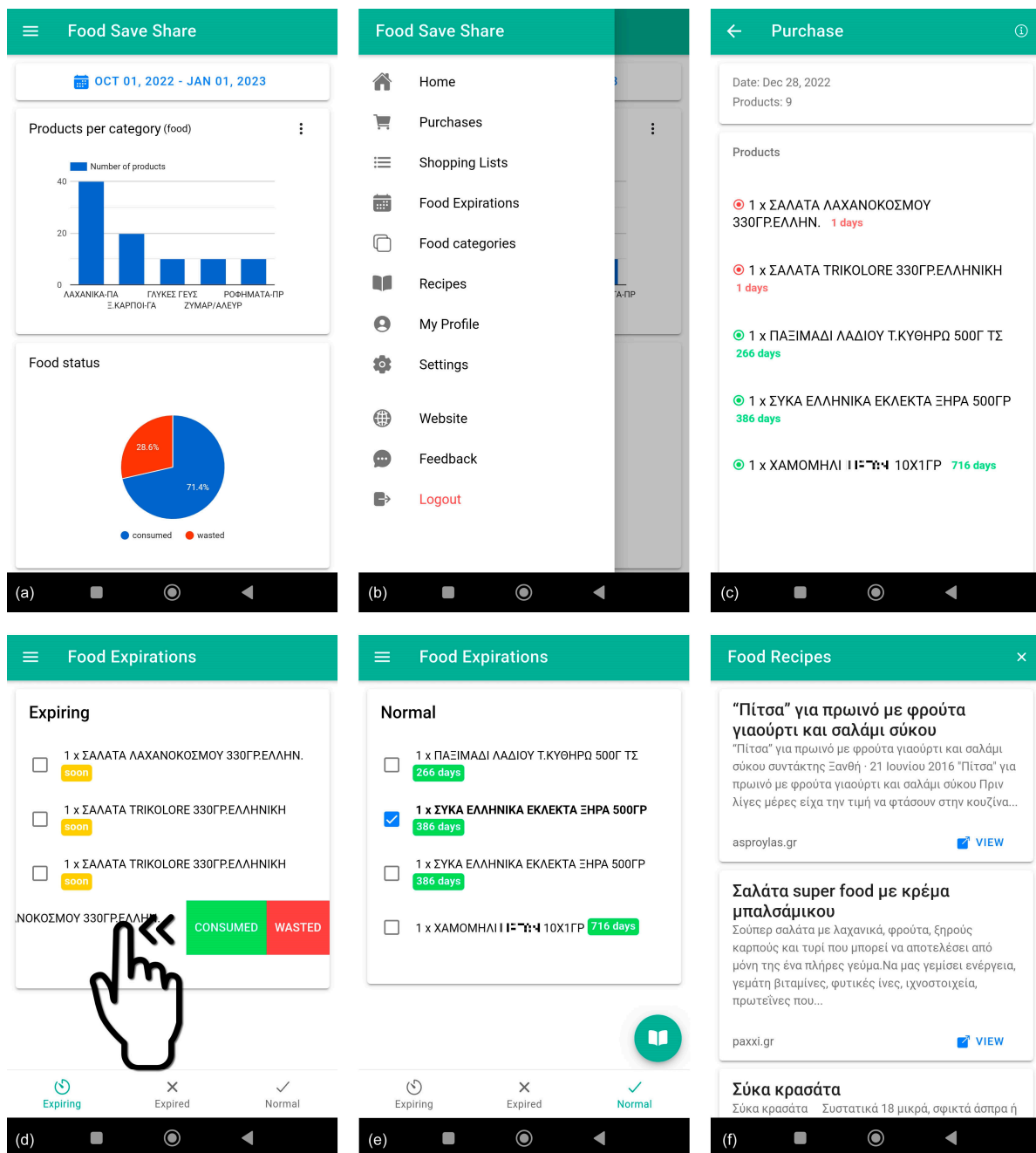


Figure 5. Screens from the Android edition of the FoodSaveShare App, showing (a) the Home-screen, (b) the full menu, (c) the Purchase screen, (d) the Food Expiration screen with the assignment of consumed or waste status to a product, (e) the selection of a product towards the retrieval of a recipe, and (f) the Food Recipes screen (indicative recipes read “Pizza for breakfast with fruits, yogurt and fig sausage”, “Salad super food with balsamic cream”, “Figs in wine”).

To avoid confusion among existing users of the retailer’s loyalty app, selected features of FoodSaveShare were adopted by the mobile app of Chalkiadakis S.A., Chalkiadakis App (Figure 6). Following incremental deployment (Figure 1), at the time of writing, the enriched Chalkiadakis App had been deployed to a user base that counts 1686 members.

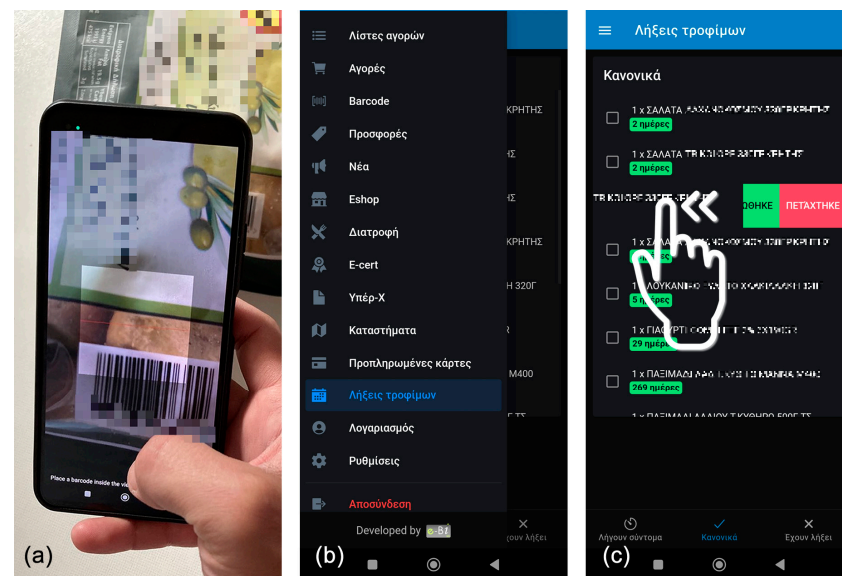


Figure 6. Screens from the Android edition of the Chalkiadakis App that has adopted features of the FoodSaveShare App, showing (a) scanning of a barcode, (b) the main menu featuring “Food Expiration” (in Greek), and (c) the Food Expiration screen with the assignment of consumed or waste status to a product.

3.6. End-User Motivation and Barriers

Our campaigns reached a total of 38,867 individuals, of whom 1424 (25.7% male and 74.3% female) accessed the survey and 340 (23.9%) completed the survey. Table 3 depicts the identity of the survey as absolute number of participants and percentage of total. Due to underrepresentation, responses under gender “Other” were neglected in further analysis. Figure 7 summarises the responses of 340 participants and their gender and age subgroups on using mobile apps to organise food purchases to reduce household food waste. Scores depict the sum of positive answers normalised between 0 and 100, otherwise the percentage of participants that used an app at the time of the survey. As shown in Figure 7, only 30.0% of the survey participants used a similar app at the time of the survey. Differences between male and female participants were negligible (scores of 31.0 and 28.9, respectively); however, older respondents (45+) were significantly less likely users ($p = 0.005$) than younger ones (18–44), scoring 23.3 and 37.2, respectively, and differences were even more pronounced among finer age groups (not shown). As shown in Figure 8, using paper lists was cited as the main reason for not requiring an app (given by 55.9% of participants currently not using an app), followed by the perception that such apps are not effective, as they would not make any difference with reducing food waste (13.4%) or using them is too time consuming (6.7%). Participants who declared that they do not own a smartphone (3.8%) were transferred to the demographic questions and exited the survey, leaving a total of 331 participants to continue with the rest of the survey.

Table 3. Demographics of the survey as absolute number of participants and percentage of total participants.

Age Group/Gender	Female	Male	Other	Total
18–29	42 (12.4%)	34 (10.0%)	1 (0.3%)	77 (22.6%)
30–44	54 (15.9%)	33 (9.7%)	0	87 (25.6%)
45–59	81 (23.8%)	54 (15.9%)	0	135 (39.7%)
60+	26 (7.6%)	14 (4.1%)	1 (0.3%)	41 (12.1%)
Total	203 (59.7%)	135 (39.7%)	2 (0.6%)	340 (100%)

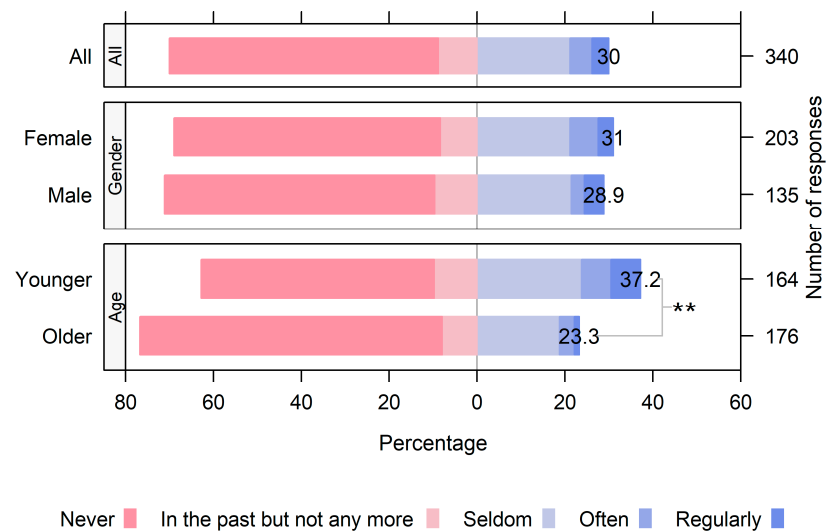


Figure 7. Survey responses of 340 participants and their gender and age subgroups on using mobile apps to organise food purchases to reduce household food waste. Scores were calculated by summing positive answers and normalising between 0 and 100. Two asterisks depicts significant difference at $p \leq 0.001$.

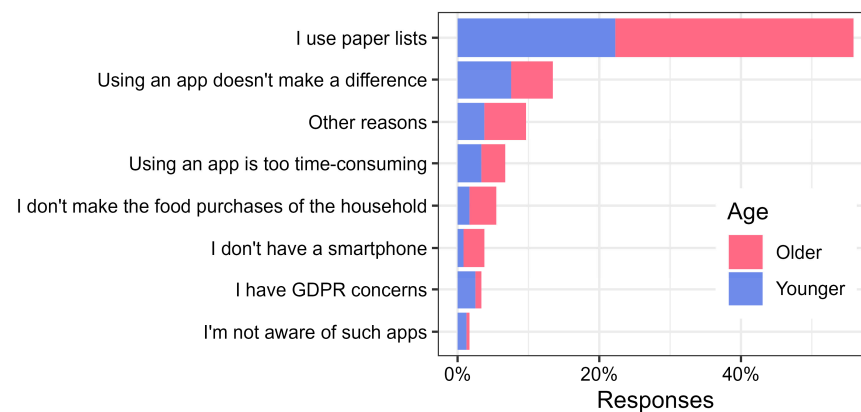


Figure 8. Reasons for not requiring a mobile app to organise food purchases by 229 participants (and age subgroups) who did not use such an app at the time of the survey.

Regarding user motivation, Figure 9 shows the survey responses of 331 participants and their gender and age subgroups on potential future use of mobile apps to organise food purchases to reduce household food waste, in case evidence supporting its effectiveness were to be presented. Here, scores were calculated by assigning answers with values from 1 to 5 and normalising between -100 and 100 . On this scale, participants answering “Neither unlikely nor likely” and considered as “neutral” scored in the range of -20 to 20 , while those with strong opinions (Very unlikely or Very likely) scored in the ranges of -100 to -60 and 60 to 100 , respectively. As shown in Figure 9, on average, participants answered on the scale of Likely (score of 44.4). Younger respondents ($18-44$) were more likely than older ($p = 0.104$) ones ($45+$) to use an app in the future, should evidence support its effectiveness, scoring 40.6 and 48.4 , respectively, with differences being more pronounced among age groups (not shown); however, at the shown resolution (Younger vs. Older respondents), differences were not significant. Differences between female and male participants (scoring 45.4 and 43.3 , respectively) were not significant either. From the users who currently do not use an app (69.2% of the total number of respondents), 22.3% insisted they would not use such an app in the future even if evidence for its effectiveness were to be presented.

Figure 10 shows the responses of 331 participants about the extent to which various app functionalities would help them to reduce household food waste. Scores were calculated by assigning answers with values from 1 to 5 and normalising between -100 and 100 . On

this scale, participants answering “Moderately” and considered as “neutral” scored in the range of −20 to 20, and those with strong opinions (Not at all or Very much) scored in the ranges of −100 to −60 and 60 to 100, respectively. As shown in Figure 10, on average, participants ranked all options on the scale of Likely (between 58.4 to 22.7). Shopping lists, product expiration, and purchased food products inventory scored higher, with 58.4, 55.3, and 45.5 points, respectively. On the other hand, recipe suggestions from expiring products, shopping list sharing, and food category statistics scored the lowest, with 36.4, 29.7, and 22.7 points, respectively. Differences among audiences were not statistically significant. Various additional ideas were also provided, most notably notifying users about discounts in near-expired food, informing about in-season produce, suggestions on the required quantities based on the size of the household, notifying users about products that are already in inventory when adding them to the shopping list, informing about optimal food storage methods, and listing most frequently purchased products. Price comparison among retailers was a popular suggestion but not feasible under the loyalty scheme.

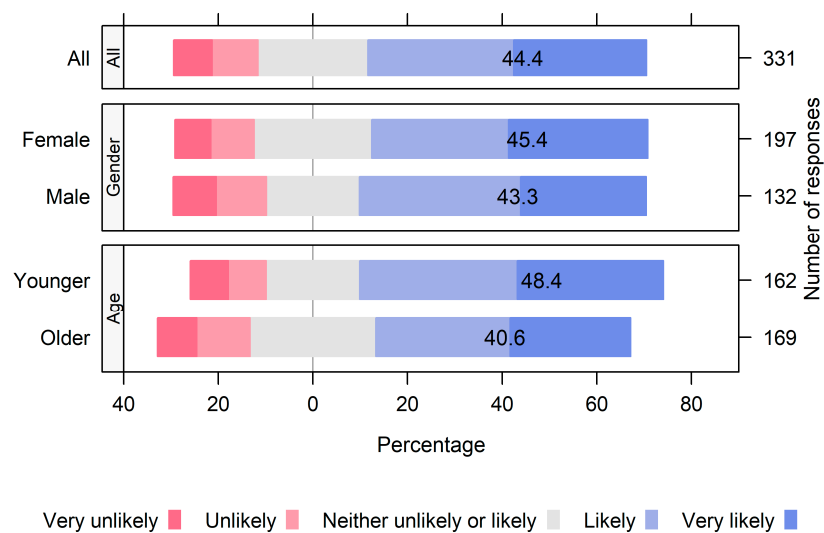


Figure 9. Survey responses of 331 participants and their gender and age subgroups on potential future use of mobile apps to organise food purchases to reduce household food waste, in case evidence supporting its effectiveness were to be presented. Scores were calculated by assigning answers with values from 1 to 5 and normalising between −100 and 100.

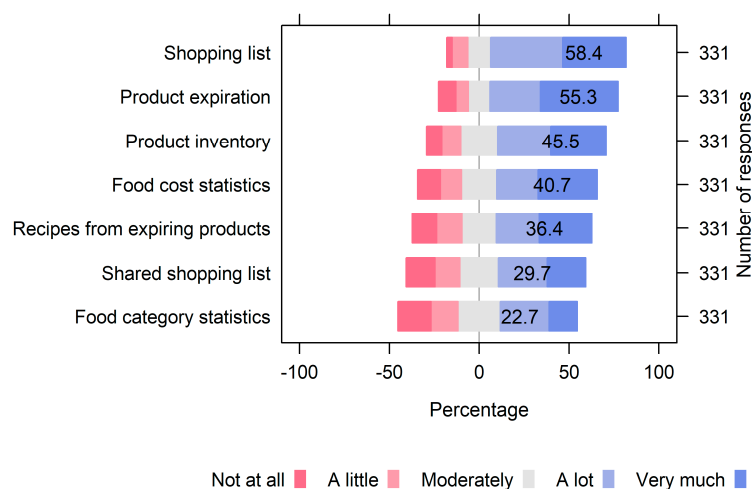


Figure 10. Survey responses of 331 participants on the extent to which some app functionalities would help them to reduce household food waste. Scores were calculated by assigning answers with values from 1 to 5 and normalising between −100 and 100.

Finally, Figure 11 shows responses of 331 participants (and gender subgroups) on whether they would be willing to allow the use of the personal data stored in their loyalty card profiles for the use of a food waste reduction app. In this regard, 10.0% of participants did not use retailer loyalty cards and, therefore, would not take advantage of several app features, and 58.6% of the participants would provide permission, while 31.4% would not provide permission, either for fear of personal data misuse (16.0%) or for mistrust in the effectiveness of such an app (15.4%). Differences among age groups and genders were not statistically significant. Eventually, among those to some extent likely to use a mobile app in the future (77.7% of total respondents), 27.9% would not give permission to use personal data (21.8%) or did not use a loyalty card (6.1%).

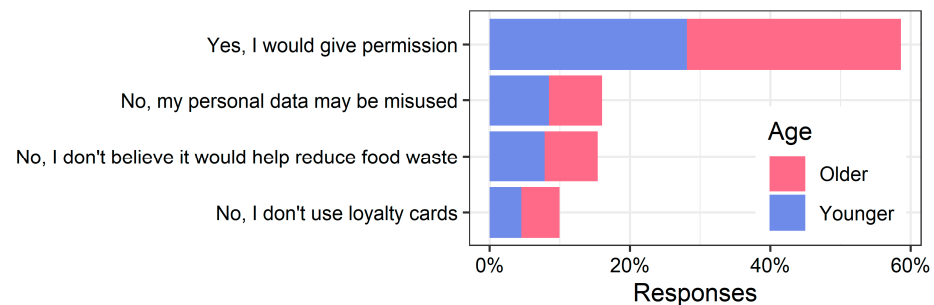


Figure 11. Survey responses of 331 participants (and gender subgroups) on whether they would be willing to allow the use of the personal data stored in their loyalty card profiles for the use of a food waste reduction app.

4. Discussion

4.1. Software

Regarding the use of Elasticsearch, it is indicative that in a simple product query, the search engine responded in 13 ms, whereas PostgreSQL 16 responded in 71 ms. The superiority of Elasticsearch 8.12 over PostgreSQL in full-text search has already been documented in grey literature [60] and owes to the fact that it is a test search engine by design, whereas PostgreSQL is by design a transactional database. Therefore, Elasticsearch proved to be the right tool for this work.

4.2. Dissemination

Following other ambitious food waste prevention actions [61,62], communication material was also issued to achieve a wider dissemination of the app, including a distinct website (<https://foodsaveshare.gr> (accessed on 5 February 2024)), respective social media accounts, and printed material (Figure 12) distributed to the public. Nevertheless, by the time of writing, the total installations of the FoodSaveShare App counted in the hundreds, whereas the number of installations of the Chalkiadakis App only from Google Play were in the tens of thousands [63]. Therefore, to achieve a higher impact, both in the short term but also in the longer term considering the additional cost of campaigning for a completely new framework or application, it is advisable to use already established communication channels.

As early as the feasibility stage of the app development, it was obvious that the most critical component for the success of any similar customer-oriented app is the strong collaboration of a retailer that will make loyalty card and product type information readily available. Without this information, many resources will have to be invested in consumer/user acquisition, which will in turn require a much more aggressive business model to make up for initial losses. In this respect, the stakeholders with the best positioning for issuing such an application are the retailer themselves, as consumers do not need to provide GDPR collect and process consent to additional actors. The close involvement of the retailer, and the fact that selected features of FoodSaveShare were adopted by the official mobile app of Chalkiadakis S.A. guarantees that the features can be maintained and used well after the lifetime of the A2UFood Project. As the ethical dimension of food

waste puts increasing pressure on retailers to reduce and recover it [64], developing such applications or including their functionalities in existing loyalty scheme apps is well-suited as part of their corporate social responsibility model (CSR) in terms of the environment and communities. Furthermore, retailers can also benefit directly by exploiting app features such as shopping list data for warehouse management and purchase list data for targeted advertising, while also taking advantage of frequent user exposure to their brand name.

The Information Campaign "Food Save Share"

Food waste may come from unnecessary purchases or excessive cooking and large serving portions. The A2UFood information campaign provides the knowledge and tools to help you reduce your food waste.

The "Food Save Share" campaign includes the following actions:

- Raise awareness on food waste.
- Provide educational workshops and seminars on food waste-prevention.
- Create and promote an app to facilitate household food management.
- Install a special software in hotels for efficient food management.





The Project is co-funded by Urban Innovative Actions of EU code UIA02-115, through ERDF.

A2UFood is implemented in the Municipality of Heraklion, Crete, with the goal to develop an innovative integrated food waste management plan.

Project duration:
March 2018 - February 2021

Main Urban Authority:
Municipality of Heraklion

Project partners:



Stay updated on:
<https://foodsaveshare.gr>
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FoodSaveShare foodsaveshare

Managing Directorate: Sector of Sanitation and Recycling of the Municipality of Heraklion
Coordinator: Lead Director of Planning, Programming and ICT, Zacharenia Drosou, tel. +302813409178
Project Manager: Manolis Skarvelialis, tel. +302813409051



(a)

Why reduce your food waste?

- You save money and natural resources.
- You contribute to the reduction of greenhouse gases emissions.
- You contribute to the reduction of waste management costs.
- You help to address a major environmental, social and ethical issue.

DID YOU KNOW THAT:

- In the EU, **20%** of food products are discarded.
- Greek households and catering services are respectively responsible for **53%** and **12%** of total food disposal.
- Food waste is responsible for **8%** of annual greenhouse gas emissions.



"FoodSaveShare" App

"FoodSaveShare" is an app developed to help you manage your food supplies in the best possible way.



More specifically, FoodSaveShare:

- Creates and stores a list of food supplies (via the reward card).
- Provides tips for better food storage.
- Provides notifications of food reaching its expiration date.
- Suggests recipes for better food usage.

* The list gets updated by linking the reward card application to an affiliated supermarket chain.

Workshops - Educational programs

Thirty seminars and training workshops on the prevention of food waste will take place in the Municipality of Heraklion, in the context of the A2UFood Project implementation. During the seminars, you will have the opportunity to meet and talk with experts on food waste issues, as well as to receive information about the social, environmental and economic impacts of food waste. The workshops will also provide guidelines about the actions you can incorporate into your daily routine to reduce the food you waste, while you will learn how to communicate this information to your family, friends and working environment. To participate: <https://Foodsaveshare.gr>

Tips to reduce food waste:

- Make sure you only purchase the food you will consume.
- Make a shopping list.
- Store the food in an appropriate way so that it can be preserved for a longer period.
- Check the expiration date regularly and consume the products before they expire.
- Look for recipes which help you use the food supplies in your cupboard or your refrigerator.
- While preparing and cooking your meal aim at minimizing the leftovers.
- Serve small portions on the dishes: if necessary repeat.
- Stay informed on alternative food preservation techniques (in brine or vinegar, freeze fresh vegetables etc.).
- Do not hesitate to choose "ugly" fruits and vegetables, as long as they look fresh.
- Read carefully and learn about the difference in the indications: "Best before" and "use by".
- Keep your fridge clean and in good condition.



(b)

Figure 12. Outside (a) and inside (b) of the FoodSaveShare campaign trifold brochure (distributed in Greek but presented here in English for convenience).

In this context, the FoodSaveShare App provides an innovative platform for monitoring reported household-generated food waste. Limitations aside, the amount of mined information (e.g., food inventory) reduces user input dramatically, thus rendering such an app better situated for such monitoring. Future versions of this or other applications addressing food waste management may focus on allowing additional (possibly optional) user input on the actual amount of product consumed or wasted, and providing tips about optimal storage of purchased food items. Nevertheless, the feature that would have a major impact on household food waste digital management is the incorporation of expiration dates in machine-readable form, ideally together with the product barcode.

4.3. End-User Survey

Regarding end-user motivation, compared to similar studies [47,65–67], participation by social media platform users was satisfactory. Our survey showed that a substantial share of users that already actively participate in social media interactions do not use mobile apps to organise their food purchases and would rather use other means. This target group, which is relatively homogeneous in terms of gender and belongs mainly to older generations (i.e., 45+), is accustomed to more traditional ways of organising food purchases (e.g., using paper lists or simply being more disciplined). It is also interesting that those who cited reasons pertaining to GDPR as a hurdle for using such an app were initially fewer (3.4%) than those who did not own a smartphone (3.8%); however, mentioning the use of the retailer loyalty card increased those concerned to as much as 16.0% of those likely to otherwise use an app under certain conditions. This is a well-justified attitude, as concerns over data sharing are often voiced due to perceived lack of standards, incentives, and trust between data providers and users, ownership, and lack of time [68]. However, here we found that the majority of participants would likely install such an app and also provide permission for the use of their personal data. Notifications on product expiration date and food product inventory were ranked highly among participants' preferences, which shows that this information is greatly valued and an important motive for using such an app. However, similarly to what other case studies found, effectiveness and time requirements are major concerns for the end-users [69].

4.4. Limitations

While this study contributes significant results towards ICT developments in household food waste management, it is important to acknowledge certain limitations in the research design and methodology. Regarding the applicability of FoodSaveShare as a survey application, limitations such as the availability of baseline information, control samples, reporting transparency, etc., that pertain to other sampling methods [10] also exist here. Additionally, the application does not consider cases where part of a product is consumed, and the rest is wasted. Regarding the end-user survey, while the sample size is limited, it falls within the range of sample sizes analysed in previous surveys that assess household food waste generation [9]. Furthermore, survey analysis run during sampling (i.e., at roughly 70% of the sample) yielded results identical with those documented for 100% of the sample, pointing to significant stability of the results.

5. Conclusions

Our study identifies critical gaps in the current research and practical applications aimed at reducing household food waste. Despite the urgent need for effective solutions, there is a notable scarcity of comprehensive digital tools offering integrated strategies for food waste prevention that engage users and instigate behavioural change. By providing a shared shopping list, keeping an expiration date log for food purchased at the cooperating retailer, providing timely push notifications for inventory products close to expiration, and providing easy access to recipes for using up leftovers, FoodSaveShare responds to these gaps and strives to modify those food-related routines that directly or indirectly have an impact on food waste generation. Unlike existing tools, FoodSaveShare integrates with retailer loyalty schemes and is tested under real customer conditions, thereby offering a novel contribution to the field. To our knowledge, this is the first app focusing on food waste prevention at the customer level in Greece. Moreover, the end-user motivation and barriers survey, which showed that potential users are still somewhat reluctant to share personal data, such as those stored by the retailers in their loyalty scheme, towards food waste minimisation, is the first of its kind in Greece.

By advancing the understanding of how digital tools can support sustainable household food management practices, our research contributes to the academic field of sustainability, especially in the context of SDG 12 and particularly Target 12.3, highlighting the role of innovation and technology in promoting sustainability. While the app addresses the

lack of similar apps in the Greek context, it has a much wider orientation, beyond the many stakeholders of the application project, including end users and food trade businesses globally. Under the limitation of baseline information, control sample availability, and usage transparency, future work can take advantage of FoodSaveShare or its development framework to assess the impact of various food-saving measures on user behaviour.

The implications of our study are far-reaching, suggesting that apps like FoodSaveShare could be key in cutting down household food waste, benefiting both the environment and the economy. Our findings indicate the importance of user engagement and the effectiveness of integrating digital tools with existing retail systems to motivate sustainable consumer habits. Additionally, our research provides clear guidance for policymakers, developers, and retailers on using technology to reduce food waste. It is evident that retailers have a great advantage over third-party developers in developing and distributing such tools since they already store the necessary sensitive information. However, they also have a social and environmental responsibility to utilise this advantage for the greater good. Our findings illustrate how innovative tools can transform consumer habits towards sustainability, emphasizing the need for more innovation and synergies in this vital field.

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Institutional Review Board Statement: Ethical review and approval were waived for this study, due to anonymous and voluntary participation in this survey.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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