Original scientific paper http://doi.org/10.24867/JGED-2022-3-005

Adaptation of smart-object dimensions in the product design process to reduce household food waste

ABSTRACT

Food waste is a huge problem across the world, but it's especially bad in developed countries such as Malaysia, according to the previous study. It is estimated that 1.3 billion tonnes of food are lost or wasted every year, accounting for one-third of all food produced for human consumption. Hence, the goal of this study is to supplement the solution within the framework of product design process based on the evaluation of food waste behaviour among household in Malaysia. As an approach for acquiring empirical data, a survey study was conducted with 52 respondents in Malaysia, including an analysis of similar existing products on the market, which was then followed by the design process. The findings suggest a multitude of design needs in preventing food waste behaviour among household in Malaysia, including the issues of the existing similar products on the market. Therefore, a few design criteria have been proposed and a set of semi-working food tracking models was successfully developed as a proposal for potential future development and production. It is hoped that the outcome of the study exhibits the synchronization of the product design process inside the smart-object dimensions in order to generate the design that helps to manage and reduce the amount of food waste created among household in Malaysia.

KEY WORDS
Design Thinking, sustainability, food waste, Internet of Things, Smart-Object dimensions

Muhammad Jameel Bin Mohamed Kamil [1]
Chuah Ee Hua [2]
Mohd Najib Abdullah Sani [1]

[1] Universiti Malaysia Sarawak, Design Technology Programme, Faculty of Applied and Creative Arts (FACA), Sarawak, Malaysia
[2] Universiti Sains Malaysia, Product Design Department, School of The Arts, Penang, Malaysia

Corresponding author:
Muhammad Jameel Bin Mohamed Kamil
e-mail:
jameelkamil@gmail.com

First recieved: 14.9.2021.
Revised: 6.12.2021.
Accepted: 13.12.2021.

Introduction

According to Gustavsson et al. (2011), when food is abandoned in the last stage of the food supply chain (FSC), which is at the retail and consumption levels, it is referred to as “food waste”. Meanwhile, Bekteş, (2010) defines food waste as the purposeful or inadvertent disposal of any organic substances that are considered as "food" in terms of culture or biology.

It is estimated that 1.3 billion tonnes of food are lost or wasted each year, accounting for one-third of all food produced for human use (Gustavsson et al., 2011). Garrone, Melacini & Perego (2014) stress that food waste and losses at the retail and consumer level in the United States average 188 kg per capita per year, or $165.6 billion in total. Meanwhile, in Malaysia, Jereme et al. (2016) indicates that households created the largest food waste in Malaysia, with the majority of unconsumed food waste consisting of expired bread, eggs, and rotten fruits, which excluded leftover food. Malaysia is well-known for its diverse and distinctive culinary culture; nonetheless, food in Malaysia is

being abandoned at an alarming rate at the consumer level. On a daily basis, roughly 16,688 tonnes of food are thrown away, enough to feed 12 million people. As Malaysia's population was predicted to reach 33.4 million

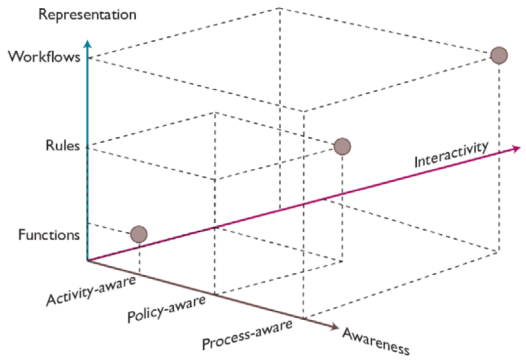
by 2020 and 37.4 million by 2030, this issue is projected to worsen in the next years, owing to economic development, population increase, and urbanization. According to Gunders (2012), food waste in the home is caused by a variety of factors, including lack of knowledge, label date confusion, spoiling, impulsive and bulk purchases, poor planning, and over-preparation, all of which are mostly related to consumer behaviour. Those leftovers are created either because some people are unaware of how to consume leftovers or because they are unaware of how to preserve food for later use in the first place. Gunders also indicates that by shopping carefully, recognizing when food goes bad, purchasing product that is fully edible even though it is less visually appealing, preparing only the quantity of food they need, and eating leftovers can help customers waste less food. Thus, it is critical to modify customers' food waste habits in order to reduce food waste.

Table 1

Food waste generated in Malaysia, adopted from Jereme et al. (2016)

Estimated food waste generated in Malaysia	Generation rate		
Source of food	**(Tonnes/day)**	**(Tonnes/year)**	**Percent**
Household	8,745	3,192,404	38.32
Wet and night markets	5,592	2,040,929	24.50
Food court / restaurants	5,319	1,941,608	23.35
Hotels	1,568	572,284	6.87
Food and beverages industries	854	311,564	3.41
Shopping malls	298	106,288	1.30
Hypermarkets	291	106,288	1.28
Institutions	55	26,962	0.32
Schools	45	21,808	0.30
Fast food / chain shops	2521	808	0.26
Total	**22,793**	**8,331,589**	**100**

This is a product design research paper that examines the problem of food waste among household in Malaysia. Product design is a discipline that has grown as a vital role in producing an innovative product via research and development. One of the current ways to improving human and value quality is to incorporate the human factor into product design by studying human behaviour, obstacles, and needs (Kamil & Abidin, 2013; Kamil & Abidin, 2015; Kamil, Abidin & Hassan, 2018; Sani et al., 2019; Kamil, Abidin & Hassan, 2019a; Kamil, Abidin & Hassan, 2019b; Chumiran, Abidin & Kamil, 2020; Kamil, Shi & Sani, 2020; Sani et al., 2020; Kamil & Sani, 2021). Through the creation of the food tracker design, the major goal of this research is to emphasise the possible growth of theoretical research that is complementary to design practises in order to develop future product design innovation that is coherent to user demands. The food tracker design was built using the frameworks of smart object as propagated by Kortuem et al. (2010). According to Kortuem et al. (2010), the smart object framework was inspired in part by the success of radio-frequency identification (RFID) technology, which is now extensively used for monitoring things, people, and animals. RFID system design is distinguished by a significant contrast between basic RFID tags and a vast infrastructure of networked RFID readers. The notion of the Internet of Things (IOTs) was inspired by the concept of smart objects produced, which articulated within the system architecture, design and development, and human interaction. In terms of core design and architectural concepts, there are three canonical smart object types: (1) activity-aware objects, (2) policy-aware objects, and (3) process-aware objects. Interactivity with function, rules, and processes was formed by these types. In order to build the food tracker design in this study, these frameworks were employed as a template for improving the system's operations. The explanation of the product design process in this study, seeks to extend the breadth of knowledge, leading to further design research inquiry with sustainability relevance.



» **Figure 1:** *Smart-object dimensions illustrate the three canonical object types, activity-aware, policy-aware, and process-aware, adopted from Kortuem et al. (2010).*

The study of the availability and efficacy of current ICT-based solutions and smart technologies for consumer food management and waste reduction

Vogels et al. (2018) investigates and assesses the availability and efficacy of current ICT-based solutions and

smart technologies for consumer food management and waste reduction. It was part of the REFRESH EU research initiative, which seeks to help Europe achieve its objective of decreasing food waste. The study has been conducted based on the strategies as follow: (1) social recipes, which refers to a community- based system of food sharing (Lim et al., 2014; Lim et al., 2017; Yalvaç et al., 2014); (2) eco-feedback, which refers to comparing one's own food waste behaviour to others (Lim et al., 2017); (3) apps and wearables, where different apps and a wearable camera were tested by consumers (Farr-Wharton, Foth & Choi, 2013; Farr-Wharton, Choi & Foth, 2014a; Ng et al., 2015; Hoem, 2017); (4) interactive or smart fridge, which aimed to help consumers organizing the food in their fridge (Rouillard, 2012; Farr-Wharton, Choi & Foth, 2014b; Nguyen et al., 2015); and (5) indirect and direct persuasion, where two variants of a recipe website were investigated in relation to consumer's environmental attitudes and their recipe choice (Aleahmad et al., 2008). Table 2 illustrate the list of apps divided in different categories based on the main functionality that have been included in the study.

According to the study, many of the applications accessible in app stores were created by individuals, have little functionality, and are not updated regularly, but commercial apps created by businesses are generally better maintained, have more feature, and have more installations. Limited functionality, sporadic updates, inadequate information from unknown sources, and inferior usability appear to be the most significant shortcomings of the currently existing apps (especially in apps with combined functionalities). According to Vogels et al. (2018), users appear to be open and interested in applications that assist reduce food waste, according to the study. Many users, however, stated that they could

Table 2

The list of apps divided in different categories based on the main functionality that have been included in the study by Vogels et al. (2018)

Categories	App's Name	Developer	Platform
Reminder apps	BEEP- Expiry Date Barcode Scanner	GPworks	Android
	Date Limite+	Loïc SENCE	Apple IOS
	Expired & Grocery Monitor	Y&A China	Android
	Expiry Date App	EWK GmbH	Android
	Expiry Reminder	CBWorkshop	Android
	Expiration Alarm	MND Apps	Android
	Food Expiration Track	TouchSi Co., Ltd.	Android
	Food Expiration Date	OcApps	Android
	Food 'n Stuff	Sirius Cybernetics Corporation	Android
	FoodLocker	Christian Ghelardoni	Apple IOS
	Food Saver	Salvatore Vivolo	Apple IOS
	Food Storage Helper	Ybgallery	Android
	Food Storage Assistant Pro	DzignStudio	Android
Food sharing apps	OLIO- Food Sharing Revolution	OLIO	Apple IOS, Android
	Ratatouille	Georgia Marenda	Apple IOS
	Afgeprijsd	Gemoro b.v.	Apple IOS, Android
	Too Good To Go	Too Good To Go	Apple IOS, Android
	RedMaden	Martin Bay ApS	Apple IOS, Android
	Rekub	IntoApps	Apple IOS, Android
	Food Share	Mindnotix Software Solutions	Android
	Waste No Food	wastenofood.org	Apple IOS, Android
Planning apps	Bring! Shopping List	Bring! Labs AG	Apple IOS, Android
	Groceree (FJ)	FJ	Android
	Shopping List Voice Input	TK Solution	Android
	Shopping List	Kiwi3	Android
Integrated apps	CogZum	Ivo Dimitrov	Apple IOS
	Eat This Much- Meal Planner	Eat This Much, Inc.	Apple IOS, Android
	Food Planner	MiniMobile	Apple IOS, Android
	Fridgely	Jump Space Apps	Apple IOS
	Frigo App	Stephane Nguyen	Apple IOS
	Frigo Magic	FrigoMagic.com	Apple IOS, Android
	Home-Time	Jay Juillet	Apple IOS, Android
	Love Your Leftovers	Holroyd City Council	Apple IOS
	Slim Koken	Voedingscentrum	Apple IOS, Android

not see an obvious need for such an app since they believed they did not waste much food. Some of the apps were found to be lacking in incentives to reward and reinforce positive behaviour, had poor user-friendliness, and took a long time to use. Despite the fact that certain apps demonstrated tiny, positive increases in awareness and motivation, none of the apps had an influence on self-reported food waste behaviour (meal planning and groceries shopping). Overall, users felt they had to put in considerably more effort (in terms of time, energy, and endurance) than they got out of the programme (convenience, insights and engagement).

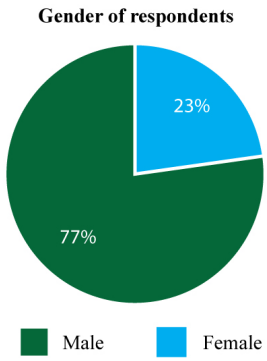
Throughout the study, Vogels et al. (2018) found that user-friendliness is an important factor, implying that the software takes little time to use and requires low cognitive effort to operate. Users will cease using an app if it is not user-friendly. Consequently, using a user-unfriendly software will not result in a change in food waste behaviour. Since users have a minimal intrinsic need to utilise food waste-related apps, Vogels et al. (2018) recommends that the apps should be exceedingly simple to use, with straightforward navigation, a simple app structure, and a limited number of alerts. Users wanted no advertising or banners, but this will be tough with a free app. Manually entering products takes too long and should be automated, such as by scanning food products. To create functionality that makes product input easier and offers correct information about projected remaining shelf life of the items, a well-maintained and up-to-date database of food products is required. However, creating such a database is difficult because most databases are only adequate for one nation and are incomplete. According to Vogels et al. (2018), incorporating a direct insight or highlighting the economic and/or ecological repercussions of user's food-waste related behaviours in an app might serve as an incentive for changing food waste behaviour. Users may establish objectives and observe the impact of their behaviour by incorporating immediate feedback or incentives in applications. Users can also compare themselves to other users. This might boost motivation and increase the likelihood of long-term use of such an app.

Materials, Method and Result

A solid foundation for the design development process set by Godfray (2014), Green, Draper & Dowler (2003), Hoem (2017), Kantor et al. (1997), and McDonald et al. (2006) who investigated the factors associated with food waste behaviour such as: (1) lack of knowledge and understanding of dates labels; (2) unaware of available foods at home; and (3) excessive buying in bulk. Their research, that is also in accord with various research regarding the existing solution to reduce food waste, such as: (1) the decomposition process of organic materials; (2) donating food surplus to people who needed before the food become inedible or spoilt; and (3) minimizing food from getting disposed by reducing the amount of food surplus generation (El–Haggar, Hamoda & Elbieh, 1998; El Haggar, 2010; Poppendieck, 1994; Quested et al., 2011; Skinner, 2017). This information is crucial in the development of food tracker design. In this study, the food tracker design was developed to reduce the amount of food waste created in the household in Malaysia. Therefore, an online survey study was conducted with 52 respondents in Malaysia. The context of the survey study was specifically designed to obtain and clarify the evaluation of food waste behaviour among home consumers in Malaysia, including the optimal design function to be applied in the food tracker design. Respondents were given 20 minutes to complete the survey study.

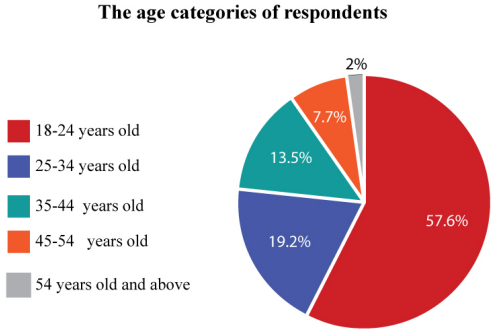
Phase 1: Assessing the Design Needs

The analysis of survey study was part of the design development process to inform design needs and enforce a defined design direction. During Phase 1, the survey results was analysed using Statistical Package for the Social Sciences (SPSS) to get a knowledge of the respondents' food waste behaviour and the appropriate design function required. The results of the survey study are illustrated in figures and table.



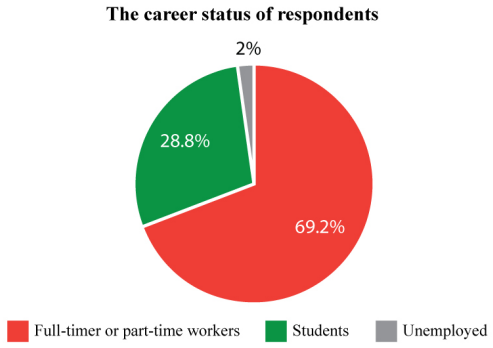
» **Figure 2:** *Gender of respondents*

Figure 2 depicts the gender of respondents who took part in the survey. Based on the data, the majority 77% of respondents are women in comparison to men (23%).



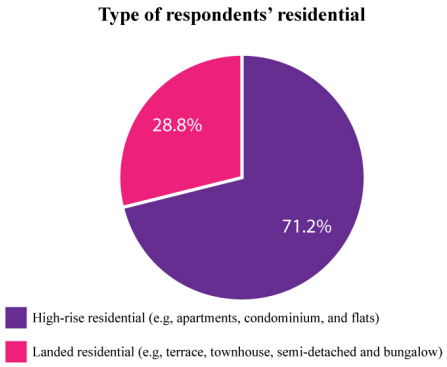
» **Figure 3:** *The age categories of respondents*

Meanwhile, Figure 3 illustrate the age categories of respondents who took part in the survey study which indicates that most of the respondents who took part in the survey study were made up from the age range of 18-24 years old (57.6%), while only 19.2% of the respondents come from the age range of 25-34 years old. Moreover, 13.5% and 7.7% of the respondents respectively from the age range of 35-44 and 45-54 years old, whereas only 2% of the respondents are from the age range of 54 years old and above.



» **Figure 4:** *The career status of respondents*

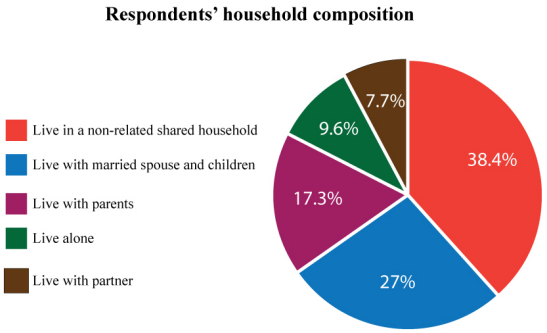
On the other hand, Figure 4 illustrates the career status of respondents which indicates that the majority 69.2% of respondents are full-timer or part-time workers while 28.8% of the respondents are students. Only 2% of the respondents are unemployed.



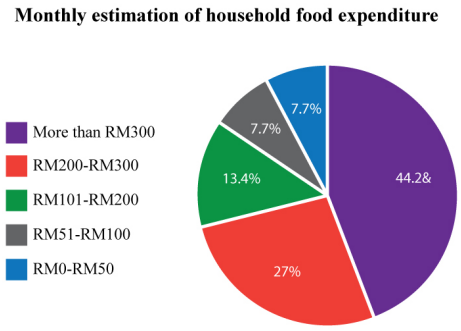
» **Figure 5:** *Type of respondents' residential*

Figure 5 show the type of respondents' residential. Based on the result, the majority 71.2% of respondents are living in high-rise residential such as apartments, condominium, and flats in comparison to landed residential (28.8%) such as terrace, townhouse, semi-detached and bungalow.

Furthermore, Figure 6 illustrate the respondents' household composition. Based on the data, the majority 38.4% of the respondents are staying in a non-related shared household followed by 27% of respondents who are staying with their married spouse and children. Meanwhile, only 17.3% of the respondents are living with their parents, followed by 9.6% of the respondents who are living alone, whereas 7.7% of the respondents are living with their partner.



» **Figure 6:** *Respondents' household composition*

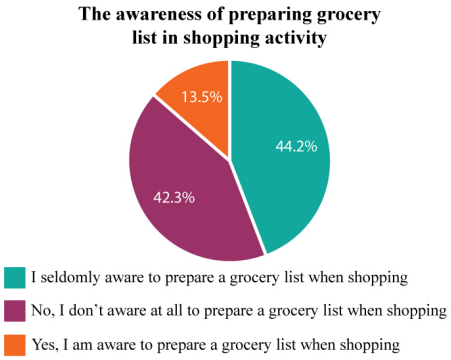


» **Figure 7:** *Monthly estimation of household food expenditure*

Figure 7 depicts the result of a survey in which respondents were asked about the monthly estimation of household food expenditure. Based on the data, the majority 44.2% of the respondents spend more than RM300 for food monthly. In addition to this number, 27% of respondents spend approximately RM200-RM300 for food monthly, followed by 13.4% of the respondents who spend around RM101-RM200 monthly.

Meanwhile, only 7.7% of the respondents who monthly spend around RM51-RM100 and RM0-RM50 respectively. As a result, it is reasonable to conclude that while monthly estimates of family food expenditure vary, the majority of households would spend more than RM300 on food each month.

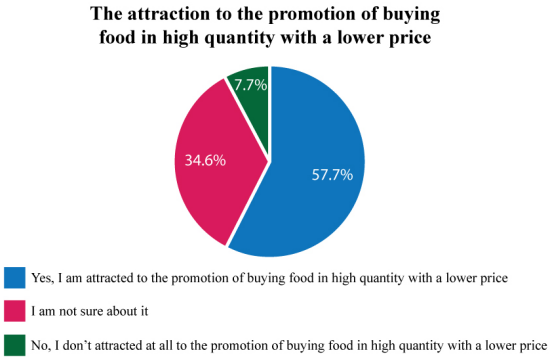
Figure 8 depicts the result of a survey in which respondents were asked about the awareness of preparing grocery list in shopping activity. Through the result, only 13.5% of the respondents are aware to prepare a grocery list when shopping while the majority 44.2% of respondents are seldomly aware to do so. However, 42.3% of the respondents did not aware at all to prepare a grocery list when shopping.



» **Figure 8:** *The awareness of preparing grocery list in shopping activity*

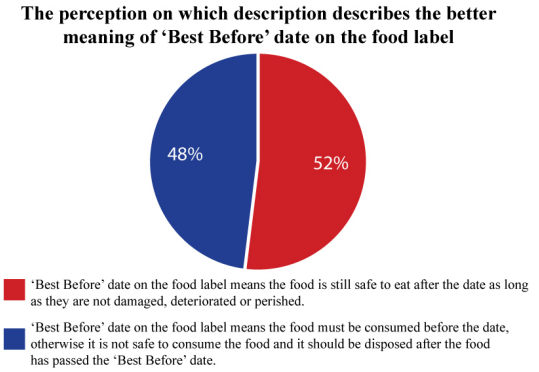
Hence, it is possible to infer that household awareness of the need of making a food list when going shopping is still low. This might lead to impulsive grocery shopping and food waste.

Figure 9 depicts the result of a survey in which respondents were asked about their attraction to the promotion of buying food in high quantity with a lower price. Based on the result, the majority 57.7% of respondents are attracted to the promotion of buying food in high quantity with a lower price while 34.6% of respondents are unsure about it. Meanwhile, merely 7.7% of respondents were uninterested in such promotions. Therefore, it is reasonable to conclude that the promotion of purchasing large quantities of food at a cheaper price has a significant influence on household purchasing decisions, resulting in needless grocery purchases and food waste.



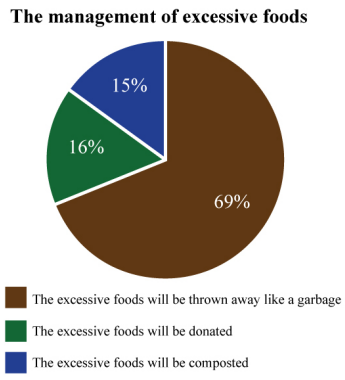
» **Figure 9:** *The attraction to the promotion of buying food in high quantity with a lower price*

Figure 10 illustrates the result of a survey in which respondents were asked about their perception on which description describes the better meaning of 'Best Before' date on the food label. Through the study, the majority 52% of the respondents perceived that 'Best Before' date on the food label means the food is still safe to consume after the date as long as they are not damaged, deteriorated or perished. Meanwhile, 48% of respondents perceived that 'Best Before' date on the food label means the food must be consumed before the date, otherwise it is not safe to consume the food and it should be disposed after the food has passed the 'Best Before' date. Based on the results, it is reasonable to conclude that more than half of the respondents in this survey were unaware of or misunderstood the date labelled, which according to Green, Draper & Dowler (2003) is connected to household food waste behaviour.



» **Figure 10:** *The perception on which description that best describes the meaning of 'Best Before' date on the food label*

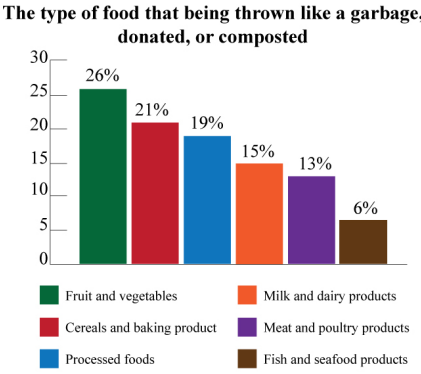
Figure 11 illustrate the result of a survey in which respondents were asked on how they manage the excessive food. The study revealed that, the majority 69% of the respondent indicates that they eventually throw away the excessive food like a garbage. Meanwhile, 16% of the respondents donated the excessive food, whereas only 15% of the respondents composted excessive food. Based on the data, it is plausible to conclude that more than half of the participants in this study are practicing a food waste behaviour.



» **Figure 11:** *The management of excessive foods*

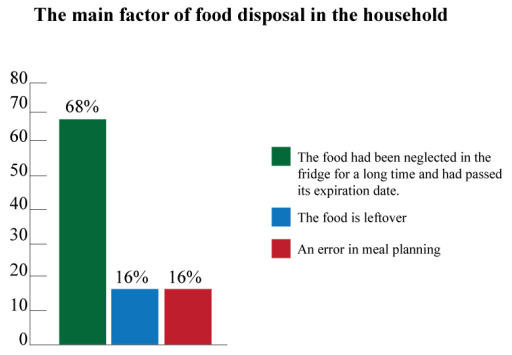
Figure 12 shows the results of a survey in which respondents were asked what type of food they threw away, donated, or composted. According to the data, fruit and vegetables are the most common type (26%) of excessive food thrown out, donated, or composted, followed by cereals and baking product (21%), processed foods (19%), milk and dairy products (15%), meat and poultry prod-

ucts (13%), and finally fish and seafood products (6%). Based on the data, it can be inferred that the percentage of food that is thrown away, donated, or composted varies depending on the type of food; nevertheless, fruit and vegetables have the greatest percentage.



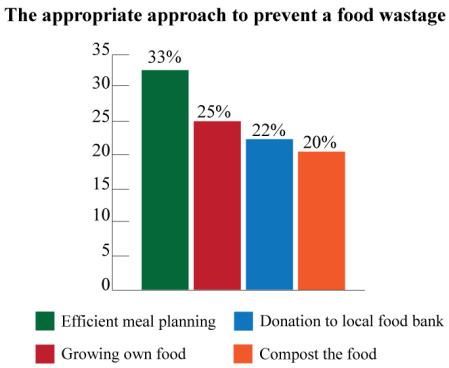
» **Figure 12:** *The type of food that being thrown like a garbage, donated, or composted*

Figure 13 depict the result of a survey in which respondents were asked about the main factor of food disposal in their household. The result indicates that the majority 68% of the respondents disposed the food because it had been neglected in the fridge for a long time and had passed its expiration date. Meanwhile, both leftovers and error in meal planning share the same percentage of 16% as a factor for the food being disposed. Based on the data, it is reasonable to conclude that food that has deteriorated, been damaged, or perished as a result of being forgotten in the fridge for a lengthy period of time and having passed its expiration date is becoming the major factor in household food disposal.



» **Figure 13:** *The main factor of food disposal in the household*

Figure 14 depict the result of a survey in which respondents were asked about the appropriate approach to prevent a food wastage. The data illustrate that the majority 33% of the respondents perceive that an efficient meal planning would be the appropriate approach to prevent a food wastage, followed by growing own food (25%), and donation to local food bank (22%). However, only 20% of the respondents indicates that composting would be the best choice.



» **Figure 14:** *The appropriate approach to prevent a food wastage*

Throughout the analysis of the survey, the information of condition and situation of food waste among household was provided based on the assessment of respondents' perception, behaviour, and background, including a multiple design needs and opportunities for the household. The understanding of the design needs through the survey study help to determine the optimal design function and design knowledge that may be improved further in the food tracker design process. As a result, five elements of solutions were developed based on the summary of the survey study (see Table 3).

Table 3

The description five elements of solutions

Elements of solutions	Descriptions pre-processing classification
Management of supply procurement	The food tracker should be able to manage purchased supplies and update the remaining food quantities in the household regularly to prevent possessed food from deteriorating, being damaged, or perishing, resulting in its disposal.
Utility, Conveniences, and Efficiencies.	The food tracker design should be able to provide users with the elements of utility, conveniences, and efficiency to boost the interactivity between the potential users and designed product.
Perception and Awareness	The food tracker design should be able to perceive potential users with the awareness of their possessed foods.
Activity Tracking	The food tracker design should be able to provide potential users with tracking features to manage and plan their possessed foods.
Personalisation and Appeal to Emotion	The food tracker design should be aesthetically appealing and easier to personalize.

Phase 2: Generating Design Ideations

Previously in Phase 1, the five elements of solutions were generated through the result of survey analysis. Meanwhile in Phase 2, the five elements of solutions help in brainstorming process to generate the design criteria of the food tracker design (see Table 4).

Table 4

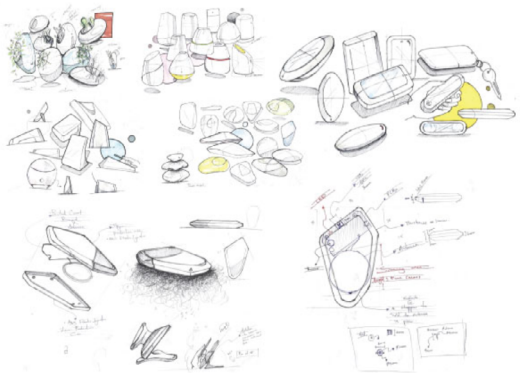
The description design criteria

Design Criteria	Descriptions pre-processing classification
Simplicity and minimalist	Aim to provide potential users with the simplicity of tracking food with minimal effort through advancement of technology.
	Minimalist interface.
	Implementing the concept of Internet of things (IOTs) in the designed product.
User friendly	Aim to provide potential users with the elements of utility, conveniences, and efficiency.
	User-friendly interface to boost the interactivity of the potential users.
	Connecting to various hardware using RFID technology for better tracking.
Interactive	Aim to provide potential user with the awareness of their possessed foods.
	Interactive and simplistic interface, reminder, planner, and notes.
Emotional design	Aim to help elevating potential users' positive thoughts through element of aesthetic.
Aesthetic	Aims to make the design form and interface more appealing and help to boost interactivity of the potential users.
	The colour of design form and interface inspired by nature to interactively react to the potential user's visual thought.
	Elegant design.
	Minimalist interface.
Quality material and Apps	Using quality, nimbler, and safer material and apps such as three-dimensional (3D) printed plastic Polylactic acid (PLA) and Adobe XD.

The food tracker design will be integrated with minimalist and simplicity criteria through the application of IOTs concept and minimal interface, based on the stated design criteria. Through technological advancements, it is envisaged that potential users would be able to track their possessed food with minimum effort. Furthermore, it is anticipated that the integration of a minimalist interface with RFID technology would provide potential users with usefulness, convenience, and efficiency. The aforementioned criteria will determine whether or not the designed product is user-friendly. An interactive and intuitive interface, as well as a reminder, planner, and notes, will be incorporated to offer potential users with knowledge of their possessed foods. Furthermore, nature-inspired colour and shape will be used in the design with the goal of raising potential users' good sentiments through aesthetic elements and making the design form and interface more appealing. The colour of the design form and interface inspired by nature is intended to connect with the potential user's visual mind and make the design seem elegant. Finally, we have also suggested that a quality, nimbler, and safer material and apps such as three-dimensional (3D) printed plastic Polylactic acid (PLA) and Adobe XD to be used for design production.

The mood board design concept (Figure 15) was first executed in Phase 2. The mood board was produced as a visual guideline based on the design objectives. Natural forms and shapes, colours, and physical qualities were all employed to create the visual guideline that was used in this study. These visual guidelines help the research team choose the best design direction based on the responses from the survey study. For example, the aesthetic characteristics of food tracker design were influenced by the forms, shapes, and colours of pebble stones. The textural features of the design will be impacted by the physical attributes of natural components buried in pebble stones, such as the soft texture.

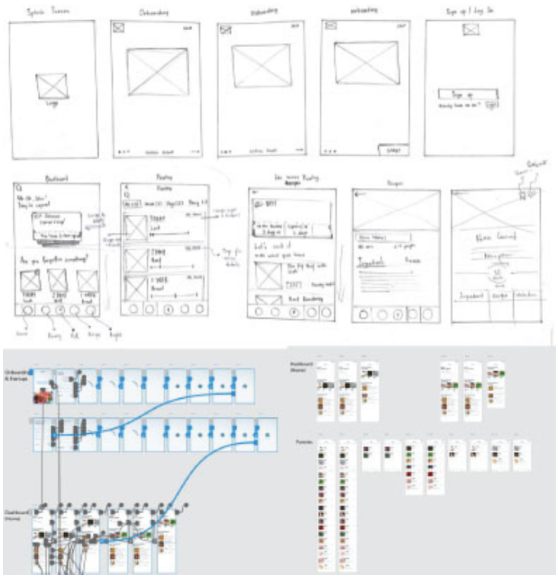
» **Figure 15:** *Design concept mood board*



» **Figure 16:** *Design ideations development*

A sketching activity (Figure 16) based on the mood board design concept was used to start the design ide-

ation process. Throughout the process, components created from design criteria and visual guidelines in the mood board design idea were used to shape the food tracker design's visual shape. Nevertheless, Lo-fi product interface development in sketches was generated before it being transformed into Hi-fi interface using software Adobe XD (see Figure 17).



» **Figure 17:** *Product interface development from Lo-fi interface in sketches to Hi-fi interface using software Adobe XD*

The result of the sketching activity was turned into a three-dimensional (3D) design using Autodesk Inventor 3D Design software at the conclusion of Phase 2 (see Figure 18). The design's dimension and visual look were realistically increased during the process. The 3D design result aids in gaining a thorough knowledge of the food tracker design, including textures, colours, and product dimensions.

» **Figure 18:** *3D design visualization*

Phase 3: Model making process

During Phase 3, the model making process was executed. Making a model helps the research team to see how the product tangible looks, and to ensure that a product is viable. This involved three-dimensional printing process using 'Ultimaker 2+' 3D printer (based on 3D files generated in Phase 2). During the process, the Polylactic acid (PLA) filament spool was loaded into the 'Ultimaker 2+' 3D printer and then fed straight into the extrusion headset to the printer's nozzle. The 0.4mm nozzle of the printer is warmed to the required temperature (around 200-210 °C), and the motor then allows it to melt and pushes the filament through the nozzle. The extrusion nozzle follows the specified coordinates, allowing the blackened material to harden and refresh on the plate. This cross-section printing cycle is continued until the item is entirely produced, layer by layer. Following that, the development of the app interface, the installation of the printed circuit board, and the product furnishing was executed (see Figure 19). Throughout the process, the technical aspects of the model were investigated on a regular basis to ensure that all design flaws were addressed. At the end of this stage, a preliminary grasp of the restrictions inherent to the food tracker design, as well as how real users would behave, think, and feel when handling the end product, was gained.

» **Figure 19:** *3D printing process, printed circuit board installation, and apps interface development*

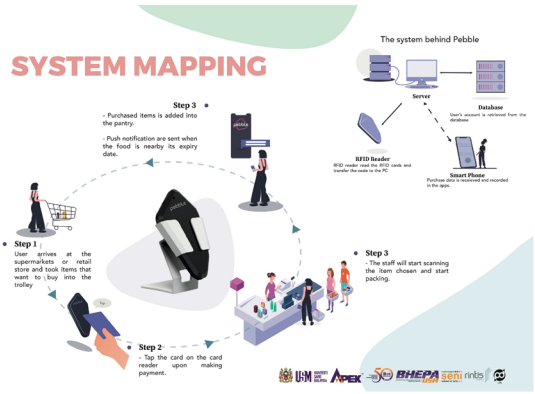
After the serial iteration phases, which include many modifications to fit the correct comfort of the user, the final semi-working model is completed (Figure 20).

» **Figure 20:** *The final semi-working model*

The aesthetic qualities incorporating the current food tracker design style or fashion, as well as the technological consideration highlighting how real users would behave, think, and feel when handling the finished product, are the key features confirming the non-working model.

Discussion

Based on the study, our research team proposes Pebble, a food tracker device aim to minimise the amount of food waste among household in Malaysia. The feature of Pebble food tracker is based on a loyalty scheme that exists in supermarkets. Pebble's apps were designed to keep track of their purchased goods' expiration dates, regularly update the remaining food quantities in the household, as well as to serve as a meal reminder for user since they frequently forget what they have in the house. Buying the same or more food may add to food waste because the commodities are frequently over their expiry date.



» **Figure 21:** *The system mapping of the Pebble food tracker*

Figure 21 depicts the Pebble's system mapping in terms of how the service works. It begins with the user taking the items desired, then the user proceeds to the checkpoint for payment once all of the goods required have been taken. When the user reaches at the checkpoint, they must place their items on the conveyor belts and scan their Pebble card. The cashier system will retrieve information and data about the user's account in Pebble applications once the card is tapped. The staff began scanning the products and retrieving information from the supermarket's database. Once the payment is completed, the item's details will be saved in the Pebble apps and system. Adapted from the frameworks of smart object propagated by Kortuem et al. (2010), Pebble food tracker was built with RFID tag's reader as a main approach of monitoring the purchased foods. Articulated within the system architecture, design and development, and human interaction through interactive interface and apps, Pebble food tracker enriched the concept of IOTs through three canonical of smart object types:(1) activity-aware objects, (2) policy-aware objects, and (3) process-aware objects. The interactivity of the interface and apps of Pebble food tracker, with function, rules, and processes was formed by these types. Table 5 shows a description of the Pebble's app user interface.

Conclusions

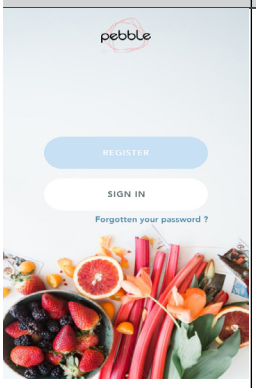
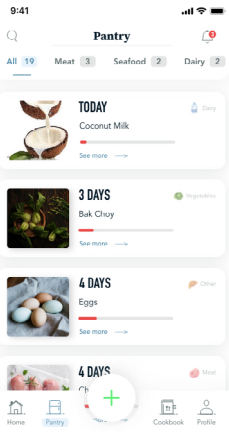
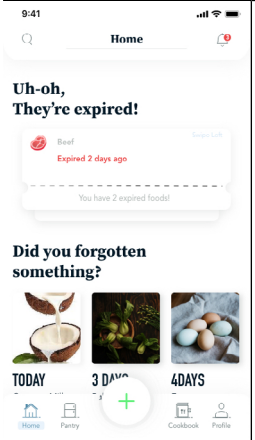
This research has successfully developed food tracking device as its design proposal to reduce the amount of food waste among household in Malaysia. The five aspects of solutions such (1) management of supply procurement; (2) utility, conveniences, and efficiencies; (3) perception and awareness; (4) activity tracking; and (5) personalisation and appeal to emotion are significant to the construction of device, including the apps. The aesthetic design, the integration of interactive interfaces, and the apps criteria in product creation have all contributed to this relevance. Furthermore, because potential users are important stakeholders in design, integrating the empathic protocol into the product design research process emphasises the importance of potential users' feedback. In this situation, the respondents' issue aids in determining the function of the produced design. The five aspects of solutions and design criteria elements have adequately reflected the potential user's need for food waste prevention. The suggested food tracker has the potential to be improved and mass-produced in the future. This may be done by putting the proposed design criteria into practise. The device is expected to help reduce global food waste as a result of this breakthrough. More importantly, the proposed design would allow us to finally reinforce a sustainable development. However, this study has a limitation where a complete user testing and assessment of the product's performance is required in the near future to further evaluate the applicability of the proposed food tracker design. Although there is evidence that apps can raise consumer awareness concerning food-waste related behaviour, such as awareness about which food products are already in stock at home or about product shelf life, more research is needed to determine whether and when these tools are effective in changing consumers' actual food waste. Furthermore, there are additional approaches to influence behaviour that need to be investigated more in connection to food waste behaviour, such as nudging tactics, financial incentives for positive behaviour (compliments, achieving goals, and earning points), and education programmes, among others.

Acknowledgements

Pebble food tracker design copyright number: AR2020004956 is patented under the ownership of Universiti Sains Malaysia.

Table 5

Pebble's app user interface

Interface	Descriptions pre-processing classification	Interface	Descriptions pre-processing classification
	User Registration/Login Pages i. To keep track of the food they have bought, users must first log in to their account. ii. To make it easier for them to control their meals.		Pantry i. Purchased products are listed in a hierarchical order, with the foods that are most likely to deteriorate at the top. ii. The foods are divided into various types to make it easier for users to find what they are looking for. iii. Swipe left on the meal users have consumed, or right on the items they have discarded. iv. The instruction will be statistically recorded.
	Getting a Pebble Card i. Newcomers must fill up their personal information and address in order to receive a Pebble card. ii. The card will be delivered to their address; no card linkage is necessary. iii. Each account is given one Pebble card. However, in a household with a few individuals, multiple cards can be connected to the shared customized account. It gives members of the household more flexibility and efficiency in keeping track of their purchased foods.		Cookbook i. The selected recipe displays a list of components that are readily available in the pantry. ii. Foods that are not in the pantry must be purchased by the user. iii. Select the shopping list icon and enter the necessary quantity. iv. When going grocery shopping, the user may view the list to keep track of what ingredients are required, preventing impulsive purchases and overstocking. v. Recipes and their instructions
	Dashboard i. Expired foods will be presented at the top. ii. Regular update of foods quantities that are about to expire in the household are listed below. iii. Recipe suggestions at the bottom of the page to show users how to use the ingredients in their pantry.		Profile i. The percentage of food consumed or discarded is displayed. ii. The user's purchase history is displayed below to help them keep track of and manage their monthly budget. iii. Grocery List (Left) iv. Barcode scanning — Scanning items purchased without a point-of-sale system (i.e., wet markets) v. Voice search – Other methods of entering food.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Aleahmad, T., Balakrishnan, A. D., Wong, J., Fussell, S. R. & Kiesler, S. (2008) Fishing for sustainability: the effects of indirect and direct persuasion. In: *CHI Conference on Human Factors in Computing Systems, CHI '08, 5-10 April 2008, Florence, Italy.* New York, Association for Computing Machinery. pp. 3021–3026. Available from: doi: 10.1145/1358628

Bekteş, A. (2010) *Research and product design to minimize food waste in western domestic kitchens.* MSc thesis - Partial fulfillment. Delft University of Technology.

Chumiran, M. H., Abidin, S. Z. & Kamil, M. J. M. (2020) Pre post observation research fosters a preliminary study in product form identity. In: *DS 104: Proceedings of the 22nd International Conference on Engineering and Product Design Education, E&PDE 2020, 10-11 September 2020, Herning, Denmark.* Wiltshire, Institution of Engineering Designers; Glasgow, The Design Society. pp. 1–6. Available from: doi: 10.35199/epde.2020.41

El Haggar, S. (2010) *Sustainable industrial design and waste management: cradle-to-cradle for sustainable development.* Cambridge, Massachusetts, Academic Press.

El–Haggar, S. M., Hamoda, M. F. & Elbieh, M. A. (1998) Composting of vegetable waste in subtropical climates. *International Journal of Environment and Pollution.* 9 (4), 411–420. Available from: doi: 10.1504/IJEP.1998.028254

Farr-Wharton, G., Choi, J. H.-J. & Foth, M. (2014a) Food talks back: exploring the role of mobile applications in reducing domestic food wastage. In: *Proceedings of the 26th Australian computer-human interaction conference on designing futures: The future of design, OzCHI '14, 2-5 December 2014, Sydney, Australia.* New York, Association for Computing Machinery. pp. 352–361. Available from: doi: 10.1145/2686612.2686665

Farr-Wharton, G., Choi, J. H.-J. & Foth, M. (2014b) Technicolouring the fridge: reducing food waste through uses of colour-coding and cameras. In: *Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia, MUM '14, 25-28 November 2014, Melbourne, Australia.* New York, Association for Computing Machinery. pp. 48–57. Available from: doi: 10.1145/2677972.2677990

Farr-Wharton, G., Foth, M. & Choi, J. H. (2013) EatChaFood: challenging technology design to slice food waste production. In: *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication, UbiComp '13, 8-12 September 2013, Zurich, Switzerland.* New York, Association for Computing Machinery. pp. 559–562. Available from: doi: 10.1145/2494091.2497311

Garrone, P., Melacini, M. & Perego, A. (2014) Opening the black box of food waste reduction. *Food policy*. 46, 129–139. Available from: doi: 10.1016/j.foodpol.2014.03.014

Godfray, H. C. J. (2014) The challenge of feeding 9-10 billion people equitably and sustainably. *The Journal of Agricultural Science.* 152 (S1), 2-8. Available from: doi: 10.1017/S0021859613000774

Green, J., Draper, A. & Dowler, E. (2003) Short cuts to safety: risk and'rules of thumb' in accounts of food choice. *Health, risk & society.* 5 (1), 33–52. Available from: doi: 10.1080/1369857031000065998

Gunders, D. (2012) *Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill.* Natural Resources Defense Council. Report number: 26.

Gustavsson, J.. Cederberg, C., Sonesson, U., van Otterdijk, R. & Meybeck, A. (2011) *Global food losses and food waste.* Rome, Italy, FAO.

Hoem, H. (2017) *The potential of a smart phone app to support consumers in preventing household food waste.* MSc thesis. Norwegian University of Life Sciences.

Jereme, I. A., Siwar, C., Begum, R. A. & Talib, B. A. (2016) Addressing the problems of food waste generation in Malaysia. *International Journal of Advanced and Applied Sciences.* 3 (8), 68–77. Available from: doi: 10.21833/ijaas.2016.08.012

Kamil, M. J. M. & Abidin, S. Z. (2013) Unconscious Human Behavior at Visceral Level of Emotional Design. *Procedia - Social and Behavioral Sciences.* 105, 149–161. Available from: doi: 10.1016/j.sbspro.2013.11.016

Kamil, M. J. M., Abidin, S. Z. & Hassan, O. H. (2019a) Assessing Designers' Perception, Analysis, and Reflective Using Verbal Protocol Analysis. In: Chakrabarti, A. (ed.) *Research into Design for a Connected World.* Singapore, Singapore, Springer Singapore, pp. 51–61.

Kamil, M. J. M., Abidin, S. Z. & Hassan, O. H. (2019b) Assessing the Attributes of Unconscious Interaction Between Human Cognition and Behavior in Everyday Product Using Image-Based Research Analysis. In: Chakrabarti, A. (ed.) *Research into Design for a Connected World.* Singapore, Singapore, Springer Singapore, pp. 63–73.

Kamil, M. J. M. & Sani, M. N. A. (2021) The Challenges and Initiatives of Teaching Product Design's Course Online During the COVID-19 Pandemic in Malaysia. *Asia Pacific Journal of Educators and Education.* 36 (1), 113–133.

Kamil, M. J. M., Shi, S. M. L. & Sani, M. N. A. (2020) Re-assessing the Design Needs of Trans-Radial Amputees in Product Design Innovation. *Wacana Seni Journal of Arts Discourse.* 19, 61–71. Available from: doi: 10.21315/ws2020.19.5

Kamil, M. J. M. & Abidin, S. Z. (2015) Unconscious Interaction Between Human Cognition and Behaviour in Everyday Product: a Study of Product Form

Entities Through Freehand Sketching Using Design Syntactic Analysis. In: *International Conference On Engineering And Product Design Education, E&PDE, 3-4 September 2015, Loughborough, United Kingdom.* Glasgow, The Design Society. pp. 369–374.

Kamil, M. J. M., Abidin, S. Z. & Hassan, O. H. (2018) The Investigation of Designers' Reflective Practice Activity Using Verbal Protocol. In: *DS93: Proceedings of the 20th International Conference on Engineering and Product Design Education, E&DPE, 6-7 September 2018, London, United Kingdom.* Glasgow, The Design Society. pp. 363–368.

Kantor, L. S., Lipton, K., Manchester, A. & Oliveira, V. (1997) Estimating and addressing America's food losses. *Food Review/National Food Review.* 20 (1), 2–12. Available from: doi: 10.22004/ag.econ.234453

Kortuem, G., Kawsar, F., Sundramoorthy, V. & Fitton, D. (2010) Smart objects as building blocks for the internet of things. *IEEE Internet Computing.* 14 (1), 44–51. Available from: doi: 10.1109/MIC.2009.143

Lim, V., Yalvaç, F., Funk, M., Hu, J. & Rauterberg, M. (2014) Can we reduce waste and waist together through EUPHORIA?. In: *IEEE International Conference on Pervasive Computing and Communication Workshops, PerCom Workshops 2014, 24-28 March 2014, Budapest, Hungary.* New York, IEEE, pp. 382–387. Available from: doi: 10.1109/PerComW.2014.6815236

Lim, V., Funk, M., Marcenaro, L., Regazzoni, C. & Rauterberg, M. (2017) Designing for action: An evaluation of Social Recipes in reducing food waste. *International Journal of Human-Computer Studies.* 100, 18–32. Available from: doi: 10.1016/j.ijhcs.2016.12.005

McDonald, S.. Oates, C. J., Young, W. & Hwang, K. (2006) Toward sustainable consumption: Researching voluntary simplifiers. *Psychology & Marketing.* 23 (6), 515–534. Available from: doi: 10.1002/mar.20132

Ng, K. H., Shipp, V., Skatova, A. & Bedwell, B. (2015) What's cooking: A digital intervention to encourage sustainable food behaviour using mobile and wearable technologies. In: *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, MobileHCI '15, 24-27 August 2015, Copenhagen, Denmark.* New York, Association for Computing Machinery. pp. 1058–1061. Available from: doi: 10.1145/2786567.2794330

Nguyen, V. N., Nguyen, T. H., Huynh, T. T., Nguyen, V. H. & Stigberg, S. K. (2015) Interactive fridge: a solution for preventing domestic food waste. In: *International Conference on Smart Homes and Health Telematics, ICOST 2015: Inclusive Smart Cities and e-Health, 10-12 June 2015, Geneva, Switzerland.* Switzerland, Springer. pp. 361–366. Available from: doi: 10.1007/978-3-319-19312-0_36

Poppendieck, J. (1994) Dilemmas of emergency food: A guide for the perplexed. *Agriculture and Human Values.* 11 (4), 69–76. Available from: doi: 10.1007/BF01530418

Quested, T. E., Parry, A. D., Easteal, S. & Swannell, R. (2011) Food and drink waste from households in the UK. *Nutritional Bulletin*. 36 (4), 460-467. Available from: doi: 10.1111/j.1467-3010.2011.01924.x

Rouillard, J. (2012) The Pervasive Fridge. A smart computer system against uneaten food loss. In: *Seventh international conference on systems (ICONS2012), 29 February 2012, Saint-Gilles, Réunion, France.* pp. 135-140.

Sani, M. N. A., Kamil, M. J. M., Azahari, B. & Sulaiman, A. R. (2019) The Assessment of the Clubfoot Children's Orthotic Need for the Development of the Foot Abduction Orthosis (Fao) Prototype Design. *International Journal of Advances in Science, Engineering and Technology.* 7 (1), 20–24.

Sani, M. N. A., Amran, A. A., Kamil, M. J. M., Romainoor, H. & Kanyan, L. R. (2020) The appropriation of product design as solution to minimise risk of exertional heat illness among Marathon runners. *International Journal of Human Movement and Sports Science.* 8 (6), 63–67. Available from: doi: 10.13189/saj.2020.080711

Skinner, V. L. (2017) *Our daily bread: the role of soup kitchens in 21st century Adelaide.* PhD thesis - Partial fulfillment, University of Adelaide.

Vogels, J. W. P. M., van der Haar, S., Zeinstra, G. G. & Bos-Brouwers, H. E. J. (2018) *ICT tools for food management and waste prevention at the consumer level.* Supply Chain & Information Management Food, Health & Consumer Research. Report number: 641933.

Yalvaç, F., Lim, V., Hu, J., Funk, M. & Rauterberg, M. (2014) Social recipe recommendation to reduce food waste. In: *Chi Conference on Human Factors in Computing Systems, CHI '14, 26 April - 1 May 2014, Toronto, Canada.* New York, Association for Computing Machinery, pp. 2431–2436. Available from: doi: 10.1145/2559206.2581226