



# Smart Product Design for Food Waste Problem in the Canteen of Chinese University

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**Abstract.** The food waste problem has become increasingly severe, especially in China's developed areas. In the south-east, the food waste problem increased dramatically, especially among young people from 18–29. In this study, 12 university students were interviewed to find out the reasons for food waste. The root causes were found to be the lack of awareness and bad eating habits. At the same time, there is a strong intention that they try to eat healthily and keep in 'good' 'figure'. A smart design solution was proposed based on the calories burnt and stomach capacity to precisely suggest the volume of food people need in one meal, thus reducing the chance of producing food waste. User evaluations were carried out, and the results were mostly positive.

**Keywords:** Smart product design · Food waste · Diet culture · Canteen · China

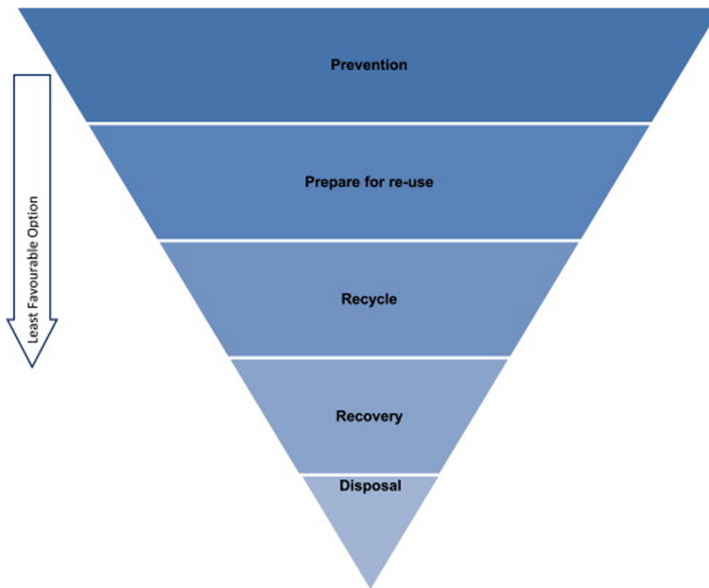
## 1 Introduction

Food waste is a serious problem in modern society for it not only waste resources on the earth, but also cause a serious environmental issue when dealing with the landfill. According to sustainable service company RTS [1], the US wasted 80 billion pounds of food in 2020, and it occupies 30–40% of all food supply in the US. Food waste has an apparent negative impact on the environment, society, and economics [2]. Food is the single most frequently occurred material in our landfills. When food decomposes, it produces methane, a greenhouse gas 21 times more potent than CO<sub>2</sub>. Landfills generate 20% of all methane emissions, which causes serious environmental damage [3]. As for the social impact, food may be no longer sufficient, facing the dramatically increasing population [4]. In the aspect of the economy, FAO (2014) estimated there is 2.6 trillion USD every year associated with food waste, equivalent to 3.3% of the global GDP [5].

With the biggest population, the food waste problem in China has become increasingly serious and is expected to increase by 278–416 million tones as the rapid economic growth [6]. Studies have shown that it is important to deal with campus food waste in China for two reasons. The first one is that in China, the numbers of students on campus have increased a lot, and college students have accounted for more than 10% of the local population. Second, campus food waste solutions can be a typical solution and offer "good practice" to other situations [7].

Studies show that there is a huge generation difference in food-wasting behaviors. Consumers in China have experienced starvation in the 1960s hardly waste food [8]. According to the research from Food and Culture, the young generation contributes to 7.3 million tons of food waste each year in UK [9]. As young people (20–29 years old) in developed areas act worse in wasting food, solving the food waste problem of this generation is urgent. The root cause of their wasting behavior should be found out as well as the motivation factor of food saving behavior. The specific investigating group is university students since they are the typical group of young people who are easily getting access to.

Since food waste is a severe problem, as shown in the data above, reducing food waste is urgent. The food waste hierarchy in Fig. 1 shows the priority of treating food waste: food waste prevention, re-use, recycle, recovery and disposal, respectively [1]. According to the hierarchy, the prevention of food waste should be given priority when considering solutions, and in the prevention stage, dieting behavior is an important aspect.



**Fig. 1.** Food waste dealing hierarchy [2]

Dieting behavior is frequently mentioned in the publications. Studies have shown that dieting knowledge has a significant influence on household food waste [10]. For example, young adults (18–25 years) are generally vulnerable to weight gain who are also the group of people that have improper diet behavior [11]. This study aims to further explore the relationship between eating habits, the motivation of dieting behavior, and food saving actions and, a design solution was proposed the food waste problem in the context of the university canteen. In the design process, problems are firstly identified, and related programs are analyzed, then the target was set to be the young generation,

and detailed user interviews were carried out to find out the root cause of food wasting behavior. Next, design solutions were proposed, and experiments were done to test the feasibility of the plan. In the end, conclusions were made, and further research plans were stated.

## 2 Related Studies

In this section, the related studies on food waste are investigated to understand food production and consumption.

### 2.1 Food Waste from the Production Line

Many governments and organizations are currently carrying out campaigns to deal with the food waste problem. The food waste problem can either be blamed on the producer or customer. Food waste generated from the production line, and some programs to prevent customer food waste were listed and analyzed.

The reason for the food waste problem from the production line can be categorized into the following four points.

- Production line inefficiencies
- Packaging failure
- Waste from restarting the production line
- No financial benefit if redistribute food [12]

Although these defects can be eased by refining the production line, like shortening the time for the machine to reach the production standard, the liftable span is really limited. Most of these issues are related to technical bottlenecks and do not contribute to a large amount of food waste, focus should be turned to the customer side instead.

### 2.2 Customer Side Food Interventions

There are many different interventions against customer food waste, including informational interventions which are the most frequently used. This includes education and training on food waste problems, prompting methods such as signs and stickers, or video portraying certain practices [13]. Although these kinds of methods cost the least, the level of involvement is limited, so they are not always effective. Some people may even not notice the information notification attaching to the table when they are having a meal.

Other programs focus on the specific situation only. For instance, Harvard Business School carried out a program of diverting food from events and conferences. These foods are often untouched [14]. This program has its drawbacks. First, it does not consider how to avoid food waste but instead focus on dealing with excess food. Second, the food redirected after the conferences may decrease quality and may affect people's health. Third, it may be effective in specific situations, but cannot solve the problem in the broader setting.

Practitioners are also paying attention to HCI in solving the issue of food waste, some small-scale design products for food producers using some interactive technologies, buy doing these, they want to promote sustainable customer buying behavior. Others focus on where food waste goes. For instance, they install BinCam on the rubbish bin and post the picture of wasted food on Facebook for reflection [15]. There is a trend to solve social problems using technology, and the usage of the mini camera mentioned above can effectively document daily food waste for further investigation, it can also raise people's awareness of how much food they waste and the content of the food they waste, thus reduce the chance they buy extra food in the future.

However, there is still a gap to increase the practicality of these methods. Several aspects can still be improved. First, a higher level of involvement is needed. Some methods (especially information intervention) only provide the customer with some messages without getting feedback. Second, using technology to influence people's behavior. Although HCI has been applied in some practices, they are mainly used as documentation and raising people's awareness, the level of interactivity should be increased. Third, detailed user research should be carried out to find the motivation behind customer food saving behavior. Dieting behavior is to be considered since there is a study stating that dieting behavior is closely related to food saving [10].

### 2.3 How to Decide How Much Food People Need?

**Calories Need.** The amount of food people need depends on many factors, including height, age, sex. The general state of health, job, leisure time activities, physical activities, genetics, body size, environmental factors, composition, and medications are taken [16]. Although many factors are influencing the food needed, the main measuring standards are calorie burnt and basic body parameters (Table 1).

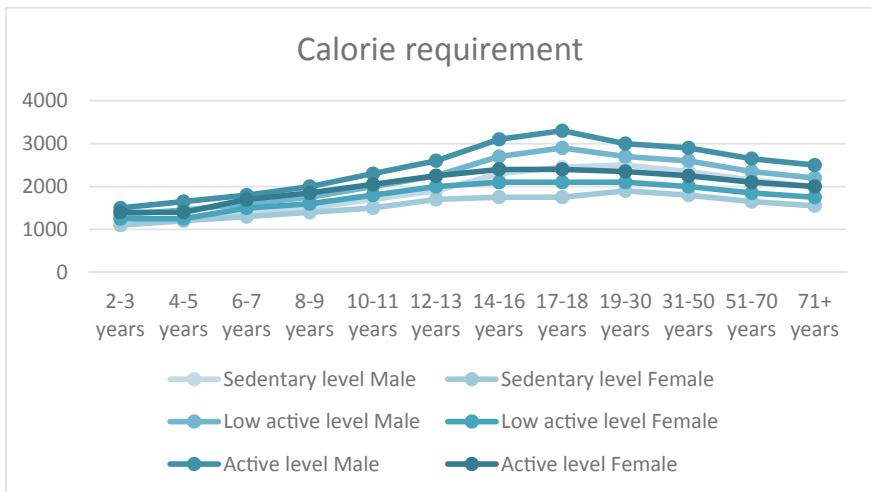
According to the data from MedicalNewsToday, calorie requirement difference on gender and age is plotted, and there is an increase in trend from age 2 to 18, while the decrease from 18 years old, male generally require more calorie intake than female as shown in Fig. 2 [16].

**Stomach Capacity.** Experts have suggested that using calories to evaluate the number of food people should eat is not enough. Another important factor to evaluate how much food people can eat is stomach capacity. The stomach capacity can alter with age and body size, and people may feel discomfort if the stomach is stretched beyond its normal volume [17]. If the stomach is full, the body will send a satiety signal to the brain, and one will no longer willing to eat more. At the same time of eating meals, the stomach is also digesting the food, different food has different digestion rate, so the signal of feeling full may also be delayed. The phases of feeling from hangry to full are shown in Fig. 3 below.

From the study done by JC. Lynegaard et al. (2020) about piglet stomach capacity, it is shown that the capacity of the stomach has a linear relationship with body weight (Fig. 4). From the limited data, it shows that the higher the body weight, the bigger the capacity of the stomach [18] (Table 1).

**Table 1.** Factors that influence calorie consumption (Yvette Brazier 2018) [16]

| Age         | Sedentary level |        | Low active level |        | Active level |        |
|-------------|-----------------|--------|------------------|--------|--------------|--------|
|             | Male            | Female | Male             | Female | Male         | Female |
| 2–3 years   | 1,100           | 1100   | 1,350            | 1250   | 1,500        | 1400   |
| 4–5 years   | 1,250           | 1200   | 1,450            | 1250   | 1,650        | 1400   |
| 6–7 years   | 1,400           | 1300   | 1,600            | 1500   | 1,800        | 1700   |
| 8–9 years   | 1,500           | 1400   | 1,750            | 1600   | 2,000        | 1850   |
| 10–11 years | 1,700           | 1500   | 2,000            | 1800   | 2,300        | 2050   |
| 12–13 years | 1,900           | 1700   | 2,250            | 2000   | 2,600        | 2250   |
| 14–16 years | 2,300           | 1750   | 2,700            | 2100   | 3,100        | 2400   |
| 17–18 years | 2,450           | 1750   | 2,900            | 2100   | 3,300        | 2400   |
| 19–30 years | 2,500           | 1900   | 2,700            | 2100   | 3,000        | 2350   |
| 31–50 years | 2,350           | 1800   | 2,600            | 2000   | 2,900        | 2250   |
| 51–70 years | 2,150           | 1650   | 2,350            | 1850   | 2,650        | 2100   |
| 71+ years   | 2,000           | 1550   | 2,200            | 1750   | 2,500        | 2000   |



**Fig. 2.** Calorie requirement difference on gender and age

Calorie burnt and stomach capacity is two important factors influencing a person’s need for food. They can be indicated and measured when suggesting the amount of food needed.

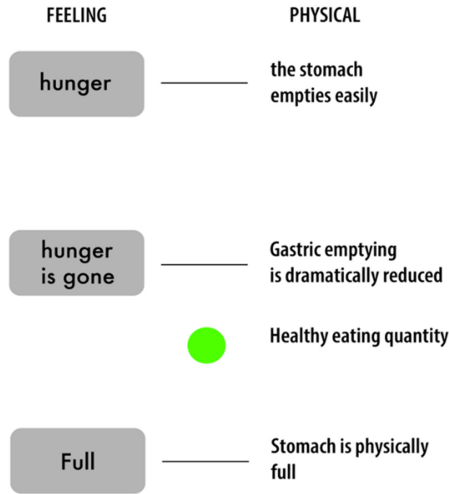


Fig. 3. Stomach capacity and feelings of fullness in different stages of eating

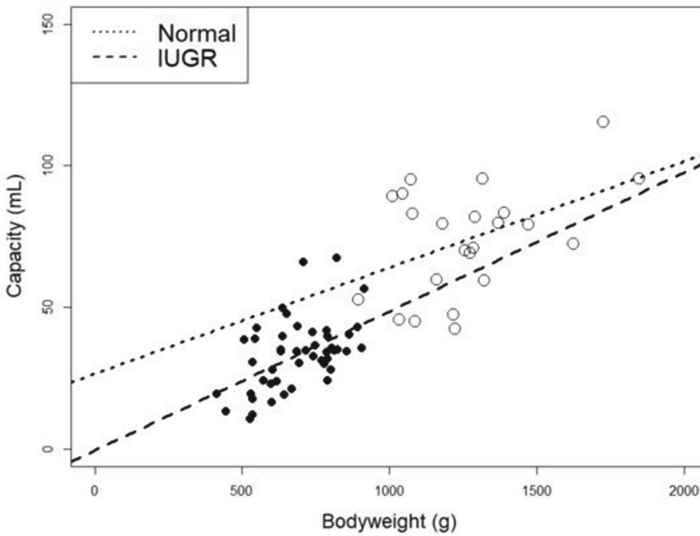


Fig. 4. Stomach capacity versus body weight (JC. Lynegaard et al. 2020) [18]

### 2.4 Food Consumption in the Canteen

According to the research, food waste in the canteen (meal catering system) is generated through four aspects: spoilage, meal preparation, unserved food, and plate waste. The latter two points which are defined as untouched food, are estimated to occupy approximately 14% per capita of waste in EU27 [19].

A study conducted in the school of UL canteen shows that most users left at least 1/3 of the food, indicating a lack of awareness, the performance of student's food saving

behavior was measured using the waste consumption index (WI), the lower the WI, the higher the consumption.

$$WI = \frac{RMW \times 100}{AMW \times \text{numMD}} \quad (1)$$

RMW = rejected meal weight

AMW = Average meal weight

numMD = number of meals served per day

WI measurement: Great-0.0 to 3.0%; Good-3.1 to 7.5%; Bad-7.6 to 10.0%; unacceptable-over 10.0%

The result from the UL canteen shows that the WI was classified mainly as Bad and Unacceptable, representing a serious problem in canteen food waste. The average food waste per student is about 220g [19].

### 3 Interview of University Students

To further understand the food waste situation in a Chinese university, the interview was conducted with 12 university students to investigate their eating habits and the reasons behind the action of wasting food.

#### 3.1 Questions for the Interview

Consumer behavior and foodservice mode research regarding food waste by Jessica, et al. (2015) was used as a reference and two questions were prepared for the interview [20]:

- Do you waste food? / Why do you waste food? (Consumer behavior)
- Under which circumstances do you most likely to waste food? (food service mode)

In addition, according to the research by Qusted et al. (2013), that consciousness is also an important factor in food waste and the following two questions were asked [8].

- If the food is too much for you, do you aware of that if you ordered too much before you made the order?
- If you realized, do you still want to order that much food?

#### 3.2 Analysis of the Interview

The interview content is guided by these questions but not limited to, aiming to create an open chat and finding out what people think. For the first question ‘Do you waste food?/Why do you waste food?’, only 1 out of 12 people said he never wasted food, the rest of the people said they wasted food in different situations. The reasons that they mentioned are (1) Part of the meal they don’t like so they only pick out the part they like

and eat them (2) The meal is too much for them to eat (3) When they tried new dishes and found that they did not like it (4) They overbought or overorder the meal because they felt hungry at the beginning.

The second question ‘Under which circumstances do you most likely to waste food?’ The result is that 5 out of 20 people mentioned that they tend to waste food when the serving mode is self-serving and since they care about the variety of the food, they tend to pick up different food, which is more than what they need. What’s interesting is that almost half of the students interviewed replied they cannot eat up the rice in one meal.

When asking the two questions about the consciousness aspect of wasting food, (1) 10 out of 12 people said they only decide how much food they need to eat based on common sense, and they are quite confident about their standard. (2) None of them know the exact amount of food they need to eat. (3) 5 out of 12 even said they never thought of eating up all the food ordered, but only finishing those parts that they like to eat. Table 2 shows the frequency of mentioned statements in the interview.

**Table 2.** Frequency of mentioned statement.

| Statements  | Frequency of mention |
|---|----------------------|
| Do not know how much they need to eat (only based on common sense)                  | 10/12                |
| Rice is often too much  | 8/12                 |
| Only like to eat certain kind of food   | 6/12                 |
| Not want to eat up all the food/ do not care if they have to throw them away or not | 5/12                 |
| Tend to waste food at the buffet  | 5/12                 |
| Would like to get a scientific guide on healthy eating                              | 11/12                |

### 3.3 Findings from the Interview

**Reasons.** From the FoodPrint organization (2020), the reasons for wasting food can be oversized portions, the inflexibility of meal selection size, and extensive menu choices. It can also be the result of some over-buying and over-preparing behavior [21].

From the interview, the following problems of the participants were found:

- Not aware of how much food and money wasted
- Overestimate the amount of food that can be eaten.
- Tend to eat only the part that the author likes.
- Waste a lot of rice.

From the literature review and interview, the root cause of young people wasting food can be summarized to be the lack of awareness of food waste and bad eating habits.



**Motivation Factor.** As mentioned in the interview results, almost all the people interviewed mentioned that they would like to get a scientific guide on healthy eating. According to the study conducted by A.S.poobalan et al. (2018), the characteristics of the young generation can be summarized into four aspects [11].

- They tend to care about the variety of ‘food’.
- They eat more food if they love it.
- The main motivation factor for diet behavior was ‘self-‘appearance’.
- They have positive attitudes towards a healthy diet, while do not eat healthily. The self-reported overweight/ obesity trend is about 22%.

Based on the existing issues of non-healthy eating and their strong motivation to have good self-‘appearance’, having a healthy meal and keep fit can be the motivating factor to have healthy eating habits. Therefore, it is reasonable to connect the controlled food quantity with reducing food waste. In addition, if people get the proper amount of food that they need, it can reduce the chance to have surplus food and thus reducing food waste. Calorie burnt and stomach volume are two factors that limit a person’s food intake, certain data need to be collected to precisely calculate the food need.

## 4 Design Solution

### 4.1 Design Flow

From the interview and the literature research, it is found that the key thing behind the food waste behavior of young people is the lack of awareness and bad eating habits. There is also a finding of their strong desire to eat properly and healthily to have a ‘good’ ‘figure’.

The research and experiment above indicate that there is a way to inform the user of the detailed calorie and volume they consume every day, and they will be less likely to waste food. Based on the research, a design solution logic was generated as shown in Fig. 5.

Three information sources will indicate the meal selection process of users.

- The user’s data, like age, sex, weight, height, etc.
- The user’s calorie burnt, which can be measured using the app on the smartphone, as well as the calorie of food taken (through food detecting)
- The data collected by the apps, which includes daily consumption and daily burnt calorie, this data will give the user a better understanding of their eating habit and enable them to eat more healthily.

This system can be applied in a buffet or canteen, where the user can self-serve the food for themselves. It can not only better suggest the amount of food needed for the food products but also help people reduce food waste and get better health.

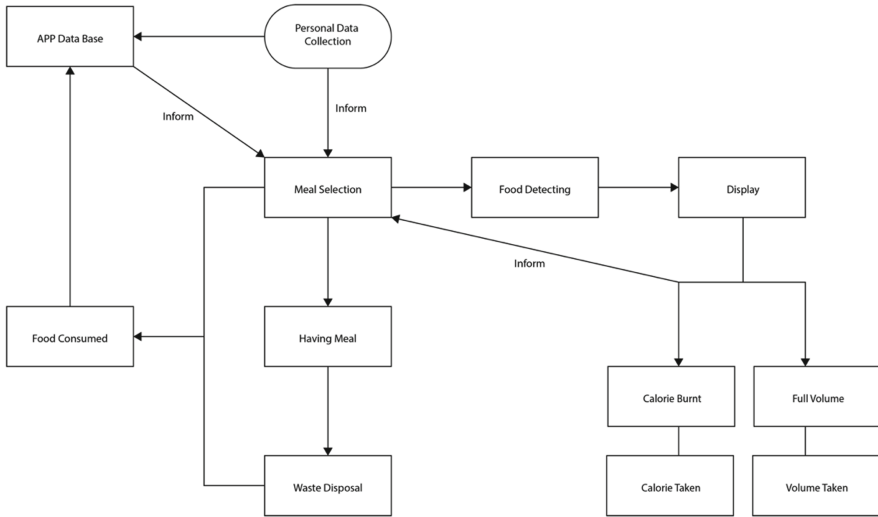


Fig. 5. Design solution logic

### 4.2 Calculation of Food Intake

After knowing how much food people need, it is also important for the system to calculate the calorie of food people get on their plate, the following two methods were tested for the system.

**Based on Resistance Difference of Food.** Different food has different resistance range, in this experiment, two different fruit, apple (500–1000) and cucumber (<500) were used as specimens, and the algorithm was set to display the relevant fruit name on the LCD, this easy-to-understand principle works when we want to detect the food in the plate (Fig. 6).

A circuit was built, and the code was uploaded to the Arduino Uno board to simulate the food detecting process (Fig. 6). From the experiment, utilizing resistance difference was proved to be an effective way to detect different kinds of food and may be possible to apply to the system. Although different food may have overlap in their resistance range, it still may work in the canteen setting when there are only limited types of food (Fig. 7).

**Spectral Analysis.** Spectral analysis is also an effective method to detect the food content; it is a more precise food-scanner than using resistance range [22]. For instance, researchers developed the TellSpec to detect nutrients and calories of the food, whose working principle is similar to the technology used to detect cancer in blood samples. The system of TellSpec has three parts: (1) Spectrometer scanner (2) an algorithm that exists in the cloud (3) an interface on your smartphone, as shown in Fig. 8.

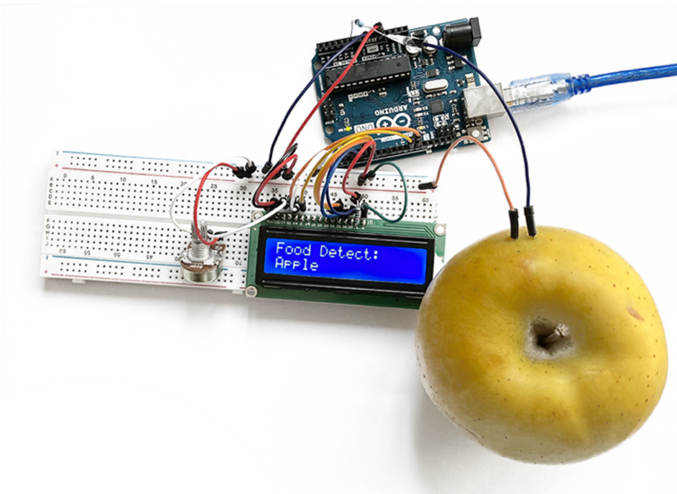
**Volume.** The food volume calculation should also be considered since volume capacity is another criterion to measure how much food people need. After acquiring the information about food type, relevant density ( $\rho$ ) values which are pre-stored in the database

```

const int frootSense = 0;
int frootResistance, high = 0, low = 1023;
int frootDetect;
#include <LiquidCrystal.h> //remove this if u don't have LCD, anyw
LiquidCrystal lcd(12,11,5,4,3,2); //remove this if u don't have LCD, anyway:
void setup(){
  Serial.begin(9600);
  lcd.begin(16, 2); //remove this if u don't have LCD, anyways it i
  lcd.clear(); //remove this if u don't have LCD, anyways i
}
void loop()
{
  lcd.clear(); //remove this if u don't have LCD, anyways it wont af
  lcd.setCursor(0,0); //remove this if u don't have LCD, anyways it wont affect.
  lcd.print("Food Detect:"); //remove this if u don't have LCD, anyways it wont
  lcd.setCursor(0,1); //remove this if u don't have LCD, anyways it wont a
  frootResistance = analogRead(frootSense);
  Serial.print("Resistance:");
  Serial.print(frootResistance);
  Serial.print("\n");
  if (frootResistance>1000 & frootResistance<1500){
    Serial.print("Apple \n");
    lcd.print("Apple"); //remove this if u don't have LCD, anyways it wont affect.
  }
  else if(frootResistance>500 & frootResistance<1000){
    Serial.print("Cucumber");
    lcd.print("Cucumber"); //remove this if u don't have LCD, anyways it wont affect.
  }
  else {
    Serial.print("No Food \n");
    lcd.print("No Food"); //remove this if u don't have LCD, anyways it wont affect.
  }
  delay(1000);
}

```

**Fig. 6.** Programming for the resistance range test



**Fig. 7.** Food testing with Arduino



**Fig. 8.** TellSpec for nutrients detection [23]

will be exacted. Another information that needed to know is the gram of food and the volume can be calculated using the equation:

$$V = \frac{m}{\rho} \quad (2)$$

In this experiment, programs were written, and a weight detector using the HX711 Balance module with the load cell was used, which can measure the weight of the food. (Fig. 9). The testing device is shown in Fig. 9.

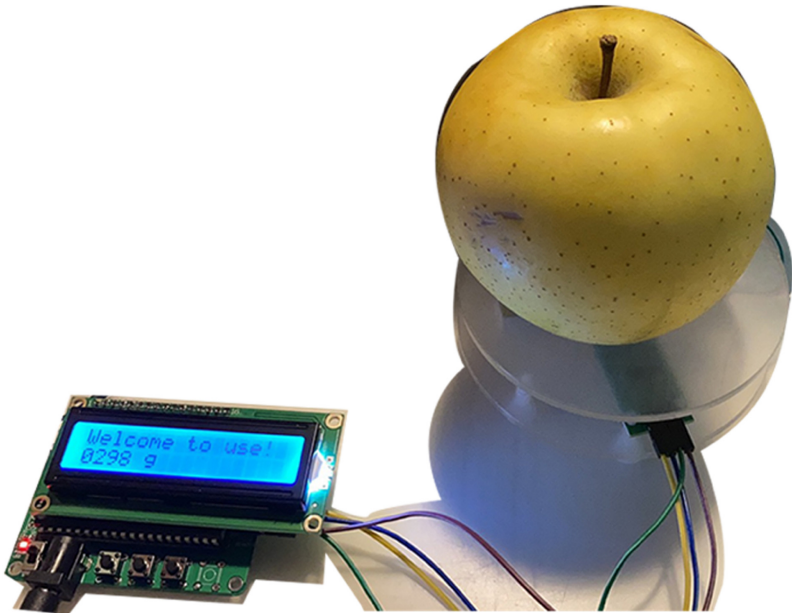
From the weight test, precise weight result was got in grams. It proved that utilizing a weight sensor is a possible way to detect the volume of food, with the help of other data available.

### 4.3 Final Concept

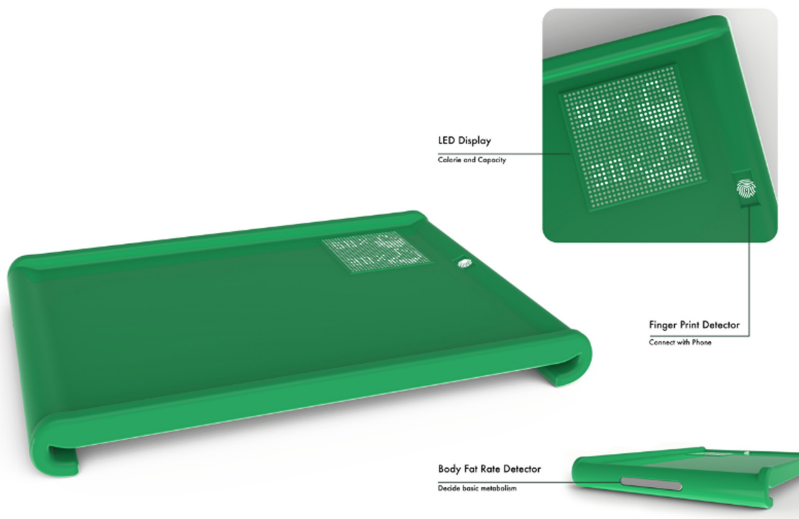
The concept from this design flow is called Future Canteen, a new way people interact to select the meal in the canteen. By selecting the type of food and put them on the plate, the relevant information about calorie consumption and volume capacity will show on the right side respectively (Fig. 10). Based on the research, two evaluation standards were used, calorie burnt and stomach capacity.

### 4.4 User Feedback

To test the effectiveness of this system, five students were interviewed, and feedbacks were analyzed. 3 out of 5 students say that this system will effectively enable them to know how much food they can eat and expect to get good health. One student mentioned that he always overestimates the amount of food he can eat due to the feeling of the



**Fig. 9.** Apple weight test



**Fig. 10.** Plate with measuring capability

hanger and waste a lot of food instead and this system will help him to avoid such a situation. Another student says she has the requirement to control the food intake,

and it is always good to know more about herself. There are a few negative feedbacks as well, two students concern that this system may somehow limit their freedom of selecting food, they worry they will not be able to eat whatever they like affected by these recommendations. Although there is both positive and negative feedback, most of them are positive.

Several implications from these feedbacks were found. Firstly, the two standards (calorie burnt and stomach capacity) should not be so strict, and there should be more data analysis to find a proper range of calorie and capacity. By doing this, the system provides more freedom for people to select the meal. Secondly, a customized plan may be preferred for people with a specific requirement for eating (e.g., control sugar intake).

## 5 Conclusion

Food waste is a serious global issue and in the context of Chinese university canteen, the situation has unique characteristics, which can influence the diet culture and habits. In this study, a design study to quantify 'people's diet scientifically, thus reducing food waste and enabling and enabling young people to live a healthier life. Compared to other programs, this proposal presents a more effective method to solve food waste, since it aims to change young' people's eating behavior and meets their need to keep in good figure. It also utilizes the current technology to collect and provide useful information to the users. The study will reduce food waste and go further to contribute to environmental protection.

Since the target group is young people in developed area of China and this study only focus on university students, the data may not be that representative without other young people in different background involved.

Future studies should further test the effectiveness of this system, for instance, typical user target will be recruited for longitudinal empirical evaluations, and their food waste data will be recorded and evaluated in the long run in the canteen setting.

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