

Development of Food Container with Spoilage Detector

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Abstract

The researchers developed an upgraded food packaging that can detect food spoilage. The research was inspired by the present issues in the industry regarding food waste and food safety. This endeavor is driven by three Sustainable Development Goals (SDG) with an objective for all nations to have a common goal that will lead to stability and economic growth. Qualitative and quantitative methods were utilized in this study, specifically interviews and surveys. The qualitative approach was used to gather insights from experts for technology development. A survey was conducted to determine relevant information regarding the market. The survey was also utilized for validation from consumers and for determining the product's market viability. About 100 respondents from the National Capital Region participated in the study. The technical feasibility aspect of the product was determined through product testing in the Department of Science and Technology-Industrial Technology Development Institute (DOST-ITDI), preliminary manufacturing, and production assessment. Based on the initial manufacturing assessment, the daily yield is 200 units and 4,400 units monthly. This study was viewed to be viable because it has a payback period of one year and seven months. The startup business begins with modest profits and sales but progressively grows over the years, leading to higher sales, profits, and positive cash flow.

Keywords

Food Packaging, Food Safety, Food Spoilage Detector, Food Waste, Hydrogen Sulfide Sensor

1. Introduction

The development of a food container with a spoilage detector called “Waste Not “was driven by the need to address specific issues related to the packaging and food industry. These issues are food waste and food safety. Food waste is a severe problem that affects the economy, environment, and society. It significantly contributes to global issues such as climate change and pollution. According to Lewis (2022), food that has been allowed to rot in landfills emits methane, which is twenty-five times more potent than carbon dioxide and contributes about 20% of greenhouse gas emissions worldwide. Another problem in the industry that is crucial to maintain and that prompted the development of a spoilage detector is food safety. According to Hanson (2021), the repercussions of food safety issues may result in minor to fatal outcomes for both consumers and food business owners. For consumers, it may be mild abdominal pain and diarrhea to debilitating infections and chronic illnesses, while for business owners, it may be its reputation and future. Upon identifying these two issues, the researchers seek to find a solution to help address the said problems. The initiative also supports three Sustainable Development Goals: Sustainable Cities and Communities, Partnership for the Goals, and Responsible Consumption and Production.

The packaging industry in the Philippines is one of the industries that have a considerably good market. In particular, the demand for food containers is rapidly growing because proper packaging tremendously improves the shelf life of a food product. In the specific instance of the project, Waste Not’s goal is to provide a food container with the capacity to identify food spoiling, track the shelf life of food to prevent food waste and check the food’s humidity and temperature conditions. The Waste Not is a food container that can detect food spoilage, and it comes with an application that can monitor the real-time status of the food. Users will be notified about the food status

through the application and email. Waste Not is set to be introduced to the industry, providing consumers with a new option for packaging and, at the same time, to ensure food safety and lessen food waste.

1.1 Objectives

The proponents' primary goal is to produce a new innovative product for the packaging industry that would help lessen food waste and, at the same time, ensure food safety. This study intends to investigate the viability of a developed product called Waste Not, a locally developed food container with a spoilage detector. Listed below are the other detailed aims and objectives of the study:

1. Propose an improvement in the packaging industry.
2. Establish the features and relevance of the proposed product.
3. Identify the cost of producing the product.
4. Test the product's technical feasibility.
5. Determine the specific target market and identify the product's market position.
6. Develop marketing strategies.
7. Establish future plans for product improvement.

2. Literature Review

The packaging industry is part of the business sector that involves anything about the design and production of packaging products (McMahon 2022). It is considered one of the industries in the Philippines with a considerably good market. The packaging industry in the Philippines is regarded as one of the most dynamic in the ASEAN area, primarily in the food industry, which provides for about half of the industrial output and 23-24% of the yearly GDP (Lavorini 2019). The demand for food containers is rapidly growing because of the fact that proper packaging tremendously improves the shelf life of a food product. According to Sand (2020), good packaging of food products extends shelf life and, at the same time, helps in meeting the demands of the food industry globally. Instances of poor packaging result in a reduced shelf life, which then presents food safety issues. According to GlobalData (2022), a data analytics company, the packaging market size in the Philippines in 2021 was valued at 60 billion units and is projected to have a Cumulative Annual Growth Rate (CAGR) for 2021 to 2026 of more than 4%.

There are several gases produced once food gets spoiled. According to Preethichandra et al. (2022), together with ammonia, one of the two harmful gases produced by bacteria during the food spoilage process is hydrogen sulfide. Hydrogen sulfide is a gas produced from decaying organics like microbes found in rotting food (Shao 2019). This means if hydrogen sulfide is detected in the food, the food is not already safe to consume. About 10 ppb to 20 ppm of hydrogen sulfide is present in spoiled food, depending on the type of food and stage of its spoilage (Preethichandra et al. 2022).

Another important factor that affects food spoilage is humidity (Yuan et al. 2020). Elevated humidity levels in several products, such as food, may stimulate bacterial growth, cause a decrease in shelf life, and potentially result in complete deterioration or spoilage (Zhang et al. 2023). Deviations from the ideal moisture level can adversely affect food products, not only the food's quality but also its safety (Moore 2020). This is why humidity is one of the things to consider when storing foods to ensure the safety of consumers.

3. Methods

The researchers sought if it is feasible to develop a food container that is also capable of detecting food spoilage. The study comprises studying the market aspect, which refers to whether or not there is a market for the specified product. The technical part pertains to the product's manufacturability and viability, and the financial component relates to business revenue growth.

This product has been developed considering three phases. The first step is the use of a qualitative technique, specifically interviews with experts, to gather insights for tech development. The second phase is the actual development of the product based on the information collected from experts. The final step is the validation from the target consumers for the need for the product using a quantitative method.

The researchers initially conducted an interview with experts to identify the necessary aspects to consider for product development and to determine the feasibility of the features planned to be incorporated into the product. After the actual tech development, the proponents determined whether or not the product has a market. A need

analysis was carried out, and a survey questionnaire was sent using online forms. The collection of questions contains demographic data, buying behaviors, spending habits, and particular features desired by the potential client while designing the new food container.

4. Data Collection

The proponents interviewed experts before the technology development to gather relevant information regarding the product. The experts interviewed were a chemical engineer, an electronics engineer, and a food technologist. A chemical engineer was one of the professionals interviewed because the product's purpose is to detect food spoilage, which is considered a chemical process. An electronics engineer was also consulted to share their expertise and knowledge about product development and to determine the necessary components of the product. Lastly, the proponents interviewed a food technologist to gain an understanding of the process of developing packaging for food products and seek some recommendations for the appropriate material for the product.

For the technology development, the first step is the conceptualization and research for the prototype. After consulting the experts, the proponents finalized the components to be used in the product. The second step is outsourcing the components. The components, specifically the sensors, were then tested to check if it does detect food spoilage. Following the component testing is the 3D designing and printing. Then, the firmware development for the base program and the front-end software development for the IoT mobile and dashboard. After developing the application, the next step is product assembly and hardwiring. Upon finishing the product, preliminary testing was done. After gathering the results, final software modifications were done for both firmware and the front end. The product underwent final testing after all the minor alterations.

To validate the need for the product and its market potential among consumers, the researchers made use of a survey. The study had 100 respondents from the National Capital Region out of its 13,484,462 population. The sample size was obtained by setting a confidence level of 90% and an alpha value of 0.10 in Raosoft. To further validate the sample technique adequacy, a KMO test was conducted. The results show that the KMO value is 0.904, and above 0.90 KMO value indicates a superb level of acceptance.

5. Results and Discussion

Would you like to buy/use a container that is able to detect food spoilage?

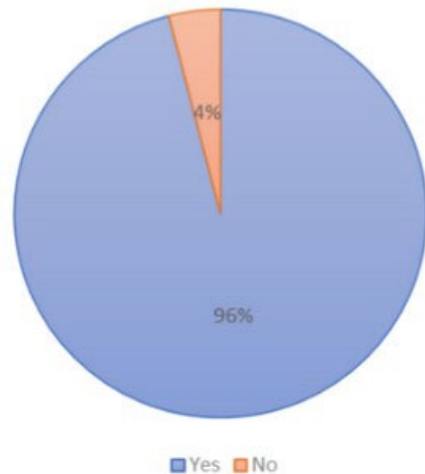


Figure 1. Customer's Willingness to Buy

Figure 1 shows that the majority of the respondents prefer to buy or use a container that can detect food spoilage. Based on the interview with a chemical engineer, the indicators of food spoilage could be pH level indicators,

methane gas sensors, and hydrogen sulfide sensors. But the issue stated with pH level indicators is (although) it is (a) possible indicator it's not applicable to all food products (C.B.K. Mayo, personal communication, March 13, 2023). For the methane gas sensors, the interviewee said, the problem with methane gas sensors is that it sometimes takes too long for methane gas to evolve from the food product (C.B.K. Mayo, personal communication, March 13, 2023). However, the best option that the interviewee provided is the hydrogen sulfide sensor. According to the interviewee, hydrogen sulfide is also one of those chemical products that come from food spoilage...a lot of food products has sulfur and once it devolves or once it decomposes, it (gets) mix with the water content (of the food), producing hydrogen sulfide (C.B.K. Mayo, personal communication, March 13, 2023).

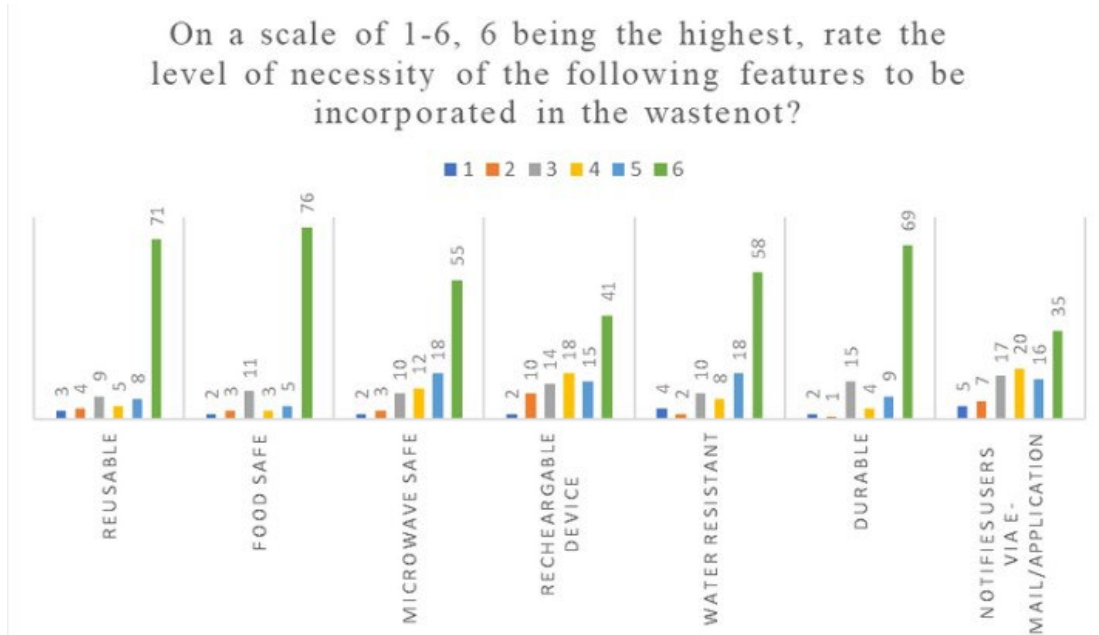


Figure 2. Features Customers Look for

Figure 2 shows the list of features that customers look for and the features' perceived level of necessity. According to the market survey, the top three things customers look for in a food container are reusable, durable, and food-safe. The advisable material for reusable packaging is corrugated plastic. According to the food technologist interviewed, the best reusable packaging is the fabricated corrugated plastic because it is easy to use, easy to bring, easy to clean, and reusable. It helps the food to prevent absorption of nasty flavors and odors (J.H. Corpuz, personal communication, April 17, 2023). Polypropylene is one the plastics that are proven to be food-safe, reusable, and durable. The other features shown in Figure 2 are water-resistant, microwave-safe, rechargeable, and notifying users. Based on the interview with an electronics engineer, there are ways to make batteries and electric circuits water-resistant. According to the interviewee, to make the batteries water resistant, there is something called a special waterproof battery pack that you put the batteries in. It's like special cases for batteries that are used mostly in water activities like fishing (and) boating (P.J. Santos, personal communication, March 16, 2023). For electrical circuits, the interviewee said, for electrical circuits, there is something called a coating, a special coating called conformal coating, this what protects the components of a circuit board so that it does not get wet or moist. Or to avoid anything that can damage the circuit board (P.J. Santos, personal communication, March 16, 2023).

On a scale of 1 to 6, 6 being the hardest, how hard is it to identify if your food is spoiled?

100 responses

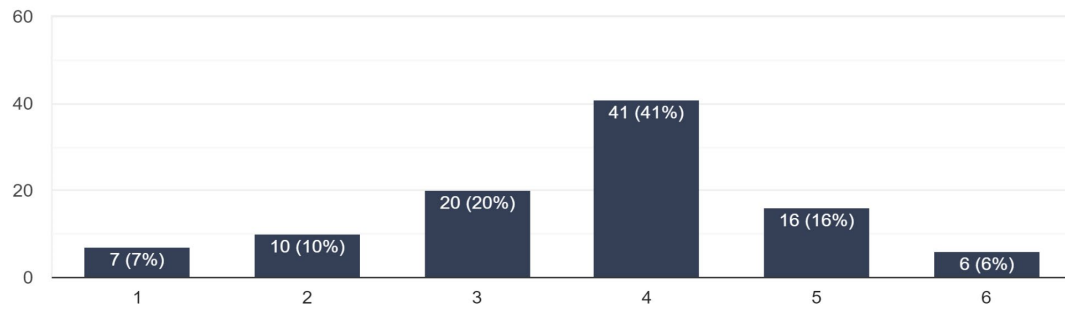


Figure 3. Level of Difficulty in Identifying Food Spoilage Based on Consumers

Figure 3 shows that the majority of the respondents find it difficult to identify if the food is spoiled. 1-3 on the scale indicates that it is easy to determine food spoilage, and 4-6 indicates the struggle.

WasteNot is a food spoilage detector integrated into a food container's lid that provides information to its users about the status of their stored food through email and application notifications. It intends to help people detect food spoilage easily to avoid food poisoning. At the same time, it aims to prevent people from wasting food by accurately knowing whether their food is safe to consume. The logo on the container lid lights up once it detects food spoilage. The product is reusable, food-safe, fridge-safe, and rechargeable. Figures 4 and 5 below show the two versions of the design of the product.

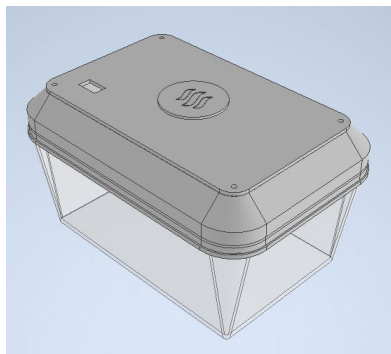


Figure 4. Product Design Version 1

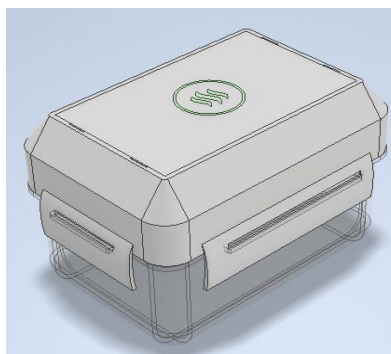


Figure 5. Product Design Version 2

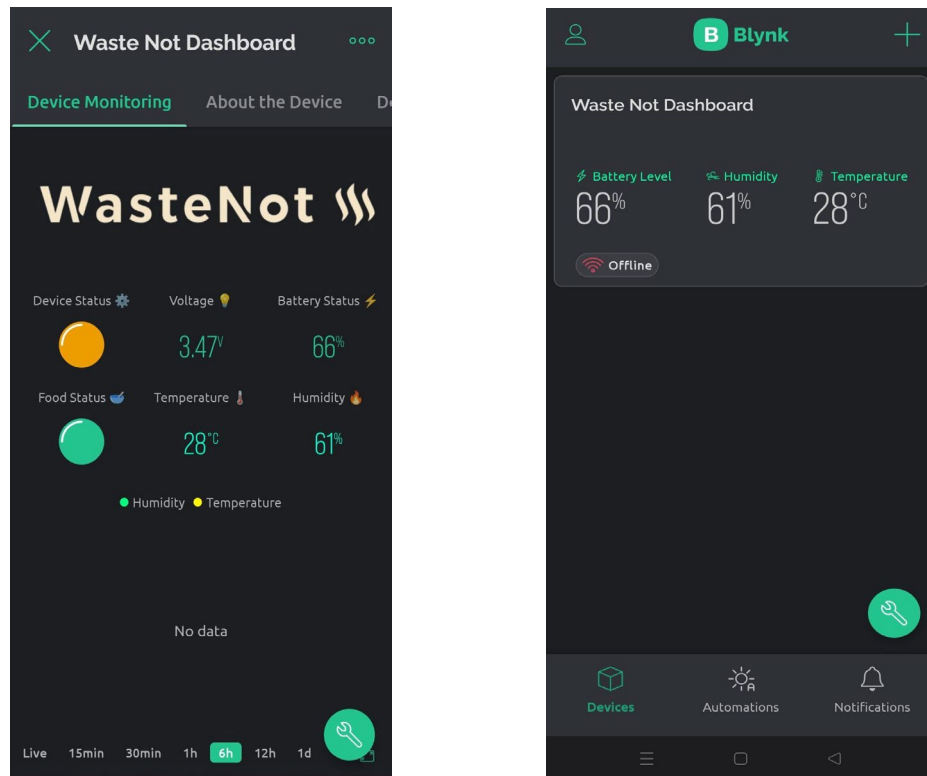


Figure 6. Waste Not Application Dashboard

Figure 6 shows the dashboard of the Waste Not application. With the application, users can get notified of the food status inside the container as well as the status of the device. Users are notified not only once the food is spoiled but also when the food is at risk of being spoiled. The application delivers a message through a notification that advises the user to store the food in a cooler environment. It occurs when the device detects any increase in humidity or temperature. The application also informs the user when the device has a low battery percentage. It also notifies when the device is at risk of getting damaged, specifically when it is stored below or above the temperature it can take, which is above 32 degrees Celsius and below 5 degrees Celsius.

<input type="checkbox"/>	☆	Blynk 2	Inbox	Humidity Condition Alert - Your food is at risk of spoilage. Humidity is above ...	Apr 18
<input type="checkbox"/>	☆	Blynk	Inbox	Battery Status 3.0 - Low battery. Please charge for 2 hours.	Apr 18
<input type="checkbox"/>	☆	Blynk	Inbox	Temperature Condition Alert - Your food is at risk of spoilage. Temperature i...	Apr 18
<input type="checkbox"/>	☆	Blynk	Inbox	Food Spoilage Alert - Your food is already spoiled. It cannot be consumed a...	Apr 11
<input type="checkbox"/>	☆	Blynk	Inbox	Humidity Condition Alert - Your food is at risk of spoilage. Humidity is above ...	Apr 11
<input type="checkbox"/>	☆	Blynk 9	Inbox	Food Spoilage Alert - Your food is already spoiled. It cannot be consumed ...	Apr 10
<input type="checkbox"/>	☆	Blynk 2	Inbox	Humidity Condition Alert - Your food is at risk of spoilage. Humidity is abo...	Apr 10
<input type="checkbox"/>	☆	Blynk	Inbox	Battery Status 1.0 - Low battery. Please charge for 2 hours.	Apr 9
<input type="checkbox"/>	☆	Blynk	Inbox	Temperature Condition Alert - Your food is at risk of spoilage. Temperature i...	Apr 9
<input type="checkbox"/>	☆	Blynk	Inbox	Humidity Condition Alert - Your food is at risk of spoilage. Humidity is above ...	Apr 9
<input type="checkbox"/>	☆	Blynk	Inbox	Welcome to Blynk.Console - password for your account. Create Password T...	Apr 9

Figure 7. Notifications through email

Figure 7 shows the sample notifications a user can receive regarding the status of the stored food and the device itself. All notifications a user can get through the application can also be seen on the user's registered email account.

The assumption for the financial aspect is that the business operation will start in the fourth quarter of the year, following a fiscal year.

Detector

Table 1. Gross Profit Margin

Gross Profit Margin					
	Year 1	Year 2	Year 3	Year 4	Year 5
Gross Profit	9,614,137	10,364,185	17,571,251	19,517,418	28,527,783
Net Sales	35,520,576	39,189,452	62,850,346	69,344,375	98,147,500
Gross Profit Margin	0.27	0.26	0.28	0.28	0.29

Note: Values in PH Peso; 1 USD is equal to 55.28 PH Peso as of June 30, 2023.

Table 1 shows the gross profit margin per year. The gross profit margin for year one is 27%, 26% for year two, 28% for years three and four, and 29% for year five. The gross profit margin of the product is considered acceptable because the value is not far from the average profit margin for 2023, which is 28.40% (Gupta 2022).

Table 2. Net Profit Margin

Net Profit Margin					
	Year 1	Year 2	Year 3	Year 4	Year 5
Net Profit	3,184,137	3,671,261	8,881,785	10,202,851	16,750,497
Net Sales	35,520,576	39,189,452	62,850,346	69,344,375	98,147,500
Net Profit Margin	0.09	0.09	0.14	0.15	0.17

Note: Values in PH Peso; 1 USD is equal to 55.28 PH Peso as of June 30, 2023.

Table 2 shows the net profit margin for years one to five. It shows that the net profit margin for the first two years is 9%. For year three, it increases by 4%. The net profit margin for years four and five is 15% and 17%, respectively. The net profit margin shows to have a good standing since the average profit margin for electronics as of 2023 is 7.08%, according to Gupta (2022).

Table 3. Return on Investment

Return on Investment					
	Year 1	Year 2	Year 3	Year 4	Year 5
Net Profit	3,184,137	3,671,261	8,881,785	10,202,851	16,750,497
Ave. Total Assets	10,792,252	11,332,435	13,097,888	15,625,847	19,164,590
Return on Investment	0.30	0.32	0.68	0.65	0.87

Note: Values in PH Peso; 1 USD is equal to 55.28 PH Peso as of June 30, 2023.

Table 3 shows the return on investment per year. The return on investment for the first year is 30%, and for year two, it increases by 2%. For year three, the return on investment is 68%, and for the following year, it slightly decreases by 3%. Year five has the highest return on investment, which is 87%. According to Speights (2023), an annual rate of return of 10% or more is considered a good ROI.

Table 4. Return on Equity

Return on Equity					
	Year 1	Year 2	Year 3	Year 4	Year 5
Net Income	3,184,137	3,671,261	8,881,785	10,202,851	16,750,497
Ave. Total Equity	10,796,034	11,254,942	12,824,073	15,209,652	18,578,821
Return on Equity	0.29	0.33	0.69	0.67	0.90

Note: Values in PH Peso; 1 USD is equal to 55.28 PH Peso as of June 30, 2023.

Table 4 shows the return on equity for years one to five. Year five has the highest return on equity with a percentage of 90%. The lowest return on equity is during the first year. According to Tsang (2023), the value for a good return on equity is 20% or higher. Therefore the ROE of the product is considered adequate.

Table 5. Payback Period

Payback Period						
	Year 1	Year 2	Year 3	Year 4	Year 5	
Net Income After Taxes	3,184,137	3,671,261	8,881,785	10,202,851	16,750,497	
Depreciation						
Training	281,986	281,986	281,986	281,986	281,986	
Office	34,065	34,065	34,065	34,065	34,065	
Total Annual Cash Return	3,500,187	3,987,312	9,197,836	10,518,902	17,066,548	
Initial Investment	10,000,000	6,499,813	2,512,501	(6,685,335)	(17,204,237)	(34,270,785)
	1	6,499,813	2.63	Payback		
		3,987,312		Period		

Note: Values in PH Peso; 1 USD is equal to 55.28 PH Peso as of June 30, 2023.

Table 5 shows the payback period. The exact payback period or the number of years needed to recover the investment is 2.63 years or approximately two and a half years.

Table 6. Break-even Analysis

Break-even Analysis					
Total Selling and Administrative Expenses	5,368,622	5,469,171	5,728,870	5,913,616	6,193,787
Gross Profit Margin	202.73	208.13	231.21	244.59	265.37
Break-even in units	26,482	26,277	24,778	24,178	23,340
Selling Price	749	787	827	869	913
Break-even in pesos	19,835,014	20,680,236	20,491,511	21,010,772	21,309,217

Note: Values in PH Peso; 1 USD is equal to 55.28 PH Peso as of June 30, 2023.

Table 6 shows the break-even analysis in units and pesos. The break-even in units for year one is 26,482, while the break-even in pesos is 19.8 million. This indicates the number of units to be sold and how much sales to be earned to cover the production costs.

6. Conclusion

After using both qualitative and quantitative techniques, the product, WasteNot is considered marketable since the majority of the respondents are willing to buy and use the product. It also shows that most of the respondents find it difficult to identify food spoilage, thus validating the need for the development of a food container with a spoilage detector.

The product is feasible because based on the initial and final testing of the device, it has met the working conditions proposed. Also, under the financial aspect, the payback period of the product produced significant results. Furthermore, the target market, or consumers' response to the survey, was in favor of buying the product.

Developing a product that can detect food spoilage easily and aids people in monitoring the real-time status of their food can positively impact the environment by reducing one of the main contributors of waste, which is food waste. At the same time, through WasteNot, people can better ensure food safety consumption. Occurrences of food poisoning can be prevented if people are able to detect spoiled food accurately. Pursuing the production of WasteNot can also create more job opportunities for individuals, which can then impact the country's economy.

The researchers suggest exploring other indicators of spoilage, such as halochromic ink and other gas sensors. According to Leite et al. (2022), halochromic sensors, specifically methyl orange and bromocresol purple 2% (w/v), were able to create a perceptible signal that indicates food spoilage through a color change. Another recommendation is to test the food spoilage detector on raw meat or fish. The researchers also propose to explore using solar power to operate the product. Solar energy is proven to be a sustainable energy source, and at the same time, it has a lower impact on the environment than other energy sources (Johnston 2022). Another proposed improvement is utilizing LoRa technology to improve the battery life of the product. According to Garcia et al. (2019), LoRa consumes less power than WiFi, although there should be necessary changes in its settings to ensure low energy consumption.

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Jaypy T. Tenerife has more than 15 years of combined teaching, consulting, and actual practice of various strategic and techno-structural level interventions in the academe, private, and non-government organizations in the Philippines. He is an Assistant Professor in the Industrial Engineering Program of the Technological Institute of the Philippines. His research areas are in organization development, gender studies, quality, management, and engineering education and training.