ARDUINO-BASED TAMBAN AND GALUNGGONG DEHYDRATOR FOR SELECTED RETAIL FISH VENDOR IN THE PUBLIC MARKET OF THE CITY OF SAN PABLO

A Design Project Presented to the Faculty of College of Engineering
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Bachelor of Science in Computer Engineering

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CHAPTER I

THE PROJECT AND ITS BACKGROUND

Introduction

Fresh fish, a food item with a short shelf life, requires careful handling to prevent deterioration, ensure safety from harmful microorganisms, and maintain its attractiveness for market sale. However, the fishing industry faces a significant challenge in managing fish waste. The Food and Agriculture Organization (FAO, 2018) reports that nearly one-third of the 156 million tons of fish produced worldwide for human consumption goes to waste. FAO (2018) expects this number to increase in the future.

Efforts to address fish waste in the fishing industry contribute significantly to multiple United Nations Sustainable Development Goals (UNSDG, 2022). Primarily, by reducing waste, the industry supports SDG 2 (Zero Hunger) through more efficient and responsible utilization of global fish production, fostering food security and alleviating hunger. This approach aligns with the overarching goal of achieving a more sustainable, hunger-free future.

In the Philippines, 25 to 30 percent of the fish supply goes to waste, leading to considerable economic and environmental repercussions. This alarming statistic underscores the urgent requirement for enhanced waste management strategies within the Philippine fishing industry, as emphasized by Islam et al. (2021). The pervasive issue of fish and seafood waste in open markets is worsened by inadequate storage facilities and low demand, as outlined by Montojo et al. (2020).

Unsold fish contribute significantly to fish waste, particularly in wet markets where most fish products are sold. According to a study by De Ungria et al. (2022), the average daily production of fish waste in Philippine wet markets was 70.3 +— 0.93 kg, with no significant differences across locations. Unsold fish not only contribute to fish waste but also impact sellers' profitability, as they cannot sell poor-quality fish. Even if they manage to sell such fish, it is typically cheaper.

Both local and global, stakeholders have observed innovative approaches to addressing the persistent challenge of unsold fish. Malaysia, during the Movement Control Order (MCO), utilized a solar dryer dome through collaboration between the Malaysian Fisheries Development Authority (LKIM) Sarawak and the Buntal Fishermen Association (PNKB) to tackle the issue of unsold fish by Silong (2020). However, the manual fish drying process, identified by Alvinika (2021), remains time-consuming, taking 4–7 days to achieve a 10% water content.

Fish vendors in the Public Market, located in San Pablo City, Laguna, are grappling with the issue of unsold fish, especially the Tamban and Galunggong. According to the study by Estrada et al. (2023), most fish sellers experience unsold Tamban and Galunggong for three (3) – four (4) days per week, with an average volume ranging from seven (7) to nine (9) kilograms. Seller's cope with this challenge by reducing the prices of unsold fish for the following business day. This predicament impacts their pricing strategies and hampers their supply chain, as they encounter difficulties procuring fresh supplies due to unsold fish.

In response to the challenge of excess unsold Tamban and Galunggong, developers have designed an automatic fish dehydrator. This innovation allows sellers to avoid reducing the price of unsold fish, which could result in losses.

Instead, they can transform the excess fish into a value-added product, potentially increasing their profitability.

The automatic fish dryer creates a value-added product from unsold fish, increasing the storage life of the fish and allowing it to be sold at higher prices later on. An Arduino microcontroller controls the device, ensuring precise regulation of the dehydrator's environment and facilitating an optimal drying process. It also notifies the user when the drying is complete.

Background of the Project

Identifying the problem in San Pablo City's Public Market from the study of Estrada et al. (2023), the developers have developed an innovative solution to address the issue faced by fish vendors, which is the unsold fish, leading to substantial product loss and diminished income potential. Conventional drying methods, often time-consuming, inefficient, and lacking stringent hygiene controls, have inspired the creation of an automated fish dryer.

The creation of automated fish dryers directly tackles these challenges. The envisioned outcome is a market where unsold fish is not a concern but an opportunity, with dried fish as a value-added product. Raynaldo (2021) suggests that the automatic fish drying system, designed for efficient fish dehydration and uniform heat distribution through a palette rotation mechanism, offers a promising solution to the excess fish supply. Beyond its potential to enhance drying effectiveness, this innovation holds economic promise for coastal communities.

In this paper, the developers created a fish dehydrator that automatically stops when it meets specific conditions during drying. One condition is reaching the desired moisture content of the fish, measured using load sensors. Another condition is the maximum drying time, which is determined through testing. This data helps determine the required drying time and acts as a safeguard against errors in the load sensor. Implementing these two conditions ensures the drying process stops after drying the fish, preventing over-drying.

In the fight against food waste, the developed automatic fish dehydrator for San Pablo City Public Market offers a potential environmental benefit beyond just reducing waste. Dehydration is a natural preservation method that could eliminate the need for chemical preservatives often used with fresh fish. This would not only extend the shelf life of the fish but also reduce the environmental impact associated with the production and disposal of these potentially harmful chemicals.

According to E.M. Rogers' Diffusion of Innovation Theory in 1962, the early adoption of a new idea is crucial. The introduction of this innovative fish preservation method aims to demonstrate its effectiveness. If successful, others facing similar industry challenges could adopt it.

Objectives of the Project

General Objective:

The general objective of the design project is to help retail fish vendors solve the problem of unsold Tamban and Galunggong by transforming them into new products that can increase their shelf life and profitability.

Specific Objectives:

Specifically, it aims to:

1. Design and develop a device that performs the following functions:

a) Monitoring and regulating the temperature;

b) Displaying the current temperature, humidity, and weight of the fish;

c) Drying a maximum of 10kg of Tamban or Galunggong;

d) Stopping the drying process automatically after completion;

e) Notifying the user via SMS the final weight after the drying process.

2. Evaluate using ISO 25010 with the following software standards: functionality, performance efficiency, usability, reliability, security, compatibility, maintainability, and portability, which can ensure the quality of the design project.
3. Prepare a deployment plan for the device.

Scope and Limitations

This project aims to conceptualize, develop, and implement a solution for the retail fish vendors in the San Pablo City Public Market, addressing the issue of unsold fish while introducing a value-added product. The client for this project is Mr. Efrain Maranan Jr., a retail fish vendor in the San Pablo City Public Market for over 12 years. The proposed initiative involves designing and implementing an automated fish dehydrator that can efficiently dry up to 10kg of Tamban and Galunggong.

The project spans the entire academic year 2023-2024, covering conceptualization, evaluation, testing, and implementation across both semesters.

The project incorporates an Arduino-controlled automatic drying system to ensure an optimal drying process. This feature includes humidity and temperature sensors for continuous monitoring. When the device detects these variables, it activates the heating element and starts the fan to ensure even heat distribution. The device automatically turns off when the fish reaches the desired moisture level, determined by weight. The detection relies on a load sensor connected to the Arduino. The user can calibrate the load sensor after several uses to ensure that the sensor readings are correct. In case of a load sensor error, the maximum drying time from tests is a safety measure, ensuring the drying process stops appropriately. Additionally, there is a one-way communication through SMS, wherein the device sends a message to the user after the drying process to notify them.

The automated fish dehydrator is designed to optimize the drying process, specifically for Tamban and Galunggong. Drying other types of fish in the dehydrator is not recommended, as its settings was set only for Tamban and Galunggong only. Also, the user must not dry large fish and small ones together as it results to uneven drying. Users are also responsible for brining, and placing the fish inside the dehydrator, as the device's primary function is solely to dry the fish. Moreover, users must clean and maintain the dehydrator after each use to ensure optimal performance and hygiene. Regular cleaning is essential to preserve the quality of dried fish and prevent cross-contamination between batches.

Additionally, there are no features to prevent the smell from emanating from the device, as it has multiple holes on both sides and at the top, through which air automatically exits. During the drying process, a fishy smell is produced, so it is recommended to place the dehydrator away from clothes and other items.

The device is designed to run exclusively on a standard household electrical outlet, which typically provides 220 volts of alternating current (AC). This means that the device will not be able to function during a power outage. It also does not have any built-in backup power systems, such as rechargeable batteries or a solar panel, to keep it running when the main power goes out.

Due to budget and time constraints, only one prototype was produced and provided to the sole client, Mr. Efrain Maranan Jr. The selection criteria for choosing a client focused on factors including need, potential impact, and a willingness to actively participate in the testing and feedback phases of the project.

Significance of the Project

The project is significant for the following:

Fish Vendors. The design project helps them minimize losses by prolonging the shelf life of their fish product and increases profitability by introducing and supplying a value-added product.

Consumers. The additional supply of dried fish from the project contributes to more stable and potentially lower consumer price. This increases the availability of a preserved fish product and makes it more affordable for consumers.

Developers. The project helps developers improve their abilities in their selected programs. Their technical skills and understanding of engineering principles grow as a result.

Future Developers. Future developers interested in working on similar device will benefit from this project. Subsequent developers can draw inspiration and this project a reference while developing their design project.

Theoretical Framework

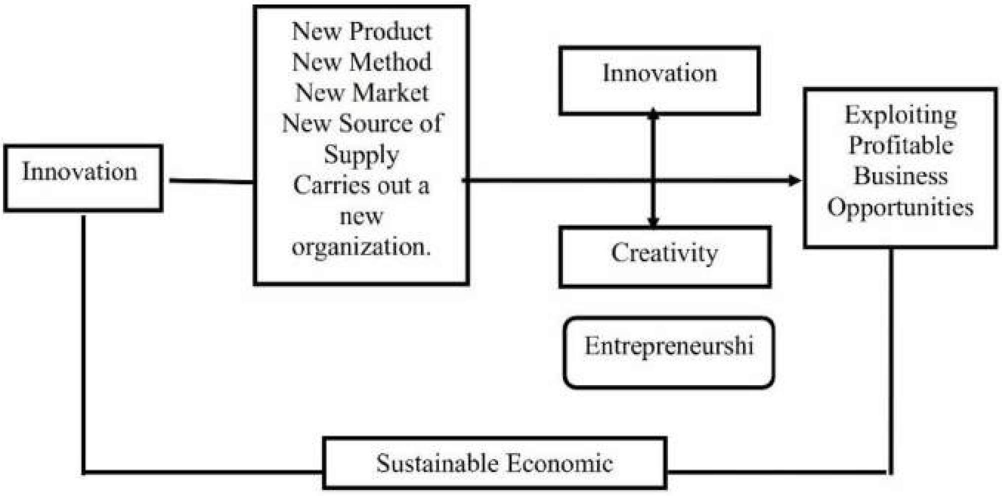


Figure 1.1 Innovation Theory of Entrepreneurship Model

The theoretical basis of this study is Joseph Schumpeter's Innovation Theory of Entrepreneurship. Schumpeter argued that entrepreneurs are willing to take risks and invest resources in developing and commercializing innovations. This process of innovation is often disruptive to existing businesses but is also essential for economic growth (Mehmood, Alzoubi, Alshurideh, Al-Gasaymeh, & Ahmed, 2019).

Turning unsold fish into dried fish using a dehydrator can offer several advantages. Firstly, removing the fish's moisture through osmotic dehydration and evaporative drying aids its preservation and prolongs its lifespan over time (Richa, 2022). This aligns with Schumpeter's idea of entrepreneurs investing resources to develop innovations that can disrupt traditional business models. Secondly, by employing technology to control the drying process, the device can ensure consistent quality and safety standards for the dried fish (Alvinika, Setyohadi, & Sulistyoningsih, 2021). In essence, the Arduino fish dryer addresses the problem of unsold fresh fish and introduces a novel product to the market, potentially creating a new niche and contributing to economic growth, as Schumpeter's theory suggests.

Besides preserving unsold fish in line with Schumpeter's innovation principles, the Arduino fish dryer also promotes environmental sustainability. Converting unsold fish into dried fish extends shelf life and addresses environmental concerns associated with traditional disposal methods. This innovation reflects a dual impact: economic viability through product and environmental responsibility by reducing food waste.

Conceptual Framework of the Project

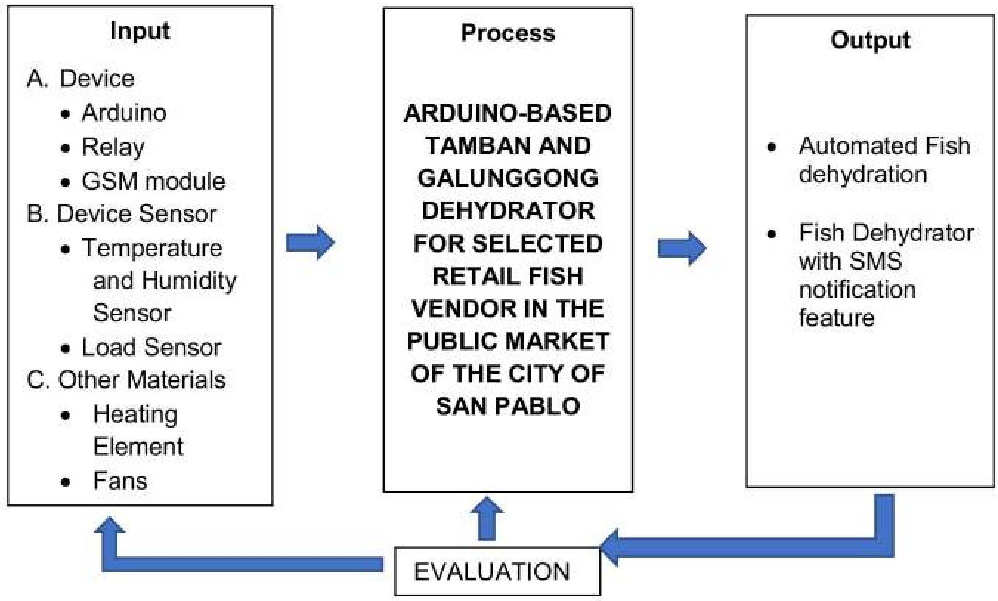


Figure 1.2. The Conceptual Framework of the Project

The first section is "Input." The fish dehydrator was made using an Arduino Uno to control the system, a heating element to raise the required temperature, an aluminum expanded wire for layering the fish, a temperature and humidity sensor to sense the necessary heat and moisture inside the device, a load cell connected to the HX711 module to measure the weight of the fish, fans for circulating air inside the device, an aluminum stucco sheet for the device's body, and a relay for additional control of the signals.

The project involved the "Process" of building the fish dehydrator for automatic fish drying. The developers design the body of the device and configure the Arduino program to control the hardware components which are the fans and heating elements based on sensor readings.

In the "Output" phase, the project's culmination is producing dried fish or other food products through the automated fish dehydrator developed by the developers. This output represents the practical application of the fish dehydrator and reflects the success of the design and configuration process. The primary objective of the device is to achieve efficient and uniform drying of Tamban and Galunggong fish that are good enough to be sold in the market.

The evaluation phase is the last step in the design of the Arduino-based fish dehydrator. A group of three project evaluators carried out the evaluation. The critic used the ISO 25010 standard criteria to assess the project, which includes functionality, reliability, performance efficiency, usability, security, compatibility, maintainability, and portability.

Definition of Terms

To provide clarification, the terms listed below are defined in the context of the project:

Arduino is a microcontroller that the developers use to control access to data from sensors and configure the output of fans and the heating element.

Dehydration is a method for removing water from fish bodies.

Fish dryer is a device that efficiently dries fish inside a closed environment, preventing contamination and speeding up the drying process. This ensures high-quality, uniformly dried fish by creating a controlled environment.

Humidity is the amount of water vapor in the air inside the fish dehydrator.

Spoilage is when a food item becomes unsafe for a customer to consume.

Temperature and humidity sensors are integrated into the fish dehydrator to monitor the internal environment and send the data to the microcontroller.

Unsold fish pertains to the fish inventory that remains at the end of a selling day. The unsold fish at the end of a selling day have yet to be purchased or consumed during the daily sales.

CHAPTER II

REVIEW OF LITERATURE AND RESEARCH PROJECTS

This chapter reviews literature, studies, and projects in relation to a design project that takes into account a variety of theories, ideas, and methods supported by current or critically important studies from both domestic and foreign sources. The project's developers were able to better conceptualize and evaluate the work thanks to these reviews. It also includes design synthesis, which aids in selecting and determining the appropriate theoretical analysis for developers.

Review of Conceptual Literature

Fish Preservation

Preserving fish quality and freshness is a significant issue for fish vendors. Given that fish is a highly perishable product, ensuring its freshness throughout the supply chain, from procurement to sale, is crucial.

A study by Estrada et al. (2023) showed that unsold fish pose a problem for the sellers' profitability. The study recommended creating a value-added product out of unsold fish that extend its shelf life. The developers suggested creating dried fish, which can help lessen the loss due to unsold fish products.

In the study of Swami et al. (2018), the drying process for food preservation is very popular for some agricultural and food products. Drying is a better option than refrigeration for food products when it comes to cost and equipment complexity. Since energy consumption is an important issue in the case of food preservation methods, the dryer uses unconventional energy, such as solar energy, to ensure minimum investment and reliability.

Fishing Industry

The study by Bell et al. (2020) confirms that climate change affects fisheries, leading to shifts in the distribution and abundance of fish populations. These changes pose unprecedented challenges to the health, well-being, and livelihoods of people dependent on fishery resources. Additionally, the study suggests that effective, long-term natural resource management is crucial for building resilience to climate variability and change impacts. Key strategies highlighted include ensuring high spawning stock biomass levels, protecting habitat, maintaining ecosystem function, and facilitating responsive management.

Species	Volume of Production (metric tons)			Percent Change (%)		Percent Share to Total Volume of Fisheries Production (%)
	2021	2022	2023^P	2022/2021	2023^P/2022	2023
Fisheries	**998,925.56**	**996,317.25**	**1,017,504.40**	**-0.3**	**2.1**	**100.0**
Milkfish (Bangus)	115,858.32	100,280.57	88,281.01	-13.4	-12.0	8.7
Tilapia	59,174.17	53,550.81	57,254.28	-9.5	6.9	5.6
Tiger prawn (Sugpo)	8,010.62	6,371.99	3,250.34	-20.5	-49.0	0.3
Skipjack (Gulyasan)	56,581.52	60,034.92	52,451.59	6.1	-12.6	5.2
Roundscad (Galunggong)	44,069.13	41,694.28	48,853.04	-5.4	17.2	4.8
Seaweed	292,140.29	323,577.15	368,797.89	10.8	14.0	36.2
Yellowfin tuna (Tambakol/Bariles)	17,415.24	22,213.05	28,537.11	27.5	28.5	2.8
Mudcrab (Alimango)	6,240.05	4,209.41	3,027.02	-32.5	-28.1	0.3
Frigate tuna (Tulingan)	22,300.60	21,967.98	20,487.59	-1.5	-6.7	2.0
Big-eyed scad (Matangbaka)	28,179.00	24,782.95	32,900.37	-12.1	32.8	3.2
Bali sardinella (Tamban)	96,876.98	79,916.60	76,441.80	-17.5	-4.3	7.5
Squid (Pusit)	11,019.94	15,643.52	11,521.79	42.0	-26.3	1.1
Blue crab (Alimasag)	8,608.59	6,075.23	4,978.52	-29.4	-18.1	0.5
Bigeye tuna (Tambakol/Bariles)	4,668.26	6,104.27	3,592.93	30.8	-41.1	0.4
Grouper (Lapu-lapu)	6,042.48	5,177.55	4,377.00	-14.3	-15.5	0.4
Indian mackerel (Alumahan)	12,178.05	9,591.67	15,404.70	-21.2	60.6	1.5
Threadfin bream (Bisugo)	8,680.82	8,626.95	6,956.36	-0.6	-19.4	0.7
Slipmouth (Sapsap)	9,721.92	9,229.97	9,426.76	-5.1	2.1	0.9
Cavalla (Talakitok)	7,362.15	7,827.96	5,767.26	6.3	-26.3	0.6
Fimbriated sardines (Tunsoy)	13,199.19	15,598.17	9,694.78	18.2	-37.8	1.0
Others	170,598.25	173,842.28	165,502.26	1.9	-4.8	16.3

P - preliminary
Note: Percent change and percent share may yield different results when computed manually due to rounding.
Sources: Philippine Statistics Authority, Quarterly Commercial Fisheries Survey, Quarterly Municipal Fisheries Survey, Quarterly Inland Fisheries Survey, and Quarterly Aquaculture Survey

https://psa.gov.ph/statistics/fisheries-situationer

Figure 2.1. Volume of Fisheries Production by Species

According to the report of the Philippine Statistics and Authority on the Fisheries Situation Report for the third quarter of 2023, the fisheries production volume reached 1,017.50 thousand metric tons, showing a positive trend with a 2.1 percent increase compared to the 996.32 thousand metric tons recorded in the corresponding quarter of the previous year. Commercial fisheries, inland municipal fisheries, and aquaculture subsectors experienced growth in production on an annual basis. Tamban and Galunggong are among the most abundant fish species in the Philippines.

Luceño et al. (2019) stated that one of the top ten species in commercial fishing in the Philippines is *Sardinella Lemuru*. Sardines have made up most of the Philippines landed catch since 1950, making them the most easily obtainable protein source for millions of Filipinos. Important economic uses of *Sardinella Lemuru* can be consumed as fresh fish are dried, processed to make fishmeal, and preserved.

The Philippines is a significant global fish producer, ranking 13th in marine capture and 4th in seaweed production in 2018. The fishing industry comprises aquaculture, municipal, and commercial fisheries, with aquaculture contributing 53% of total production. This industry is vital for providing food security, livelihoods, and export earnings, with fish being the main protein source for Filipinos. Around 2 million coastal residents engage in fishing activities, contributing to approximately US$1.6 billion in fishery exports in 2018. However, the industry faces pests, diseases, water quality degradation, harmful algal blooms, overfishing, illegal fishing, climate change, and a lack of capital and government support (Tahiluddin, 2021).

Fish Dehydration

Drying processes play a crucial role as unit operations in the food manufacturing sector by effectively decreasing moisture content. The resulting products usually take the form of powder, flakes, granules, sheets, or particles, tailored to meet the specific needs of manufacturers and determined by the chosen drying technologies employed throughout the production process (Menon, Stojceska, & Tassou, 2020).

The primary objective of the drying process for fish goods is to extend their shelf life, enabling more prolonged periods of storage while minimizing the need for excessive packing and reducing shipping weights. The evaluation of a food product's quality is determined by the extent of physical and biochemical deterioration that takes place during the dehydration procedure. The storage stability of a fish product is enhanced with a decrease in water activity, and fish products that have undergone drying at lower temperatures have favorable storage stability (Okos, 2018).

Air is the predominant gas employed for fish dehydration, and its moisture content plays a crucial role in estimating drying parameters. According to Adeyeye (2019), the moisture content and color of dried fish are influenced by the drying process. Additionally, the drying method employed plays a role in determining the moisture content of the dried fish. Moreover, an inverse relationship is observed between drying power, drying rate, and the time taken for the drying process.

Liu et al. (2023) investigate the advantages and applications of using dehydration techniques in processed and ready-to-eat foods. The study examines current dehydration technologies, investigates emerging advancements, and discusses effective strategies for managing bacteria in food products. They emphasize using advanced food science and technology to enhance the overall quality of processed foods. Notable research areas highlighted in the article include intelligent drying and dehydration-induced modification technology. Furthermore, the article emphasizes the growing interest in advanced drying methods, such as pulsed-spouted microwave freeze-drying and infrared freeze-drying, which provide superior capabilities.

https://www.superbheater.com/heaters/industrial-tubular-heater/ce-approved-1500w-electric-tubular-heater.html

Figure 2.2. Heating Element

Heating elements are necessary for drying. Based on the findings of Aboud (2019) on heating food, the main objectives are to enhance the food's shelf life and flavor. Traditional heating methods involve radiation, convection, and conduction for heat transfer. However, a combination of microwave and infrared heating techniques is utilized to improve energy efficiency, resulting in rapid heating of the food.

Fang et al. (2020) discussed the benefits of electric heating garments for those in cold environments. It highlights the advantages of electrical heating, such as reusability, controlled temperature, and safety. The study covers material preparation, electric-thermal properties, and the pros and cons of flexible heating elements. It also delves into smart garment research and application progress, offering insights into flexible heating elements and smart garment research.

https://pixabay.com/illustrations/arduino-arduino-uno-technology-2168193/

Figure 2.3. Arduino Uno Microcontroller

Arduino is an open-source electronics platform that facilitates the development of interactive and programmable projects through hardware and software. The core hardware component is the Arduino board, which houses a microcontroller (typically an Atmel AVR or ARM processor), digital and analog input/output pins, and connectors for external devices like sensors and actuators. The software aspect involves the Arduino IDE (Integrated Development

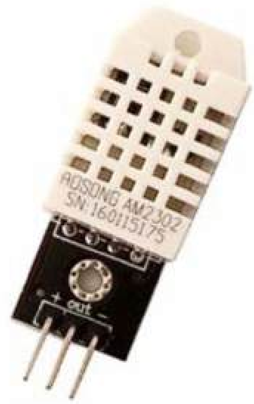
Environment), a platform for writing, compiling, and uploading code to the Arduino board. Programs, referred to as sketches, are written in a simplified version of C/C++ (Ismailov, 2022).

The Arduino contains everything needed to support the microcontroller; connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. Everything required to support the microcontroller is included; the Arduino board needs to connect to a power source. The Arduino UNO can be powered by a USB cable from a computer or a wall power supply (Benjamin, 2020).

Additionally, according to Ismailov (2022), Arduino is widely employed in research for diverse applications, including developing devices that interact with the environment through sensors. Additionally, developers utilize Arduino to establish internet-connected systems, enabling data transmission via HTTP requests or Wi-Fi modules for remote monitoring and control. Its versatility is evident in creating and implementing innovative projects across various domains, such as wearable fashion, space exploration, and robotics. The platform's adaptability makes it a valuable tool for developers exploring creative and interdisciplinary applications in their work.

Temperature and Weight Monitoring

Based on the findings of the study by Li et al. (2022) it is evident that humidity sensors play a vital role in industries such as atmospheric environment management, medical devices, agriculture, aerospace, and industrial production. The study highlights the increasing demand for humidity sensors that surpass the capabilities of existing models in terms of responsiveness, recovery time, selectivity, stability, and repeatability. To address this demand, the study focuses on the development of a ZnO/SnO2 humidity sensor using a solvothermal technique. The humidity-sensing mechanism of the sensor is analyzed through the evaluation of the Complex Impedance Spectrum (CIS).



https://components101.com/sensors/dht22-pinout-specs-datasheet

Figure 2.4. DHT22 Module

The DHT22 utilizes a capacitive humidity sensor element for precise measurement of relative humidity by detecting changes in capacitance induced by moisture in the air. This feature makes it well-suited for applications requiring critical humidity monitoring, including climate control, agriculture, and environmental research. In terms of temperature measurement, the DHT22 employs an NTC (Negative Temperature Coefficient) thermistor, gauging the resistance of the thermistor as it varies with temperature. This approach enables the sensor to determine the ambient temperature accurately, adding versatility to its applications in various settings (Koestoer, 2019).

https://www.aliexpress.com/item/32817425302.html

Figure 2.5. Load Cell with HX711 Module

The load sensor is described as a device that measures the weight of an object. Specifically, the study utilizes a load cell sensor, which converts the pressure or force applied to it into an electrical signal. This signal is then amplified and converted using the HX711 module, which interfaces with the Arduino Uno microcontroller. The system aims to enhance baggage weighing processes at airports by automating the measurement and display of baggage weight on an LCD screen and printing out relevant information using a thermal printer. (Ramadhan, 2023).

In the study of Yanti (2022), a load sensor with an HX711 amplifier was used to continuously monitor the weight of the fish during the drying process. The project made the fish lose 50% of its weight in just 4.48 hours. The system demonstrates the utilization of fuzzy logic in controlling fish drying equipment, resulting in a reduction of drying time by approximately ten (10) hours compared to the duration required for sun drying.

Review of Research Literature

Local

The study entitled "*Traditional Fish Processing Techniques Applied in the Philippines and Turkey*" by Tahiluddin et al. (2022) explores the prevalence and characteristics of Traditional Fish Processing Techniques (TFPT) in the Philippines and Turkey. Both countries widely employ TFPTs, including drying, salting, pickling, and smoking methods, especially among low-income coastal communities. Based on a review of literature from 1950 to 2021, the research reveals similarities in the application of TFPTs in the two nations, with variations primarily seen in the finished products. The Philippines stands out for its diverse and unique processed seafood offerings compared to Turkey. The more prosperous and varied fisheries resources in the Philippines contribute to a higher consumption rate of aquatic products among Filipinos. The study highlights the Philippines' exclusive use of fish product fermentation in TFPT, a method not commonly found in Turkey.

Based on the study titled "*Histamine Profile of Dried-Salted Fish Sold in Local Supermarkets of Samar, Philippines*" of Amascual et al. (2020), dried and salted fish are popular fishery products in the Philippines, particularly in Samar. The trade and processing of marine resources provide business opportunities in the region. However, the quality of dried fish products has declined due to various factors, such as unsanitary conditions, improper handling, and histamine contamination. Following the regulatory authorities' set histamine limit, dealers aim to sell their goods in supermarkets. The Food Safety Act of 2013 enhances food safety regulations to protect consumers from illnesses and ensure product quality. A recent study conducted in Samar analyzed histamine levels in dried and salted fish products available in local supermarkets. The research explored the relationship between fish variety, market location, and histamine formation and concentration. By addressing histamine-related concerns, the study contributes to consumer health and safety.

According to Cain (2019) the appropriate technology for development. Lower-income families in both rural and urban areas of the Philippines commonly use traditional fish preservation techniques such as smoking, drying, and fermenting. Approximately 33 percent of the annual fish catch is processed using these methods. Although not a strong preservative, smoking adds flavor and color to the fish. The smoked and dried fish are sold for approximately US $0.04 per fish. The study highlights the operational costs, which include fish purchases, labor wages, and fuel. Additionally, it mentions the efforts of the Bureau of Fisheries and Aquatic Research to improve techniques and enhance productivity among municipal fishermen.

Improper solid waste management of fish waste contributes to pollution, leading to the Philippine aquaculture industry being deemed unsustainable by the Comprehensive National Fisheries Industry Development Plan. According to De Ungria et al. (2022), promoting a circular economy by reusing waste can enhance sustainability in the fish industry. This study surveyed and interviewed fish vendors in Metro Manila to identify efficient and feasible methods for reusing and disposing of fish waste. The data collected can inform policies on repurposing fish waste and fostering a circular economy. Same study results indicated that wet market fish stalls in Metro Manila produce 1.8 tons of fish waste annually. Most waste is collected and segregated by garbage collectors, but practices vary and are inconsistently enforced, making current management methods ineffective. Educating industry workers, implementing recycling methods, and recommending these practices to local governments can help develop a circular economy and provide an additional income source for the fish industry.

According to Uba et al. (2020) , in Iloilo unsold mussels are transformed into value-added products. These products are then distributed to nearby municipalities, utilizing motorcycles for transportation. The majority of itinerant vendors sell their goods within Dumangas and the adjacent municipalities of Barotac Nuevo and Leganes. Some vendors extend their reach to Anilao, Janiuay, Dingle, Banate, and Pototan, which are approximately twenty (20) to thirty (30) kilometers from the collection site.

In Bataan, Tuyo processing and wholesaling are more profitable than tinapa, with tuyo's gross margin at 36% of total returns and 57% of marketing/variable costs, compared to tinapa's 30% and 42%, respectively. Retail margins for both are lower, at 16% of total returns and 19% of marketing/variable costs, indicating that processing/wholesaling is more profitable than retailing. Given the 0.05% bank savings interest rate as the opportunity cost of capital, both tuyo and tinapa processing/wholesaling and retailing are viable enterprises. Tuyo's higher marketing margin of P60/kg over tinapa's P40/kg is due to its longer shelf life from sun drying (De Leon, 2021).

Even though fish processing is a great way to preserve fish, the threat of having bacteria cannot be disregarded. According to Maribao (2022), spoilage bacteria found in both fresh and processed fish and fisheries products. Common spoilage agents in processed fish, such as salted, dried, and hot-smoked varieties, include molds, yeasts, and bacteria. Spoilage molds are most commonly associated with the genera Aspergillus and Penicillium. Yeasts, particularly species of Rhodotorula and Candida, are frequently linked to fish stored at low temperatures. Notable spoilage bacteria include Pseudomonas, Alcaligenes, Aeromonas, Enterobacter, Bacillus, Enterococcus, Psychrobacter, Escherichia coli, Listeria, Brochothrix, and Shewanella. Further research into the microbial ecology of aquatic food products is necessary to fully understand the role microorganisms play in spoilage.

Additionally, the study of Ortega et al. (2024) on the quality and food safety of dried white goby focuses on the demographic profile and drying practices of fish processors. Key safety and quality parameters, including organoleptic, microbiological, and physicochemical characteristics, were evaluated. Results indicated that women predominantly handle fish drying, primarily using traditional sun-drying methods in coastal communities. Organoleptic testing showed no significant quality differences except for flavor, with Socorro receiving the highest acceptance. Microbiological analyses revealed that all samples met the Philippines' quality and safety standards for commercial dried fish.

To meet the increasing food demands due to population growth, fish farmers might produce lower quality fish. Effective fish growth monitoring is crucial for improving the quality of fish products, which benefits the aquatic animal food production industry. However, manual weighing and measuring can stress the fish, adversely affecting their health and leading to poorer quality or even fish mortality. An automated aquaculture system equipped with weight prediction technology, using image processing techniques and predictive analysis, enhances the growth and survival rates of Nile Tilapia (Tolentino, 2020).

The results of the study of Castro (2021) on "*Analyzing Consumer Preferences for Credence Attributes of Fish and Fishery Products in Davao City, Philippines*" indicated that seafood consumers prioritize food safety over environmental sustainability when selecting policies for their seafood products. This does not reflect a general preference for specific policies among consumers. Instead, consumers showed a stronger inclination towards food safety-related policies, such as food safety certifications and traceability systems. Despite a limited understanding of food safety dimensions, consumers placed greater importance on policies that would enhance their overall trust in the safety of food sold in the market. Across all consumer segments, food safety emerged as the most preferred policy, highlighting it as a major concern for consumers. Consequently, the general preference for food safety information suggests a potential adaptation of food safety product labels.

Foreign

One of the oldest known methods of food preservation is drying. Traditional methods have been used to dry the fish everywhere fish is caught. Fish can be dried using various techniques, from conventional sun-drying to sophisticated industrial processes managed by computers. It is essential to consider how drying affects the product's nutritional content. A community may profit more from adopting a fish-drying method that produces a more stable and wholesome product and generates employment in other industries than the higher costs associated with the process. However, evaluating the costs and benefits of introducing new technology is only sometimes straightforward. The most popular technique for drying fish is undoubtedly exposing it directly to the sun. Fish from larger types may be split, and some fisheries use brining or salting as a pretreatment before laying their catch out to dry (Doe & Olley, 2020).

The effectiveness of the dehydration process in producing dried and cold-smoked fish is discussed in the article by Ershov et al. (2020). A dry region with low moisture conductivity features close to the surface is the outcome of the dehydration process. The goal of the project is to create a system that can efficiently remove moisture at drying rates that are both constant and decreasing. The suggested approach includes material relaxation and drying processes looped at the drying rate reduction stage. The product's internal moisture causes the dehydrated near-surface area to relax, allowing it to reenter the dehydration process with high conductivity characteristics. It is recommended that the relaxation regime calculation approach be in line with the second critical point on the fish dehydration kinetics curve. The suggested technology reduces electricity consumption by 8–12% compared to conventional approaches.

Based on the study of Sminorva et al. (2019) in energy efficient systems and regimes at fish products drying processes, it was discovered that the choice of salting technique impacted salt absorption and water loss during the salting process; the drying experiments showed two drying stages with decreasing rates without a constant rate period. The initial drying stage was influenced by the specific salting method employed. To develop modern food processing technologies, it is essential to prioritize technological systems that minimize labor and energy consumption. A heat pump-based technology has been developed to produce dried fish snacks, incorporating a specialized unit for efficient processing of fish mince. This advancement aims to address product quality, uniformity, environmental safety, process productivity, and complexity challenges.

Fish is one of the most demanded foods because of its health benefits, such as its high protein and lower fat content compared to other animals. However, the quality of fish is quickly declining, so one of the solutions to prevent it is preservation, one of which is drying. Fish drying has the principle of reducing the water content of the material so that the growth of microorganisms will stop and be inhibited. There are two methods of fish drying: traditional and modern. Some people still use traditional methods and simple tools that are negligent about hygiene, which can harm the environment. The modern way of drying is by using devices. Temperature, airflow, desired moisture content, drying energy, and drying capacity all significantly impact drying fish. Drying too quickly can cause harm to the surface material being dried, preventing it from being balanced with the speed of air traveling to the surface material. Rapid drying may cause the surface material to harden; clogging may prevent the air in the substance from evaporating; and employing too high a temperature may harm the material (Raja, 2023).

In recent years, there has been an increasing interest in finding uses for fish byproducts deemed unsuitable for direct human consumption but remain in primary production. Fish protein hydrolysate is one of the most effective ways, out of all the potential solutions, to extract essential nutrients from that material. This article aims to provide an overview of the knowledge currently available on the manufacturing of dried fish protein hydrolysates, with particular attention to the equipment used for moisture removal and the process of dehydration during production. Since the drying process is thought to require the most energy, it is explained in great depth. The article highlights issues related to the energy requirements of drying and suggestions for enhancing energy efficiency. This paper also gives valuable details about the state of fish protein hydrolysate in the middle of the process, where the raw material comes from, the main steps of the technology scheme, and the tools that were used (Petrova, Tolstorebrov, & Eikevik, 2018).

According to Rahman (2020) in his study of Osmotic dehydration of foods. Osmotic dehydration of food has potential advantages for the fruit and vegetable processing industries. The technique of removing water from cellular solids by immersing them in a concentrated aqueous solution is known as osmotic dehydration. While solute uptake or leaching occurs solely by diffusion, the osmotic process primarily uses diffusion and capillary movement to remove water. Apple slices treated osmotically showed a shift in their water sorption properties to the right. Analysis using scanning electron microscopy showed that osmotic therapy improved the preservation of the cellular structure. The solute residues were retained within the product via osmotic pretreatment, which also affected the product's flavor and dielectric characteristics. Because osmotic dehydration may be done at low temperatures, it requires less energy than air- or vacuum-drying. The most widely utilized osmotic agents are sodium chloride for vegetables, seafood, and meat and sugar for fruit.

Abraha et al. (2018) found that fish is a valuable source of protein and nutrients and that several processing techniques are used to maintain the fish's quality and availability. These techniques include canning, cooking, freezing, smoking, and drying. Proteins, lipids, vitamins, minerals, and sensory elements, including color, flavor, texture, and appearance, are the most impacted components. Denaturation, coagulation, decreased protein digestibility, oxidation, and vitamin loss are examples of chemical composition alterations. Texture, color, and yields are physical changes that impact the quality of fish and fishery products.

For the longer shelf life of the products, they came up with this study of dehydration of agricultural products that can reduce shipping and packaging costs as a result of reduced weight and volume; many product developers are attracted to osmotic dehydration due to its sound and quality food preservation (Gallo, 2018). They came up with the design of a shaken tank type without jacketing, constructed in stainless steel AISI 304 caliber 14 with a thickness of 3 mm film, heated using a clamping resistor, and having a control panel with three variables (temperature, stirring rate, and pressure) that can affect the final product.

The study of Natarajan et al. (2022) emphasizes preserving food products in India, a predominantly agricultural country. With agriculture contributing 61% of income, the paper underscores the need for proper training in preservation technology for India's development. The study identifies a significant issue of post-harvest food losses (60% of total losses) due to ineffective preservation methods.

Review of Research Projects

Local

Sandfish processed and dried using traditional procedures yield low-quality, low-value items for the market. Trondillo et al. (2018) demonstrated that smoking and sun drying are standard methods of drying, which might result in insufficient drying, especially in bad weather, and leave smoke residue and scorch marks. To ascertain the impact on product quality and cost, a combination of hot air drying and solar drying was contrasted with the conventional method of smoke drying followed by sun drying. The findings demonstrated that substantial shrinkage happened irrespective of the drying method applied. Samples that underwent the conventional method shrank more, yet this difference was not statistically significant. Alterations in muscle and collagen fibers were seen using scanning electron microscopy between primary drying (solar or hot air drying) and secondary drying (solar or sun drying). An evaluation of the dried samples conducted by a producer, consolidator, and exporter revealed that the processed sandfish dried under Treatment II was of higher quality and could fetch prices up to 25–89% more than those dried under Treatment I.

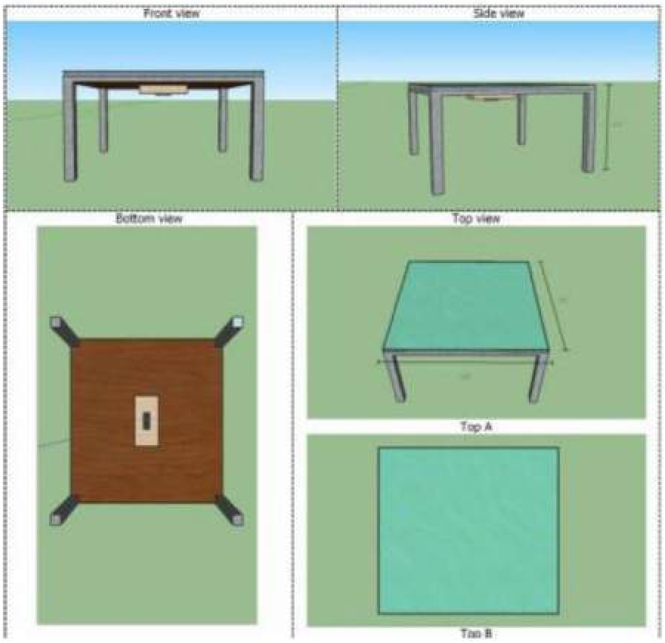
The main goal of the project of Paman et al. (2020) was to ascertain the drying behavior of yellowfin tuna (*Thunnus albacares*) skin to provide benchmark data for processing tuna skin into edible material. They utilized airflow speeds of

0.95 m/s and 0.80 m/s and a drying temperature of 47±3°C. From an initial moisture content of 61.86% w.b., the final product's goal moisture content of 10.00% w.b. was reached. The results showed that the drying rate was initially faster at 0.95 m/s air velocity than at 0.80 m/s. Case-hardening was noted at 0.95 m/s at 1.50 hrs, which caused drying to slow down. As a result, it took longer to reach the final moisture content of 0.95 m/s. This resulted in notable variations in drying rates and times, with slower airflow rates of 0.80 m/s producing superior drying properties. The study's conclusions can be applied to developing a mildly drying tuna skin processing method that uses less energy.

https://thesai.org/Downloads/Volume14No7/Paper_26Optimizing_Drying_Efficiency_Through_an_IoT.pdf

Figure 2.6. Direct Solar Dryer System

The project developed by Miano et al. (2023) in coastal areas of the Philippines addresses the challenges of traditional fish drying methods through the implementation of an Internet of Things (IoT)-based Direct Solar Dryer System added that utilizing Arduino Uno and ESP-32, optimizes drying efficiency with a web data logger and SMS notification system. Focusing on drying Sardinella fish in Agusan Del Norte, the research assesses temperature, heat index, humidity, and temperature range alert conditions through a web application portal. The IoT-based solar dryer effectively accelerates drying while maintaining optimal conditions. The system's monitoring and notification capabilities and remote data visualization offer a reliable solution to the challenges faced by fish-drying farmers. This design could be a model for upgrading traditional drying methods for various food products with IoT technology.



https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3717498

Figure 2.7. Weight Monitoring System for Tilanggit Dried Fish With SMS Notification

The project developed by Curpoz et al. (2020), focuses on tracking the weight and moisture levels of fish during the drying process. The system collects data via a prototype and displays it in a desktop application, which also calculates moisture levels and shows real-time graphs. Fifty people, including fishermen, consumers, faculty, and businessmen, tested the system. They rated its functionality, reliability, and usability, with overall high scores: 3.97 for functionality, 3.66 for reliability, and 4.55 for usability, all indicating strong approval. The system was deemed successful and satisfactory. Some recommendations for improvement included enhancing the system's design and refining weight measurement accuracy.

Lugnasin et al. (2023) developed an off-grid IoT multilevel solar dryer for fish, focusing on drying anchovies (dilis), a common fish in the region. The new solar dryer was tested against the traditional sun-drying method to compare effectiveness. The solar dryer effectively trapped heat, maintaining higher temperatures inside (38.96 °C on the top rack, 36.47 °C on the middle rack, and 36.86 °C on the bottom rack) compared to the ambient temperature of 30.43 °C. It dried the anchovies four hours faster than traditional sun-drying. Data from the monitoring system confirmed that the solar dryer was efficient in drying the fish.

http://research.manuscritpub.com/id/eprint/2528/1/Dumaguit2452023AIR101042.pdf

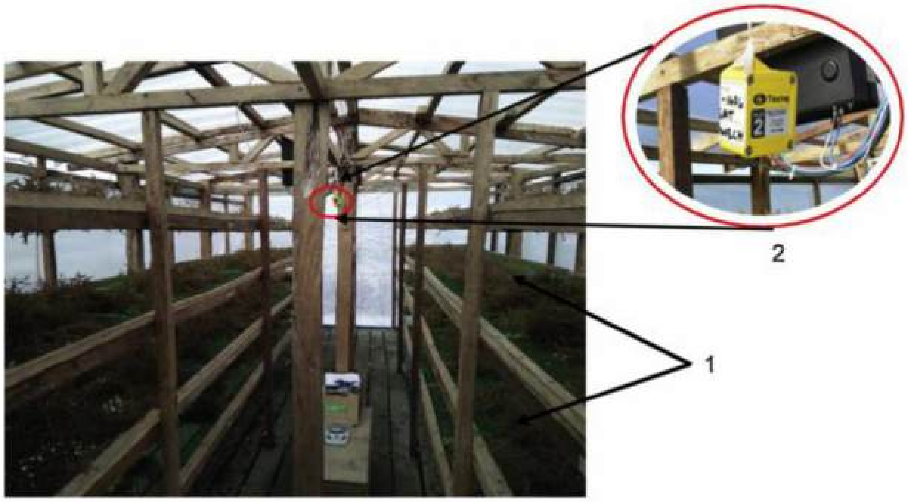
Figure 2.8. Automated Squid Dryer Chamber

Dumaguit et al. (2023) aimed to develop an indoor dual-source drying system with IoT technology to detect moisture during drying. This automated system was compared to traditional drying methods and saved 34 hours. It monitored humidity and temperature in real-time using image processing techniques. Conducted over a year in Brgy. Canlanipa, Surigao City, the study involved designing and building the dryer using Arduino Uno, Raspberry Pi 3b, sensors, and a motor. After creating a working prototype, developers tested it with wet squid samples and made improvements based on feedback. The automated dryer dried squid in just 14 hours, compared to 48 hours using traditional methods, while maintaining high quality with 10% moisture content. This indoor system was efficient and reliable, working well regardless of weather conditions and proving to be a significant improvement over traditional drying method.

https://www.sciencedirect.com/science/article/abs/pii/S0144860919301219

Figure 2.9. Actual Prototype of Seaweeds Solar Dryer

The project developed by Bertulfo (2022) focused on accessing a solar dryer specifically designed for local seaweeds. It involved examining the drying characteristics of seaweeds and fitting them with various drying models. The Midili-Kucuk model was identified as the most suitable for predicting and describing the seaweeds' drying behavior). A comparative analysis was conducted between traditional sun-drying methods and the newly developed solar dryer in terms of drying rate and drying time. The findings indicated that the solar dryer exhibited significantly improved performance in both drying rate and overall drying time compared to sun-drying methods.



https://sci-hub.st/https://doi.org/10.1016/j.aquaeng.2020.102068

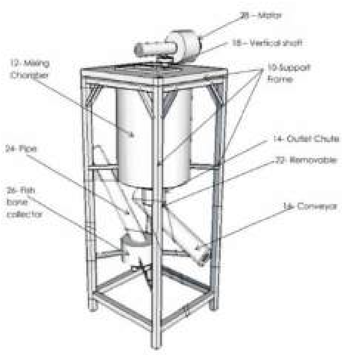
Figure 2.10. Dryer with Installed Temperature and Humidity Sensor

Pangan (2020) developed a device focused on optimizing the dryer's settings for different scenarios: sunny days, cloudy or rainy conditions, and nighttime drying. Developers experimented with adjusting the air inlet by varying the height of foldable sidings and timing the operation of exhaust fans to maximize the combined effect of solar and air drying. Significant findings included the effectiveness of fully opening the sidings without exhaust fans for nighttime drying, and partially opening them with exhaust fans for daytime conditions. These adjustments underscored the need to tailor dryer settings based on specific weather conditions to achieve optimal drying efficiency and maintain product quality.

https://biomech.uplb.edu.ph/wp-content/uploads/2021/06/PJABE-Vol17-No1-2-2021-Pangan-et

Figure 2.11. Modified Solar Dryer

University of the Philippines Visayas developed a Modified Solar Dryer (MSD) to improve the quality of dried fish. This technology has been extended and transferred to Partido State University. Fish dried using a Modified Solar Dryer (MSD) developed by Bigueja et al. (2022) is of superior quality due to controlled conditions and has the highest sensory acceptability. On rainy days, the MSD needs an additional heat source to prevent spoilage. The MSD is favored for its fast drying time and protection from dust, flies, and rodents. It also show that drying time for split mullet fish depends on brine concentration and drying conditions, with higher temperatures and lower humidity speeding up the process.



https://www.researchgate.net/publication/358508523_Development_and_Evaluation_of_Mechanized_Fish_Paste_Maker

Figure 2.12. Mechanized Fish Paste Maker

The Mechanized Fish Paste Maker made by Enriquez (2022) reduces manual labor in fish paste production by integrating the mixing and straining processes into a single compartment. Its performance efficiency is rated at 51.02% higher than traditional methods. Test results indicate that the machine significantly shortens the production time, enabling the production of bottled fish paste within one month. Consequently, it eases the workload for fish paste makers. Additionally, the cost-benefit analysis reveals that the machine can boost production by reducing operation time and lowering the number of laborers needed.

Foreign

Moula et al. (2023) aim to create a solar-powered innovative dehydrator using Arduino and the Internet of Things. The system uses solar energy to preserve food by heating the chamber and removing moisture. The Arduino microcontroller controls temperature sensors, an exhaust fan, a Wi-Fi module, and an LCD, allowing users to monitor and control the dehydrator remotely.

Murali et al. (2023) developed an energy-efficient solar hybrid dryer with a biomass-based gasifier heat backup for drying shrimps in sunlight and off-sunshine hours. The hybrid dryer utilized water as heat storage and a biomass gasifier as backup heat. Shrimp samples dried in the hybrid mode achieved the desired moisture content in 6 hours with an average drying rate of 0.47 g/g dm.h. The hybrid mode was economically favorable, with significant annual savings and a low payback period of 0.62 years.

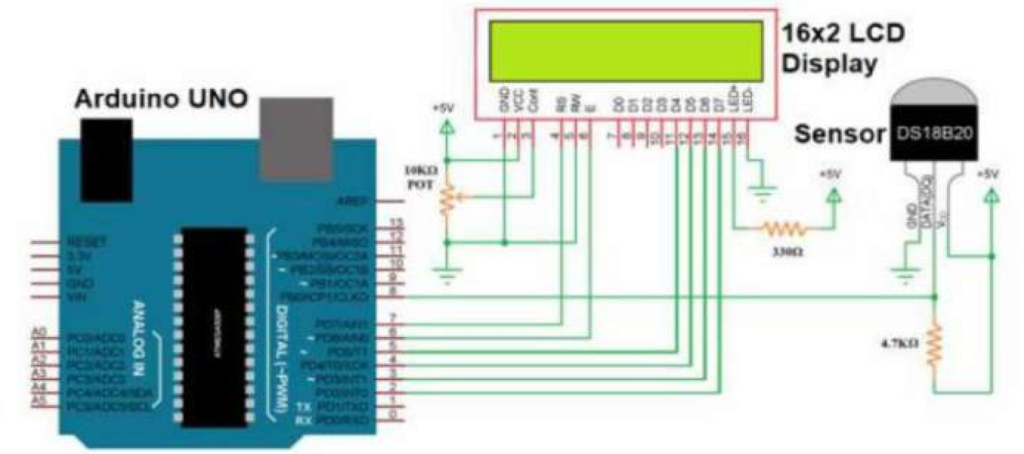
Damayanti et al. (2020) developed a device that automatically detects dehydration and urine pH levels. Equipped with color and pH sensors, the device can measure urine color levels, read pH values, and calculate the required body fluid for treatment. Testing has shown the device to be feasible and accurate, with a percentage error of 3.5% and sensitivity and specificity values of 60% and 70%, respectively. This device offers a potential solution for at-home dehydration detection.

https://www.semanticscholar.org/paper/Fish-Dryer-With-Temperature-Control-Using-the-Fuzzy-Muradi-Munir/7a9d4e8703e27ec824cc676c8fd9dde44d54521b

Figure. 2.13. Fish Dryer Using Fuzzy Logic

An Arduino-based fish dryer is a system that uses an Arduino microcontroller to control the temperature and drying process of fish (Raja, 2023). Their system aims to preserve processed fish by reducing its water content and inhibiting spoilage. The temperature and airflow velocity are essential factors in the drying process, with temperatures of 50°C and 60°C being chosen for this study.

In addition, preserving fish through drying is a standard method to extend its shelf life, and temperature and airflow velocity are essential factors in the drying process. This study chose temperatures of 50°C and 60°C to meet nutritional standards, and an airflow velocity of 1.5–2 m/s was used. The fish dryer system utilized sensors, a heater, a fan, and an Arduino Mega to control temperature and weight, ensuring that the drying temperature did not go beyond the set point using fuzzy logic.



https://www.ijscia.com/full-text-volume-2-issue-5-sep-oct-2021-810-821/

Figure. 2.14. DS18B20 Temperature Sensor Circuit Connections

Another type of dryer, a refractance window dryer, also utilizes an Arduino control system to dry food products efficiently on a conveyor belt (Mutumba, Kigozi, Tumutegyereize, & Ssenyimba, 2021). An automated system using an Arduino control system, sensors, a water pump, and a conveyor motor was developed to dry food products effectively using a refractance window dryer. The system was successfully simulated and tested before implementation, achieving a temperature range of 95±3°C and ensuring high product quality. The Arduino-based system is recommended for the dryer and can be scaled up for larger machines. System simulation using Proteus (ISIS) software. Additionally, a continuous refractance window dryer has been calibrated for drying temperature using an Arduino-based system, allowing for a wide range of products to be dried.

Lastly, Setiawati et al. (2020), developed and tested a temperature control system for a rotating tray hybrid dryer using an Arduino Mega microcontroller. The system was validated through laboratory experiments and data analysis with Microsoft Excel. The temperature sensor readings corresponding to the exhaust fan and blower conditions, with an electric power consumption of 13.57 watts and an electric current requirement of 0.062 A, demonstrated the system's successful operation.

Design Synthesis

The presentation of various dehydrator projects offers a comprehensive overview of food preservation methods. These projects vary from simple drying domes to sophisticated devices equipped with specific algorithms tailored for efficient drying. Both local and global initiatives showcase remarkable systems that demonstrate significant advancements in expediting the drying process.

The similarities between all of the related project and literature is that their main goal is to preserve food. There are specific devices that are similar to the developers' design project. Some of the noteworthy projects are the Automated Squid Dryer Chamber by Dumaguit et al. (2023), the usage of a weight sensor by Curpoz et al. (2020), and the project by Miano et al. (2023) that adds a GSM module to the designed solar dryer.

There are also differences among the projects. For example, Alvinika et al. (2021) use fuzzy logic, while some projects, such as that of Dumaguit et al. (2023), rely solely on temperature and a controlled environment, utilizing image processing to effectively dry the fish. Some research projects employ a complete machine dedicated to drying, like those by Raja (2023) and Trondillo et al. (2018). Others use solar energy as the heat source, as seen in the projects by Pangan (2020), Bigueja et al. (2022), and Bertulfo (2022).

On the other hand, this project distinguishes itself through its integration of multiple functionalities derived from various innovations, notably featuring an automatic stopping function. In contrast to many singularly focused projects, the developers prioritize user-centric design and practicality, aiming to assist users in effectively mitigating losses associated with unsold fish.

CHAPTER III

DESIGN AND METHODOLOGY

This chapter encompasses the Arduino-Based Tamban and Galunggong Dehydrator for Selected Retail Fish Vendors in San Pablo City Public Market's project design, development, testing, evaluation/validation criteria, design instruments and procedures, and project deployment plan.

Project Design

In the study by Estrada et al. (2023), it was found that unsold fish pose a profitability challenge for sellers in the San Pablo City Public Market. Sellers often resort to reducing prices for unsold fish in subsequent business days. Currently, the only preservation method employed is placing the fish in containers with ice, leading to increased capital expenditure, as seen in Figure 3.1.

Figure 3.1. Current Way of Dealing with Unsold Fish

Estrada et al. (2023), suggest a practical solution, transforming unsold fish into value-added products. Currently, sellers do not process unsold fish, and the study emphasizes the need for alternative preservation methods. Creating value-added products can not only address the issue of unsold inventory but also extend the fish's shelf life, potentially reducing sellers' losses. One suggested preservation method is creating dried fish from unsold stock. However, the drying process is time-consuming and relies heavily on ample sunlight. Given that fish sellers cannot afford to miss a business day, sun drying becomes an impractical solution for them.

They are lessening the losses and increasing the profitability of sellers by transforming their unsold fish into dried fish. The developers proposed having a drying system that does not rely on sunlight and speeds up the drying process for fish. This automatic fish dehydrator offers convenience for sellers since it dramatically reduces the time required for the fish to dry, making it ready for sale immediately.

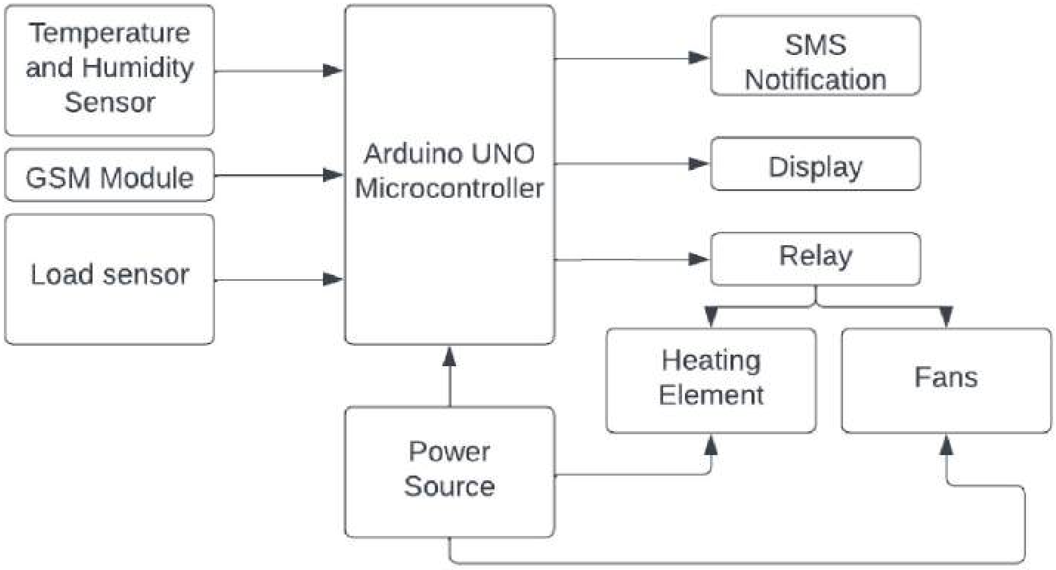


Figure 3.2. Automated Fish Dehydrator Block Diagram

Figure 3.2 represents the block diagram design of the automatic fish dryer. The sensors sends data to the microcontroller and use the provided data to display the current values of the temperature, weight of fish, and humidity inside the dryer. Based on the readings, the microcontroller can turn on and off the heating elements and fans to maintain the required temperature inside the dryer. To ensure the safety of the dried fish for human consumption, the developers employ stainless steel and aluminum to prevent oxidation over time while drying the food.

The following is a thorough explanation of the block diagram.

A. The Arduino UNO microcontroller controls the dehydrator based on the signals given by the sensors.

B. In order to automatically turn off the dehydrator after drying, the load sensor is utilized to register the weight of the fish before the drying process and continuously monitor it until it reaches the dry weight of the fish.

C. The temperature inside the dehydrator is be measured using a temperature sensor. The ideal temperature for drying fish is 37 to 42 °C in the first 5 hours and 53 to 58°C in the succeeding time.

D. The microcontroller utilizes the relay to control the temperature inside the dehydrator by turning the fans and heater on and off based on the sensors' readings.

E. The GSM module is used to notify the user after the drying process.

F. The fan and heating element uses a 220V AC supply, while the Arduino uses a 9V DC supply.

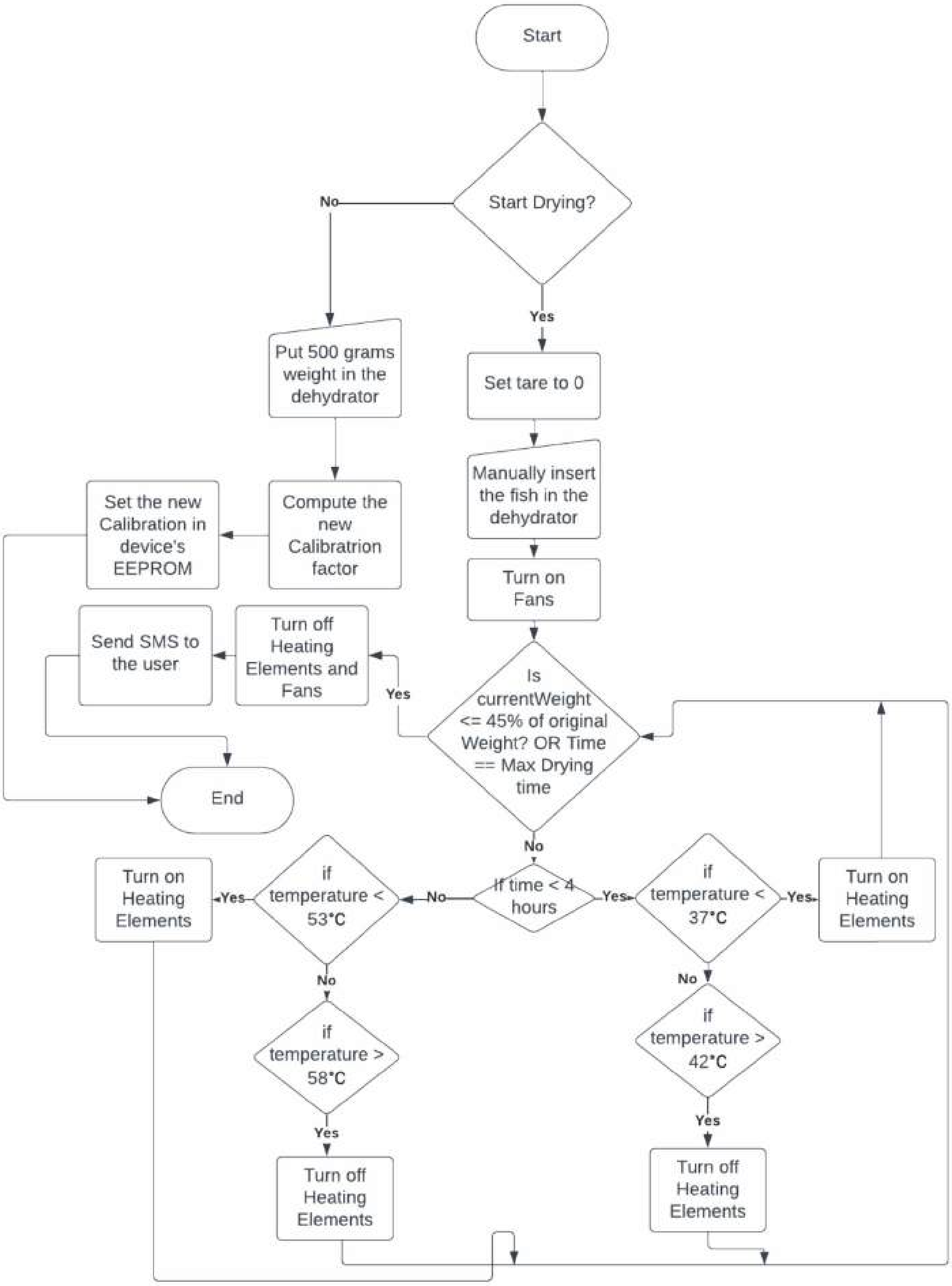


Figure 3.3. Flowchart of the Project

The flowchart detailing the operation of the automatic fish dehydrator illustrates a well-defined program cycle as shown in Figure 3.3. The user can calibrate the load sensor or initiate the drying process when powered up.

If the user chooses to calibrate the weight sensor, they need to place an object with a known weight inside the dryer. The calibration object, provided by the developers, ensures that the weight in the program matches the actual weight of the object. Afterward, the device will automatically compute a new calibration factor and save it to the device's EEPROM for future use.

On the other hand, if the user chooses to start the drying process, the weight sensor is set to tare before the fish is placed inside the dehydrator. The user has to manually load the cleaned and brined fish into the fish dehydrator. The initial weight of the fish is recorded for subsequent comparison with the current weight sensed by the load cell.

Regarding temperature control, during the first 5 hours, the temperature inside the dryer should be around thirty-seven (37) – forty-two (42) degrees Celsius to prevent instantly drying the fish, which may result in cooking the fish. After five (5) hours, the temperature inside the dehydrator should rise to fifty-three (53) – fifty-eight (58) degrees Celsius until the weight of the fish reaches 45% of its original weight.

A fail-safe mechanism is incorporated to prevent prolonged operation in the event of a load cell failure and enhance safety measures. A condition restricts the maximum drying time from the duration required to dry fish during testing effectively.

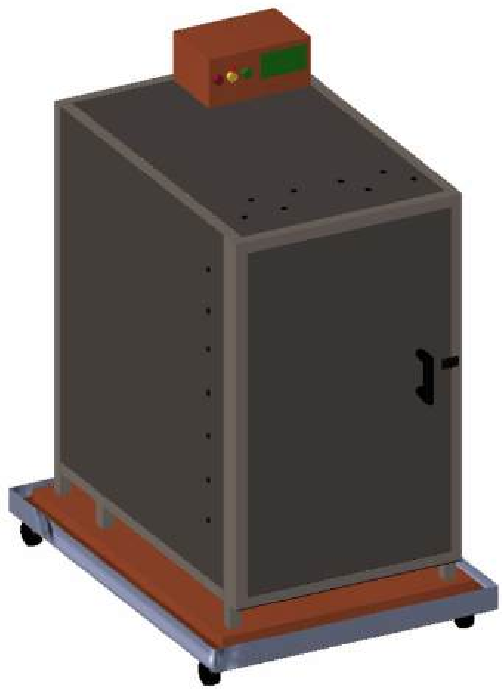


Figure 3.4. Isometric View of the Project

Figure 3.4 represents the image of the fish dehydrator. The fish dehydrator is constructed using aluminum sheets and square bars. According to Hodges (2021), aluminum is a metal widely used to manufacture kitchenware, utensils, and packaging materials for food. The European Food Information Council notes that aluminum naturally occurs in almost all rocks and soils and is present in water, air, and the human body.

The selection of aluminum for the fish dehydrator enclosure is driven by its advantageous combination of cost-effectiveness and resistance to rust. Unlike stainless steel, aluminum is more budget-friendly while offering comparable durability. Additionally, the corrosion-resistant nature of aluminum ensures that the dehydrator remains in optimal condition over time, especially in the moisture-rich environment associated with fish processing.

As seen in Figure 3.4, the dehydrator is equipped with wheels for easy mobility, ensuring convenience, especially considering its weight. Additionally, holes on the side of the dehydrator allow moisture to escape from the inside.

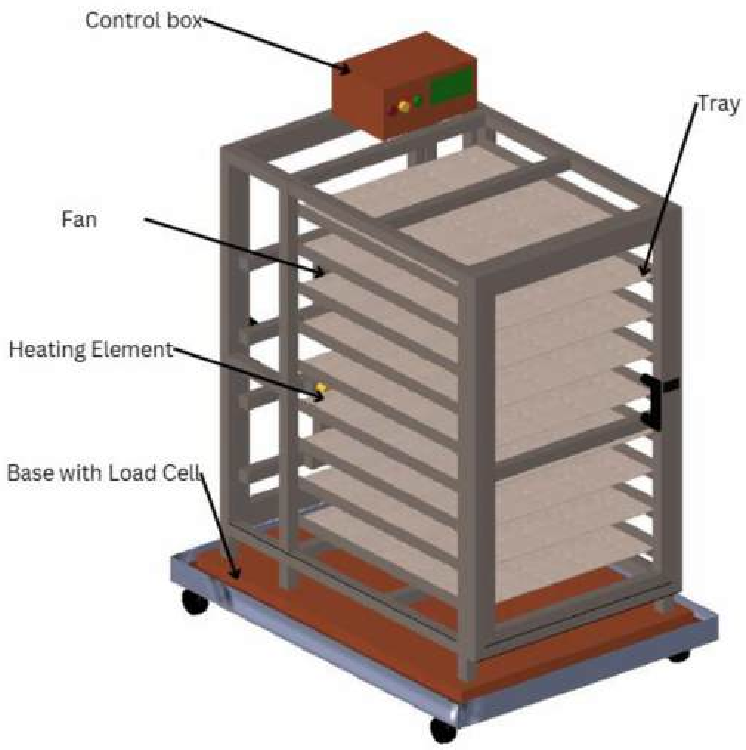


Figure 3.5. Fish Dehydrator Setup Component Design

The device's internal structure, as seen in Figure 3.5, comprises the components needed for dehydration. The fish rack's foundation is made of stainless steel, while the fish rack is made of aluminum. The fish rack is not fixed inside the dehydrator; instead, it is mounted at the top of the base (Marine Plywood). The base has a load sensor at the bottom. The sensor monitors the weight of the fish in the rack. The device has nine (9) fish racks and can dry up to 10kg of Tamban or Galunggong. See *Appendix H.2* for the detailed blueprint of the project.

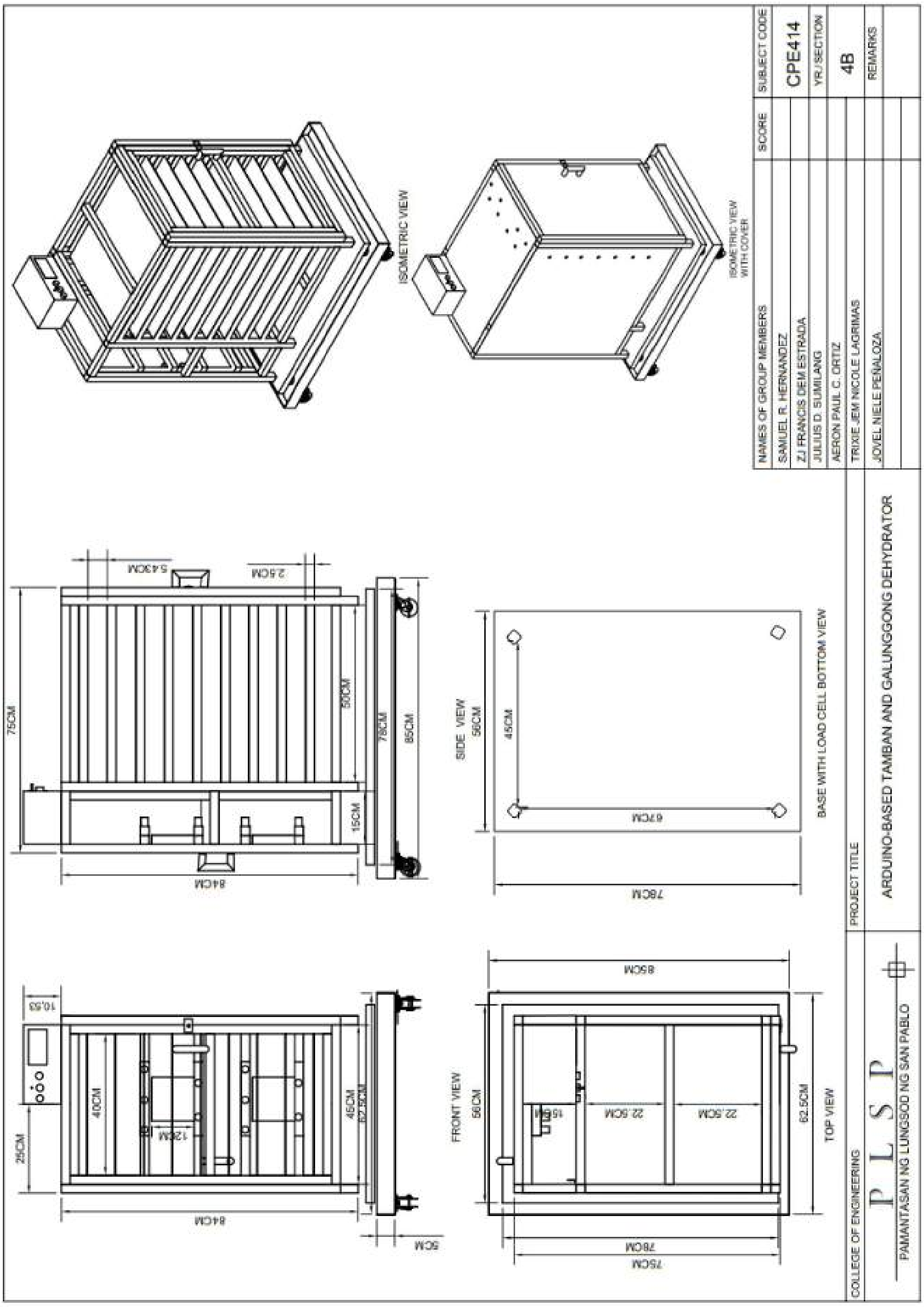
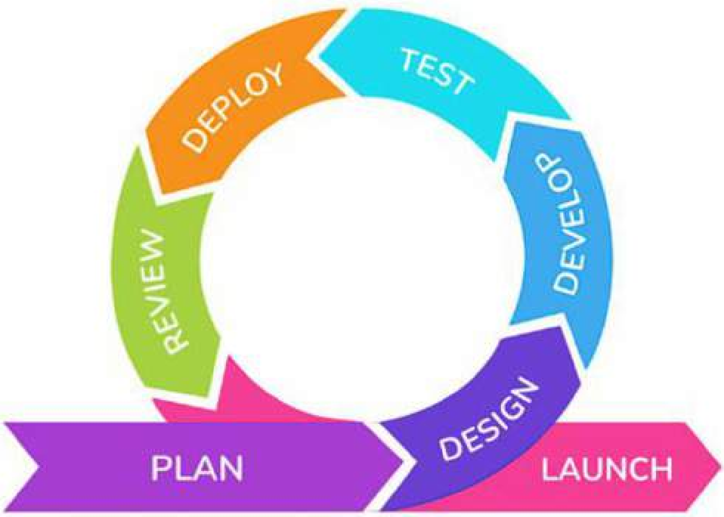


Figure 3.6. Top, Bottom Front, Side, and Isometric View of the Project

Project Development and Testing Procedures

The project is developed using agile project management methodologies, and its testing phase adhere to the ISO25010 standard. The implementation is align closely with the project's designated design.

Following a thorough assessment of the client's specific needs in design, development, testing procedures, and deployment, the decision to adopt the agile methodology was made. This choice is visually represented in Figure 3.7, illustrating a strategic alignment with the client's requirements across various project phases. The agile approach was selected as it offers a dynamic and flexible framework that accommodates iterative development, ensuring a responsive and adaptable strategy to address evolving project demands.



https://maheshkasbe.hashnode.dev/what-is-software-development-life-cyclesdlc-what-are-agile-methodologies

Figure 3.7. Agile Model

The Agile Software Development Life Cycle (SDLC) stands out as a widely embraced model in software development. The Agile approach segments the product into incremental builds and then delivers in iterative cycles. Breaking down each task into manageable time frames ensures the inclusion of functional elements in each build. The ultimate product encompasses all the necessary features (Vu, 2020). Additionally, the agile approach permits the developers to have the freedom to adjust and add additional functionalities to the project.

The initial phase of agile development involves *Planning Phase.* In this context, developers evaluated the feasibility of introducing an automatic fish dehydrator for sellers. Estrada et al. (2023) established the foundation for these requirements through surveys and observations focused on the challenges encountered by retail fish vendors. The developers developed plan by brainstorming ideas on how can they solve the issue of unsold fish using technology.

After identifying the plan, the developers formulated the *Design Phase* of the device. To establish a robust design foundation, the developers researched pertinent data and existing devices and sought advice from their advisors. Visual aids, including the block diagram in Figure 3.2 and the flow chart in Figure 3.3, were employed to visualize the device's structure and necessary components. These visual representations not only assisted the developers in understanding the intricacies of the device but also enabled them to pinpoint potential issues and bugs that might arise during the development process.

The subsequent phase is the *Development Phase*, during which the code for the device is generated by the provided design outlined in the flowchart and block diagram. Here, the teams' programmer meticulously translate the conceptual design into functional code, while concurrently, the team fabricates the physical body of the device to ensure it adheres to design specifications and fulfills its intended purpose. This stage represents the practical implementation of the conceptualized design, merging software development with constructing the device's tangible components, laying the groundwork for the rigorous testing phase that follows.

During the *Testing Phase*, the device prototype undergoes comprehensive testing, evaluating each of its modules and components for functionality and performance. This critical stage involves the collaborative efforts of three key roles: the Project Manager, Programmer, and Tester. The Project Manager oversees the testing strategy, ensuring alignment with project objectives and requirements. The Programmer plays a crucial role in validating the code's functionality, while the Tester systematically assesses the device's performance against predetermined criteria. Through this rigorous process, potential issues are identified and addressed early in the development cycle, preventing costly rework and ensuring a high-quality prototype.

The *Deployment Phase* represents the stage in which the device has undergone thorough testing and is now prepared for use by its intended users. In this phase, the automated fish dehydrator is ready for use by the intended users. The complete deployment phase of the device can be seen in the project deployment plan part of this paper.

Following the successful deployment of the device, the developers' transition into the *Review Phase*. During this phase, they ensure that the device is functioning as intended and that the end users are employing it correctly. This comprehensive review is essential for identifying any potential issues, as well as opportunities for refining and enhancing the prototype. By closely monitoring user interaction and device performance, the developers can gather valuable feedback, which is instrumental in guiding future improvements and ensuring the device meets all desired specifications and user needs.

Once the review process is completed, the *Launch Phase* commence, marking the stage when the device is fully prepared for its intended user. During the launch, a memorandum of understanding was signed by both parties—the school and the client—to formalize the understanding and ensure the device will be utilized for the client's benefit. This agreement underscores the commitment of both parties to the successful and beneficial use of the device.

Testing Procedures

Software Testing

The primary objective of software testing is to ensure that a software application or system functions correctly and meets its specified requirements. It involves systematically evaluating the software to identify defects, errors, or bugs to ensure the software's reliability, functionality, and performance.

The teams' programmer conducts software testing to ensure the code functions correctly according to its intended purpose. The team systematically tests the code and makes necessary adjustments based on the output of the sensors. This iterative process of testing and refining the code helps identify and address potential issues, ensuring that the software aligns effectively with the system's intended functionality.

Hardware Testing

All developers test the hardware parts of the automated fish dehydrator. Each module is tested to see if they are all working and functional. Below are thorough explanation of the testing procedures for each piece of hardware used.

Load Sensor Testing

The load sensor used in this project has a precision of ten (10) grams for each cell, with a total tolerance of plus or minus forty (40) grams. To ensure the accuracy of the sensor output and verify that the device can determine the weight of the fish as 45% of its original weight, the following test are performed:

1. Measure the initial weight of an item using a weighing scale.
2. Compare the readings of the device with the original weight.
3. Calculate the error.
4. Record the gathered data in a table

Specific Objectives Testing

This test aims to ensure all functionalities of the device operate as intended. The following details the comprehensive testing procedures designed to achieve the objectives of the device.

Temperature Monitoring and Regulation Testing

The device employs fans and a heating element to warm and disperse air inside the dehydrator, utilizing relays to control its operation based on specific conditions. The DHT22 is used for temperature monitoring, and the following test outlines the procedures developers used to verify the device's capability to monitor and regulate temperature:

1. Initiate the drying process by turning on the device and pressing green button.
2. Check whether the relay connected to the heating element and fan is activated, when the temperature displayed on the LCD falls below 53°C.
3. Verify if the relay connected to the heating element is deactivated when the temperature displayed on the LCD reaches 58°C.
4. Record the gathered data in a table.

Drying of 10kg of Tamban or Galunggong Testing

To validate the device's capability to dry +-10kg of Tamban or Galunggong, specific testing procedures are conducted. These tests ensure that the device can effectively perform its core function. The following test procedures are performed:

1. Start the device by turning it on.
2. Put 10kg of Tamban or Galunggong inside;
3. Record the data every 1 hour until the weight of the fish reach 45%.
4. Put the data in a table.

Automatic Stopping Function Testing

The device features an automatic stopping function with two conditions: reaching the maximum drying time as a safety feature and attaining the desired fish weight. To test it, developers observe if the device shuts off upon meeting either of the two conditions and record the data in the table.

SMS Notification Function Testing

The device is equipped to send information to the user when the drying process is complete. To test this, developers wait for the drying process to conclude and verify the functionality of the GSM module by receiving an SMS through the installed SIM card.

Project Evaluation

The project evaluators are five (5) CpE practitioners, seven (7) retail fresh fish vendors in San Pablo City Public Market, and three (3) dried fish vendors for a total of fifteen (15) evaluators. The evaluators used ISO 25010 with the following software standards: functionality, reliability, performance efficiency, useability, security, compatibility, maintainability, and portability.

Validation Criteria

This project used a five-point Likert scale to evaluate the device's acceptability. As shown in Table 3.1, the Likert scale offers a range of response options with corresponding descriptive equivalents that capture evaluators' opinions or attitudes. A structured rating system, Likert scales allow evaluators to choose the response that best aligns with their viewpoint after a statement or question is presented.

Table 3.1. Five-Point Likert Scale

Likert Scale	Interval	Adjectival Rating
5	4.51-5.00	Highly Acceptable
4	3.51-4.50	Very Acceptable
3	2.51-3.50	Acceptable
2	1.51-2.50	Fairly Acceptable
1	1.50 and below	Not Acceptable

After gathering the data, the arithmetic mean is utilized to evaluate and assess it. The arithmetic mean, the average, is the most straightforward and commonly employed mean measure. It entails adding up a set of numbers and dividing that sum by the total count of numbers in the series (Chen, 2021).

The formula is as follows:

$$A = \frac{\sum fx}{N}$$

Where:

A = Arithmetic mean

fx= All the items in the group

N = Total number of items in the group

Design Instruments and Techniques

The design instrument used in the project design is the ISO 25010 evaluation model for the device software. The evaluation is a mix of close-ended, as they choose their response based on the given evaluation questions, and open-ended, as the developers seek the evaluators' review regarding the device that can be found in *Appendix F*. The evaluation is composed of the following parts:

Part I includes evaluating the device's functionality, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

Part II asks the evaluators to evaluate and provide feedback on the device's overall performance.

Project Deployment Plan

After the completion of the device prototype, the developers sent it to Mr. Efrain Maranan Jr., a fish vendor at San Pablo City Public Market, as the project's beneficiary after final approval as part of the deployment plan. The device is responsible for the dehydration of unsold fish to lessen the probability of losing profit. The developers provided a user manual to the designated device operator, a reference for maintaining the device modules and addressing system issues after the handover.

Table 3.2. Project Deployment Plan

Strategy	**Activities**	**Persons Involved**	**Duration**
Approval from Beneficiaries	Letters for the PLSP	Client and Developers	5 minutes
Setting up the Device	Assembly and reviewing for potential problem	Developers	30 minutes
Handover of the Device	User Manual Discussion	Developers	10 minutes
Training	Hands-on Basic Fundamentals of Handling of the Device	Client and Developers	1 hour

The procedures for deploying and utilizing the device in Barangay San Gabriel, City of San Pablo, are outlined in Table 3.2. The initial step involves obtaining approval from the client by providing a letter of acceptance. Following this, the device is set up and reviewed for any potential issues. Subsequently, the device is handed over to the client. The final step is to train the client on how to operate the device.

CHAPTER IV

RESULTS AND DISCUSSIONS

This chapter covers the project's economic and schedule feasibility as well as the technical and operational feasibility, testing, evaluation results and analysis, and deployment results. The evaluation's findings suggest more improvements to the device.

Project Technical Feasibility

Project Design Technical Discussion

The device aims to help retail fish vendors lessen their losses and increase their profitability due to the large amount of unsold fish, especially during summer when there is too much supply. Arduino Uno Microcontroller controls the device. It can turn the fans and heating elements on and off using a relay depending on the readings of the DHT22 sensor that senses the temperature and humidity inside the dehydrator. Moreover, a load sensor is integrated into the system to monitor the weight of the fish within the dehydrator continuously. Once the fish reaches 45% of its original weight, the Arduino Uno automatically turns off the relay, controlling the fans and heating element. Additionally, it sends an SMS notification to the user, indicating that the drying process has been completed. This automated process helps to streamline operations and ensure efficient fish drying while minimizing manual intervention.

Software Specification

The device's control system is implemented on an Arduino Uno microcontroller. The Arduino Integrated Development Environment (IDE) and

Arduino Command Line Interface (CLI) are used for software development and simulation. The microcontroller serves as the core unit, orchestrating all device functionalities. The software directly controls relays, managing the drying process.

Programming Environment

The Arduino Uno microcontroller that runs the device uses the C++ programming language and has been programmed using the Arduino IDE version 2.3.2. It uses multiple libraries, including SoftwareSerial, LiquidCrystal I2C, DHT sensor library, HX711, and the EEPROM.

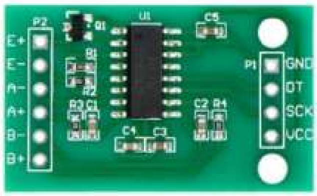
The Components of Dehydrator

The Arduino fish dehydrator is constructed using an Arduino Uno R3 microcontroller as the central unit. Additional hardware includes 220V fans and heating elements, an HX711 amplifier with a 50kg load cell, a SIM800L V2 module for potential remote communication, a 20x4 LCD for user interface, an LM2596 step-down power supply module for voltage regulation, buttons for user input, jumper wires for connections, and a PCB board to house and connect some of the components.

https://store.arduino.cc/products/arduino-uno-wifi-rev2

Figure 4.1. Arduino Uno R3

The project utilized the Arduino Uno R3 microcontroller as its central processing unit. This board boasts a 16 MHz clock speed, 6 analog inputs for sensor data, and 14 digital pins for controlling various functions. Notably, 6 of these pins can generate pulse-width modulated (PWM) signals for precise control. The Arduino Uno is programmed using the Arduino IDE software via a USB connection. For this project, a 9V, 2A power supply was chosen. While the Arduino itself can operate within a 5V to 24V range, the higher voltage ensures sufficient power delivery to the entire system, including the LCD display connected to the board.



https://botland.store/pressure-sensors/12479-hx711-amplifier-for-tensometers-5904422319366.html

Figure 4.2. HX711 Amplifier

The HX711 is a specialized 24-bit analog-to-digital converter (ADC) designed to interface directly with bridge sensors in weighing scales and industrial control systems. Its main job is to amplify load cell signals and send them to another microcontroller so it can process them.

https://www.makerlab-electronics.com/products/dht22-temperature-humidity-sensor-module

Figure 4.3. DHT22 Sensor

The DHT22 sensor, sometimes referred to as the DHT22 or AM2302, is a digital temperature and humidity sensor that has an excellent reputation for accuracy and reliability. It uses a thermistor and a capacitive humidity sensor to monitor temperature and relative humidity, respectively, very precisely. The DHT22 sensor provides real-time data for precise temperature and humidity inside the dehydrator

https://proto-pic.co.uk/product/load-cell-sensor-50kg

Figure 4.4. Load Cell Sensor

The device utilizes four strain gauge load cells, which are transducers that convert applied force into a measurable electrical signal. These sensors are typically constructed from high-strength alloy steel designed to deflect proportionally under load. This deflection alters the electrical resistance within the strain gauges, resulting in a corresponding change in voltage or current output. By employing four load cells, the device achieves a maximum capacity of 200kg when the weight is evenly distributed across the platform.

https://www.dev.faranux.com/product/sim800l-v2-0-5v-wirelessgsm-gprs-module-quad-band

Figure 4.5. Sim800L V2 GSM module

The SIM800 GSM module is a cellular modem commonly used for embedded systems and Internet of Things (IoT) applications due to its versatility in cellular communication. It requires a stable power supply of 5V and 2A to function correctly. Insufficient power can lead to operational issues such as frequent restarts, as experienced with the SIM800L v2 module.

https://homeplusexpress.com/heating-element-restring-coil/

Figure 4.6. Heating Element (Coil)

The device employs a dual-coil heating system for optimized temperature distribution. The lower portion utilizes a 300-watt coil, while the upper portion features a 200-watt coil. This configuration addresses the natural tendency of hot air to rise within the device. By incorporating a higher wattage heater element in the lower section, the developers aim to achieve a more uniform temperature profile throughout the drying chamber

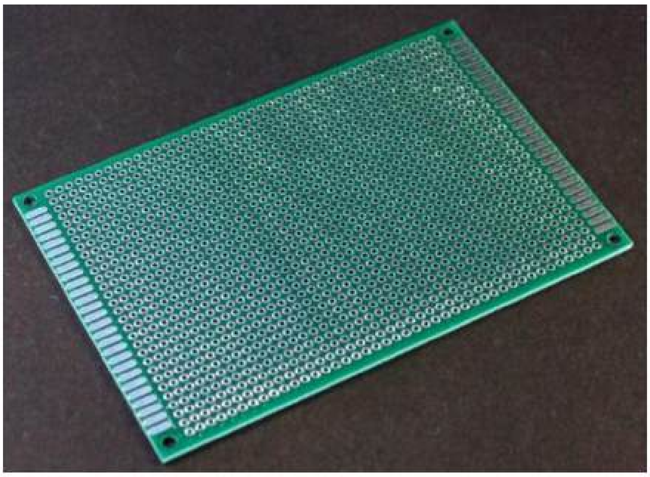
Figure 4.7. 4x20 Liquid Crystal Display

The device incorporates a 4x20 character Liquid Crystal Display (LCD) for user interaction. This display format allows for the presentation of information on up to four lines, with each line accommodating a maximum of 20 characters. The LCD serves as the primary interface, providing real-time data on crucial parameters such as weight, humidity, and internal temperature of the dehydrator chamber.

https://www.makerlab-electronics.com/products/fotek-solid-state-relay-module-ssr-40da

Figure 4.8. Solid State Relay

The device employs Solid-State Relays (SSRs) for control of its heating element and ventilation fans. SSRs are electronic switches that utilize semiconductors for silent, high-speed operation and extended lifespans compared to traditional electromechanical relays. This specific SSR model features a DC control input range of 3-32VDC and can handle AC loads from 24VAC to 380VAC. In this application, the SSRs feature a DC control input range of 3-32VDC. They are responsible for controlling the AC power delivered to the heating element (rated for 500W) and the fans (rated for 70W) within the dehydrator. Notably, the maximum current rating of these specific SSRs is 30A, providing ample headroom for the dehydrator's operational requirements.



https://protosupplies.com/product/pcb-8-x-12-cm-universal-prototype-board/

Figure 4.9. Printed Circuit Universal Board (8x12)

The PCB board plays a crucial role in integrating the buck converter and the SIM800L module, serving as a vital bridge between them. Its intricate network of copper traces functions like electrical highways, designed to carry power from the buck converter at the precise voltage required by the SIM800L module. These traces not only deliver the necessary power but also facilitate the seamless flow of communication signals between the SIM800L and other interconnected components within the system.

Furthermore, the PCB provides a robust and secure mounting platform for both the buck converter and the SIM800L module. This stability is essential for maintaining a reliable and well-functioning system, as it minimizes the risk of disconnections or damage that could disrupt operation

Schematic Diagram of the device

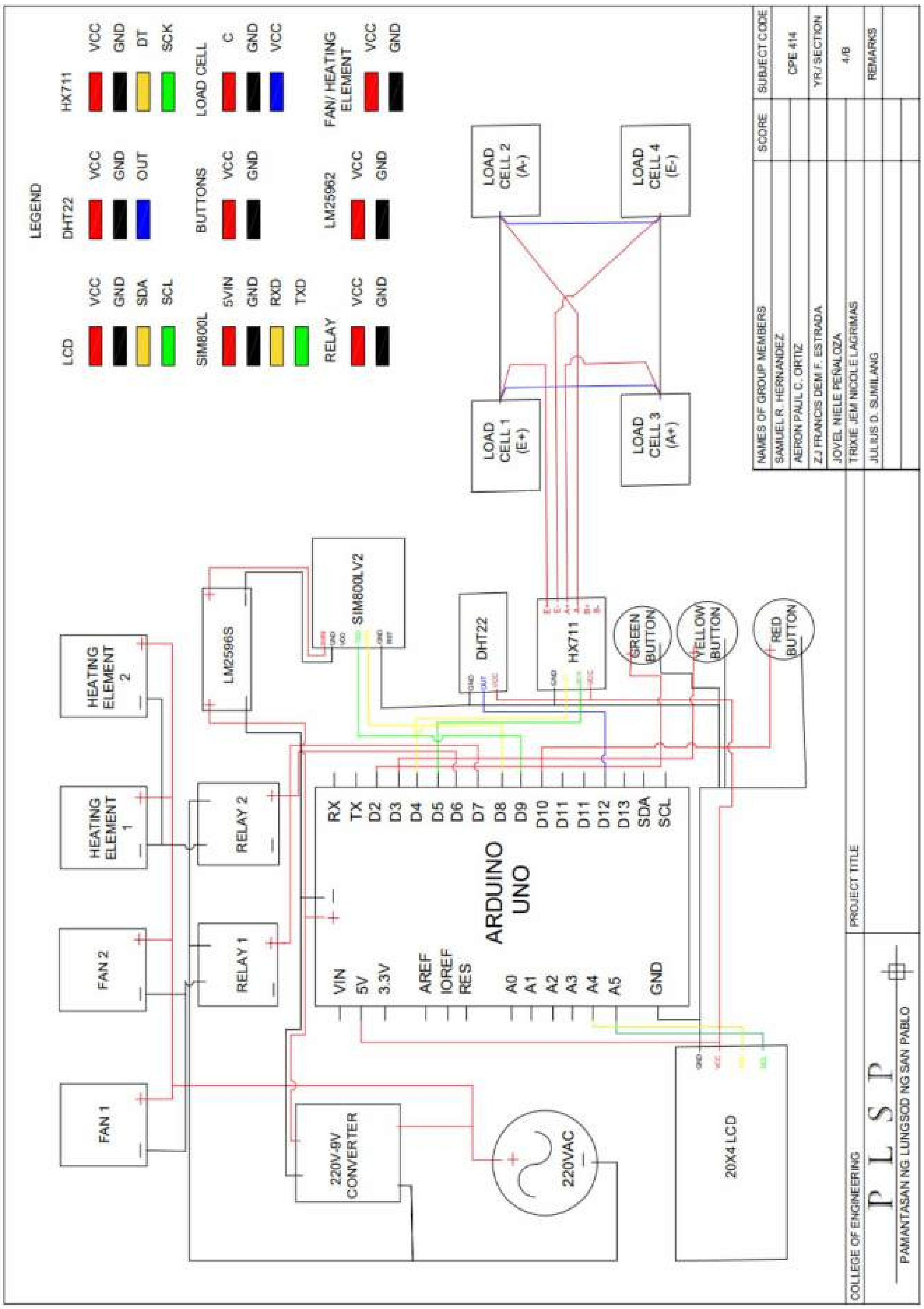


Figure 4.10. Schematic Diagram of the Device

This schematic diagram represents a control system built around an Arduino Uno microcontroller, designed for Arduino-based fish dehydrator. The Arduino Uno is powered by 9v while the Sim800l V2 is powered by 5v that came from the step-down converter.

On the input side, a DHT22 sensor is used for measuring temperature and humidity, connected to digital pin D12, and powered by the Arduino's 5V and GND pins. Additionally, an HX711 load cell amplifier, connected to four load cells arranged in a wheatstone bridge configuration, measures weight and connects to digital pins D4 and D5. Three buttons, a green button on digital pin D2, yellow button on digital pin D3, and red button on digital pin D10 provide manual user input.

The output side includes two relays connected to digital pins D7 and D8, which control two fans and two heating elements, allowing the system to regulate temperature and airflow. The system also features a SIM800L V2 GSM module, connected to the RX and TX pins (D8 and D9), for sending data remotely, and a 20x4 LCD display connected via I2C to analog pins A4 (SDA) and A5 (SCL), providing a user interface to display system information.

The entire setup is powered and regulated carefully, ensuring that each component operates at its required voltage level, with appropriate connections to the Arduino's voltage references and ground. This control system integrates temperature, humidity, and weight measurements with user inputs and remote communication capabilities, making it suitable for applications requiring precise environmental control and monitoring.

Project Operational Feasibility

Design of Project

Figure 4.11 shows the actual image of the Arduino-based Tamban and Galunggong dehydrator. Constructed from aluminum, the device is designed to resist rust over time, making it more cost-effective than using stainless steel. Insulation is utilized between two aluminum sheets to prevent heat loss through the cover, ensuring optimal energy efficiency. Additionally, several strategically placed holes on the sides allow moisture to escape, preventing it from returning to the food and ensuring a more effective dehydration process. This thoughtful design enhances the device's overall performance and durability, making it a practical solution for long-term use.

Figure 4.11. Fish Dehydrator Setup

The LCD enables users to monitor the current status of the drying process, as depicted in Figure 4.12. It provides real-time information and offers insights into its progress. It gives information about the current temperature, humidity and weight of the fish inside the dehydrator.

Figure 4.12. Liquid Crystal Display

The dehydrator described has a significant capacity for processing fish, specifically Tamban or Galunggong, during its operation. Figure 4.13 show the details of its design, the dehydrator is equipped with a total of 9 trays. Each tray is capable of holding more than 1 kg of fish at a time, allowing for efficient and high-volume processing.

Figure 4.13. Trays Inside the Device

Testing, Evaluation Results, and Analysis

Program Testing Results

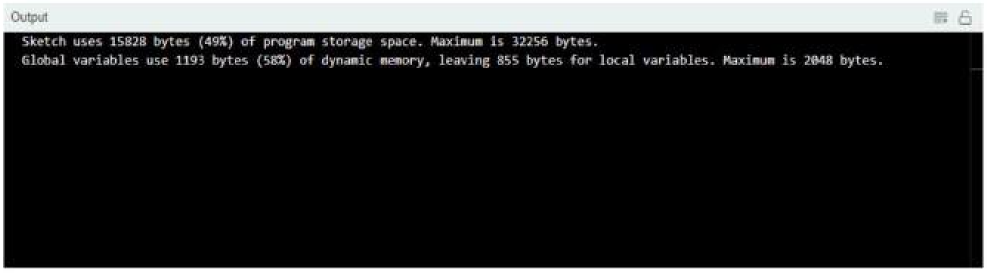


Figure 4.14. Program Testing Results

The program was error-free and capable of satisfying the specific objectives of the device, as illustrated in Figure 4.14. The program was tested through the use of the LCD screen to see if the device was working as it should be.

Load Sensor Testing Results

Table 4.1. Load Sensor Testing Results

Load Sensor Readings Image	Weighing Scale Image	Load Sensor Readings	Actual Weight using a weighing scale	Error
		0.18kg	183g or 0.18kg	0%
		0.51kg	518.7g or 0.52kg	1.96%
		0.22kg	221g or 0.22kg	0%

To ensure the load sensor's accuracy in weight measurement, a calibration and testing procedure was implemented. This step is crucial for the device's successful operation and program execution. During testing, a high-precision weighing scale capable of gram-level readings was used as a reference as seen in Table 4.1. The developers employed objects with varying low weights to evaluate the load sensor's accuracy across its measurement range.

Temperature Regulation and Monitoring Testing Results

Table 4.2. Temperature Regulation and Monitoring Testing Results

Actual Picture of Display	Actual Picture of Relays	Expected Result		Actual Result		Analysis
		Fans	Heating Element	Fans	Heating Element	
		On	Off	On	Off	The relay functioned properly
		On	On	On	On	The relay functioned properly
		On	On	On	Off	The relay functioned properly

Table 4.2 represents the results of temperature regulation and monitoring testing. Based on the results, the device is capable of regulating the temperature by turning the relay on and off where the heating element is connected based on the readings of the DHT22 sensor.

Drying Tamban and Galunggong Fish Testing Result

An initial experiment evaluated the dehydrator's performance in drying Galunggong fish as seen in Table 4.3. It follows Raja's (2023) study, at temperatures between 50 °C and 60 °C. Developers placed 9.96 kg of fish in the dehydrator at 7:10 PM. The average initial weight per fish was 21.80 grams, which decreased to 9.37 grams after 12 hours and 6 minutes, representing a 57% weight reduction.

Fish were weighed before and after dehydration. Initially, the scale showed 10.04 kg, decreasing to 4.31 kg after drying. The dehydrator initially read 9.96 kg, showing an error of 0.8%, and finally read 4.48 kg, with a 3.79% error, indicating slight discrepancies in its weight measurements. However, the quality of the dried fish was poor, indicating that the temperatures between 50 °C and 60 °C were not suitable in the device.

Table 4.3. Drying 10kg of Galunggong Testing Result

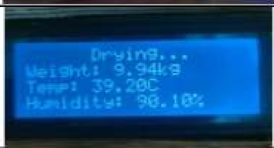
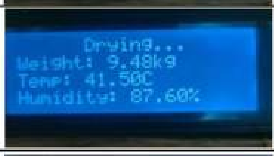
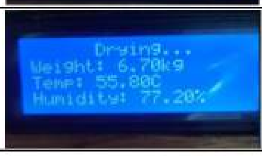
Actual Photo	Hours	Time	Weight	Humidity
	0	7:10 pm	9.96 kg	81.60%
	1	8:10 pm	9.78 kg	90.80%
	2	9:10 pm	9.23 kg	87.60%
	3	10:10 pm	8.73 kg	85.20%
	4	11:10 pm	8.21 kg	83.80%
	5	12:10 am	7.71 kg	81.60%

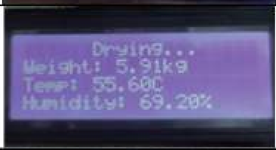
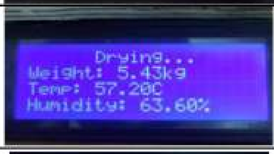
	6	1:10 am	7.06 kg	79.30%
	7	2:10 am	6.63 kg	76.40%
	8	3:10 am	6.22 kg	73.30%
	9	4:10 am	5.79 kg	69.70%
	10	5:10 am	5.38 kg	66.00%
	11	6:10 am	5.01 kg	61.60%
	12	7:10 am	4.63 kg	57.50%
	12.01	7:16 am	4.48 kg	54.60%

The second test involved drying 10.20 kg of Tamban fish, starting at 10:36 PM as seen in Table 4.4. It following Ramos' (2021) technique of beginning with low heat and then increasing to over 45 ºC. The average weight of each fish before dehydration was 16.74 grams, which decreased to 7.27 grams after 11 hours and 51 minutes, a 56.5% weight reduction.

Measured with a weighing scale, the overall weight of the fish was 10.23 kg initially and 4.39 kg after drying. The dehydrator readings were 10.20 kg initially (0.29% discrepancy) and 4.59 kg after drying (4.56% discrepancy), the latter considered acceptable due to debris on the tray.

Table 4.4. Drying 10kg of Tamban Testing Result

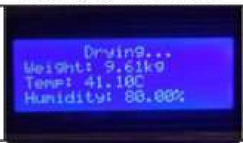
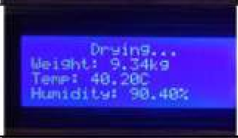
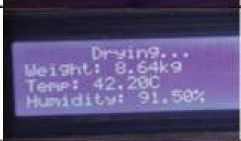
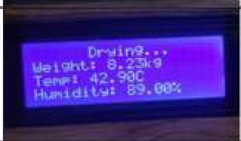
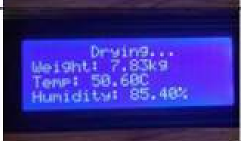
Actual Photo	Hours	Time	Weight	Humidity
	0	10:36 pm	10.20 kg	78.00%
	1	11:36 pm	9.94 kg	90.10%
	2	12:36 am	9.48 kg	87.60%
	3	1:36 am	8.86 kg	85.20%
	4	2:36 am	8.23 kg	82.90%
	5	3:36 am	7.63 kg	80.80%
	6	4:36 am	7.10 kg	78.90%
	7	5:36 am	6.74 kg	77.20%

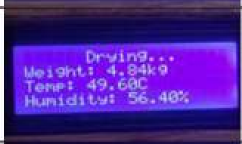
	8	6:36 am	6.32 kg	77.90%
	9	7:36 am	5.91 kg	69.20%
	10	8:36 am	5.43 kg	63.60%
	11	9:36 am	4.95 kg	58.00%
	12	10:27 am	4.59 kg	54.30%

The final test involved drying 4.13 kg of Tamban and 5.49 kg of Galunggong fish with a total of 9.61kg of fish, starting at 10:36 pm which can be seen at Table 4.5. The average weight of each fish before dehydration was 48 grams. After 16 hours and 48 minutes, the average dry weight of each fish reached 20.35 grams, representing a weight removal of 57.6%.

The total weight of all fish, measured with a weighing scale, was 9.62 kg. However, the dehydrator readings indicated 9.61 kg, with a slight discrepancy of 0.10%. Following dehydration, the device displayed a reading of 4.32 kg, while the actual weight of the fish, measured with a weighing scale, was 4.17 kg. This resulted in a difference of 3.47%.

Table 4.5. Drying 10kg of Tamban and Galunggong Testing Result

Actual Picture	Hours	Time	Weight	Humidity
	0	4:00 pm	9.61 kg	80.00%
	1	5:00 pm	9.34 kg	90.40%
	2	6:00 pm	9.13 kg	92.40%
	3	7:00 pm	8.94 kg	93.30%
	4	8:00 pm	8.64 kg	91.50%
	5	9:00 pm	8.23 kg	89.00%
	6	10:00 pm	7.83 kg	85.40%
	7	11:00 pm	7.40 kg	78.10%
	8	12:00 am	6.95 kg	74.00%
	9	1:00 am	6.52 kg	69.20%
	10	2:00 am	6.11 kg	63.30%

	11	3:00 am	5.79 kg	60.10%
	12	4:00 am	5.47 kg	59.40%
	13	5:00 am	5.17 kg	63.80%
	14	6:00 am	4.84 kg	56.40%
	15	7:00 am	4.50 kg	53.60%
	16	8:00 am	4.40 kg	54.20%
	16.7	8:48 am	4.32 kg	54.30%

Automatic Stopping Function Testing

Table 4.6. Automatic Stopping Function Testing Result

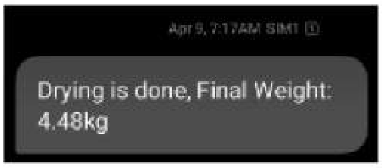
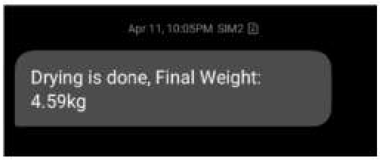
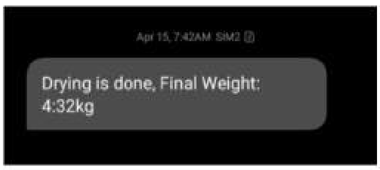
Initial weight	Expected Result	Actual Result	Analysis
9.96 kg	The fan and heating element will turn off at 4.48kg	The fan and heating element turned off at 4.48kg	The device functioned properly
10.20 kg	The fan and heating element will turn off at 4.59kg	The fan and heating element turned off at 4.59kg	The device functioned properly
9.61	The fan and heating element will turn off at 4.32 kg	The fan and heating element turned off at 4.32kg	The device functioned properly

The device should stop the dehydration process when it reaches 45% of its original weight. Based on the testing on Table 4.6, the fans and heating elements automatically turn off after reaching the desired weight of the fish inside the dehydrator.

SMS Notification Function Testing

To minimize the human effort constantly checking the dehydrator, an SMS notification feature has been added to notify the user when the drying is done along with the weight of the dried fish. Based on the results below, the SMS Notification function of the device is working as expected.

Table 4.7. SMS Notification Function Testing Result

Screenshot of Message	Expected Result	Actual Result	Analysis
	The device will send a message at 4.48kg	The device sends a message at 4.48kg	The device functioned properly
	The device will send a message at 4.59kg	The device sends a message at 4.59kg	The device functioned properly
	The device will send a message at 4.32 kg	The device sends a message at 4.32kg	The device functioned properly

Summary of Testing

Based on the summary of testing in Table 4.8 the device successfully achieved all of its specific objectives. The temperature monitoring and regulation were effective, facilitated by the use of a DHT22 sensor. This is a critical component, as noted by Moula et al. (2023), who emphasized that a temperature sensor is essential for monitoring and controlling a dehydrator. Regarding the drying of Tamban and Galuggong, the device's performance was slower compared to the one developed by Alvinika (2021), which can dry fish in 9 hours. However, it's important to note that Alvinika (2021) conducted tests using only one kilogram of fish, whereas the developers tested their device with ten kilograms of fish, which naturally leads to longer drying times. Despite this, both devices significantly outperformed traditional drying methods, which can take up to three days to reduce the fish to 45% of its original weight, as shown in Table 4.33. Thus, while there are differences in drying times based on the amount of fish processed, the device still demonstrates a marked improvement over traditional techniques.

Table 4.8. Summary of Specific Objectives Testing

Testing	Expected Output	Actual Result
Temperature monitoring and regulation testing	The relay connected to the heating element turns on and off based on the output given by the sensor.	The relay connected to the heating element turns on and off based on the output given by the sensor.
Drying Tamban and Galunggong testing	Tamban and Galunggong will be dried	The Tamban and Galunggong was dried.
Automatic stop testing	The device will stop when the weight reaches 45%,	The device stopped when 45% of the weight was reached.
SMS Notification Function Testing	The device will send text message to the user after drying process.	The device sends text message to the user after drying process.

Evaluation Results

The Arduino-based Tamban and Galunggong dehydrator underwent evaluation by five (5) CPE Practitioners, seven (7) fresh fish vendors, and three (3) dried fish vendors. They assessed whether the system met the International Organization for Standardization (ISO) software quality standards, including functional suitability, reliability, performance efficiency, usability, security, compatibility, maintainability, and portability of the overall device. The developers prepared a video presentation demonstrating the device's functionality and appearance to aid in evaluation. The video presentation was utilized to get the evaluation of the fresh fish sellers, dried fish sellers, and the four (4) CpE Practitioners.

CpE Practitioners' Evaluation Result

Table 4.9. CPE Practitioners' Evaluation Results Based on Functional Suitability

Criteria	Mean	Verbal Interpretation
Functional Completeness	5.00	Highly Acceptable
Functional Correctness	4.20	Very Acceptable
Functional Appropriateness	5.00	Highly Acceptable
Overall Mean	**4.73**	**Highly Acceptable**

The functional suitability evaluation results for CpE Practitioners are summarized in Table 4.9. The device fulfills all designated duties and user objectives, scoring a mean of 5.00 for both functional completeness and functional appropriateness, which means that the device is "Highly Acceptable". The functional correctness achieves a score of 4.20, with the verbal interpretation of

"Very Acceptable." Overall, with a mean score of 4.73, the evaluation indicates that the device's functional suitability is "Highly Acceptable."

Table 4.10. CpE Practitioners' Evaluation Results Based on Reliability

Criteria	Mean	Verbal Interpretation
Maturity	5.00	Highly Acceptable
Availability	5.00	Highly Acceptable
Fault Tolerance	4.00	Very Acceptable
Recoverability	4.80	Highly Acceptable
Overall Mean	**4.70**	**Highly Acceptable**

The evaluation findings of the CpE Practitioners based on reliability are shown in Table 4.10. The highest mean scores went to maturity and availability, both at 5.00 with the verbal interpretation of "Highly Acceptable," meaning that the device meets standard reliability requirements under normal operation, is accessible when needed, and continues to function. The fault tolerance score is 4.00, which is "Very Acceptable", and the recoverability score is 4.80, which is "Highly acceptable." The device's reliability overall mean score was 4.70 overall, which is indicates that the device's reliability is "Highly Acceptable".

Table 4.11. CpE Practitioners' Evaluation Results Based on Performance Efficiency

Criteria	Mean	Verbal Interpretation
Time Behavior	4.00	Very Acceptable
Resource Utilization	4.80	Highly Acceptable
Capacity	4.20	Very Acceptable
Overall Mean	**4.33**	**Very Acceptable**

Table 4.11 displays the evaluation findings for the performance efficiency of the device. Resource Utilization received the highest mean score of 4.80. It was verbally interpreted as "Highly Acceptable" meaning that the device satisfy the requirements when operating with a specific set of resources. Capacity has a mean of 4.20 with the verbal interpretation of "Very Acceptable". The mean score for time behavior is 4.00, which means "Very Acceptable". Lastly, the with an overall mean of 4.33, the device's performance efficiency is "Highly Acceptable," indicating that it performs well in relation to the amount of resources required under the given circumstances.

Table 4.12. CpE Practitioners' Evaluation Results Based on Usability

Criteria	Mean	Verbal Interpretation
Appropriateness Recognizability	4.80	Highly Acceptable
Learnability	4.80	Highly Acceptable
Operability	4.80	Highly Acceptable
User Error Protection	4.00	Very Acceptable
User Interface Aesthetics	5.00	Highly Acceptable
Accessibility	4.00	Very Acceptable
Overall Mean	**4.33**	**Very Acceptable**

The one with the highest mean based in usability in Table 4.12 is the user interface aesthetics, which has a mean score of 5.00 and is "Highly Acceptable." This means that the device's user interface is excellent and easy to follow. The appropriateness of recognizability, learnability, and operability has a mean score of 4.80 with a verbal interpretation of "Highly Acceptable." The user error protection and accessibility have a mean score of 4.00, which means "Very Acceptable."

Table 4.12 makes it apparent that the device's usability was evaluated as "Very Acceptable" by the CpE Practitioners, with an overall mean score of 4.33. This measure pertains to the efficacy, effectiveness, and contentment that designated users can have when using the device in a drying fish.

Table 4.13. CpE Practitioners' Evaluation Results Based on Security

Criteria	Mean	Verbal Interpretation
Confidentiality	4.00	Very Acceptable
Integrity	4.00	Very Acceptable
Non-repudiation	4.20	Very Acceptable
Authenticity	4.00	Very Acceptable
Accountability	3.80	Very Acceptable
Overall Mean	**4.00**	**Very Acceptable**

The evaluation of CpE Practitioners based on security is detailed in Table 4.13. Non-repudiation has the highest mean score of 4.20, which means "Very Acceptable". Confidentiality, integrity, and authenticity have a mean score of 4.00, with verbal interpretation of "Very Acceptable". Accountability, scoring 3.80, is the lowest interpreted as "Very Acceptable." The device's overall security mean score is 4.00 which indicates that the verbal interpretation of "Very Acceptable."

Table 4.14. CpE Practitioners' Evaluation Results Based on Compatibility

Criteria	Mean	Verbal Interpretation
Co-existence	5.00	Highly Acceptable
Interoperability	4.80	Highly Acceptable
Overall Mean	**4.90**	**Highly Acceptable**

Table 4.14 presents evaluation results for CpE Practitioners based on Compatibility, focusing on criteria like co-existence and interoperability. Co-existence has a mean score of 5.00 which means “Highly Acceptable, indicating excellent compatibility with other systems. Interoperability also scores highly at 4.80 with a verbal interpretation of “Highly Acceptable”, suggesting strong interaction with other components. The overall mean of 4.90 with the verbal interpretation of “Highly Acceptable” across the device’s Compatibility.

Table 4.15. CpE Practitioners’ Evaluation Results Based on Maintainability

Criteria	Mean	Verbal Interpretation
Modularity	4.00	Very Acceptable
Reusability	4.80	Highly Acceptable
Analyzability	4.80	Highly Acceptable
Modifiability	4.00	Very Acceptable
Testability	4.80	Highly Acceptable
Overall Mean	**4.48**	**Very Acceptable**

Table 4.15 presents the evaluation results of CpE Practitioners based on maintainability. Reusability, analyzability, and testability stand out with scores of 4.80 each, indicating the device components can be effectively reused in various contexts and with the verbal interpretation of “Highly Acceptable”. Modularity and modifiability both achieve a score of 4.00, interpreted as “Very Acceptable” in terms of organization and adaptability to changes. The overall mean score of 4.48 consolidates these findings, suggesting that while the system excels particularly in reusability, analyzability, and testability, it maintains a “Very Acceptable” interpretation based on maintainability.

Table 4.16. CpE Practitioners' Evaluation Results Based on Portability

Criteria	Mean	Verbal Interpretation
Adaptability	4.80	Highly Acceptable
Installability	5.00	Highly Acceptable
Replaceability	3.80	Very Acceptable
Overall Mean	**4.53**	**Very Acceptable**

Table 4.16 displays the evaluation findings for the portability of the device. Installability achieves a mean score of 5.00, denoting it as "Highly Acceptable" for its ease of installation. Adaptability scoring 4.80, meaning it is "Highly Acceptable" for its flexibility and ability to adjust. Replaceability, scoring 3.80 means "Very Acceptable" for its capability to be replaced when needed. The device's portability has an overall mean of 4.53 with a verbal interpretation of "Very Acceptable" performance across all criteria evaluated in the device.

Fresh Fish Vendors' Evaluation Result

Table 4.17. Fresh Fish Vendors' Evaluation Results Based on Functional Suitability

Criteria	Mean	Verbal Interpretation
Functional Completeness	4.57	Highly Acceptable
Functional Correctness	4.71	Highly Acceptable
Functional Appropriateness	4.71	Highly Acceptable
Overall Mean	**4.67**	**Highly Acceptable**

Table 4.17 shows the evaluation result of fresh fish vendor based on device's functional suitability. The evaluation table shows that functional completeness and functional correctness scores 4.71, which means that the

device is “Highly Acceptable” for its comprehensive coverage of functionalities. Functional completeness has a mean of 4.57 verbally interpreted as “Highly Acceptable”. The overall mean of 4.67 reflects a “Highly Acceptable” interpretation across all criteria evaluated.

Table 4.18. Fresh Fish Vendors’ Evaluation Results Based on Reliability

Criteria	Mean	Verbal Interpretation
Maturity	4.14	Very Acceptable
Availability	4.43	Very Acceptable
Fault Tolerance	4.57	Highly Acceptable
Recoverability	4.14	Very Acceptable
Overall Mean	**4.32**	**Very Acceptable**

The evaluation table in Table 4.18 indicates that maturity and recoverability of the device both scores 4.14 with a verbal interpretation of “Very Acceptable”. Fault Tolerance scores 4.57, indicating it is “Highly Acceptable” for its capability to maintain operation despite faults or disruptions Availability achieves a mean of 4.43, also has a verbal interpretation of “Very Acceptable” for its consistency in being accessible when needed. The overall mean of 4.32 reflects a verbal interpretation of “Very Acceptable” performance across all criteria evaluated.

Table 4.19. Fresh Fish Vendors’ Evaluation Results Based on Performance Efficiency

Criteria	Mean	Verbal Interpretation
Time Behavior	4.57	Highly Acceptable
Resource Utilization	4.57	Highly Acceptable
Capacity	4.86	Highly Acceptable
Overall Mean	**4.67**	**Highly Acceptable**

The evaluation of the Fresh Fish Vendors based on Table 4.19, shows that the device's system is highly suitable when it comes to Performance Efficiency. The evaluation table reveals that time behavior and resource utilization both score 4.57, which means that the device is "Highly Acceptable" for its efficiency and effectiveness in managing time and resources, respectively. Capacity achieves a score of 4.86, denoting it as "Highly Acceptable" for its capability to handle 10kg of fish. The overall mean of 4.67 reflects a "Highly Acceptable" performance across all criteria evaluated.

Table 4.20. Fresh Fish Vendors' Evaluation Results Based on Usability

Criteria	Mean	Verbal Interpretation
Appropriateness Recognizability	4.86	Highly Acceptable
Learnability	4.86	Highly Acceptable
Operability	4.57	Highly Acceptable
User Error Protection	4.14	Very Acceptable
User Interface Aesthetics	4.57	Highly Acceptable
Accessibility	4.43	Very Acceptable
Overall Mean	**4.57**	**Highly Acceptable**

The evaluation of the fresh fish vendors reveals the usability of the system's device, as displayed in Table 4.20. Fish vendors evaluates usability criteria including appropriateness recognizability and learnability, both scoring 4.86, denoting them as "Highly Acceptable" for their ease of recognition and learning capability. Operability and user interface aesthetics follows closely with a mean score of 4.57 with a verbal interpretation of "Highly Acceptable". Accessibility scores 4.43, which means "Very Acceptable" for ease of access. User error protection scores 4.14, also “Very Acceptable” for safeguarding against user errors. The overall mean score of 4.57 has a verbal interpretation of “Highly Acceptable” performance across all usability criteria, emphasizing strong usability and user interface design in the evaluation.

Table 4.21. Fresh Fish Vendors’ Evaluation Results Based on Security

Criteria	Mean	Verbal Interpretation
Confidentiality	4.00	Very Acceptable
Integrity	4.29	Very Acceptable
Non-repudiation	4.43	Very Acceptable
Authenticity	4.43	Very Acceptable
Accountability	4.29	Very Acceptable
Overall Mean	**4.29**	**Very Acceptable**

Table 4.21 presents the evaluation results for Fresh Fish Vendors based on security. Non-repudiation and Authenticity both score 4.43, indicating they are “Very Acceptable” for ensuring messages cannot be denied and verifying data origin, respectively. Integrity and Accountability both achieve a score of 4.29, noted as “Very Acceptable” for maintaining data accuracy and traceability. Confidentiality scores 4.00, deemed “Very Acceptable” for data privacy assurance. The overall mean score of 4.29 with the verbal interpretation of “Very Acceptable” performance across all criteria.

Table 4.22. Fresh Fish Vendors’ Evaluation Results Based on Compatibility

Criteria	Mean	Verbal Interpretation
Co-existence	4.57	Highly Acceptable
Interoperability	4.43	Very Acceptable
Overall Mean	**4.50**	**Very Acceptable**

Table 4.22 presents the evaluation results for Fresh Fish Vendors based on compatibility, focusing on criteria such as co-existence and interoperability. The vendors scored the device's co-existence with a mean of 4.57, with a verbal interpretation of "Highly Acceptable". Similarly, their interoperability garnered a mean of 4.43, with a "Very Acceptable" verbal interpretation. Notably, the overall mean of 4.50 which means that the device is "Very Acceptable" in terms of Project's compatibility. In this evaluation, co-existence emerged as the highest-rated aspect, while interoperability obtained the lowest mean score.

Table 4.23. Fresh Fish Vendors' Evaluation Results Based on Maintainability

Criteria	Mean	Verbal Interpretation
Modularity	4.29	Very Acceptable
Reusability	4.86	Highly Acceptable
Analyzability	4.29	Very Acceptable
Modifiability	4.43	Very Acceptable
Testability	4.71	Highly Acceptable
Overall Mean	**4.51**	**Highly Acceptable**

Table 4.23 presents the evaluation results of Fresh Fish Vendors based on Maintainability. Reusability achieves the highest mean score of 4.86, marking it as "Highly Acceptable" for its effective reuse across different contexts. Testability follows closely with a score of 4.71, indicating it is also "Highly Acceptable" for its ease and effectiveness in testing components. Modifiability has a mean score of 4.43, with a verbal interpretation of "Very Acceptable" for its ability to be modified as needed. Modularity and Analyzability both score 4.29, interpreted as "Very Acceptable" for their structured organization and ease of analysis. The overall

mean score of 4.51 with a verbal interpretation of “Highly Acceptable” performance across all criteria evaluated, emphasizing the device’s reusability, effective testing capability, and strong adaptability through modification and structured organization.

Table 4.24. Fresh Fish Vendors’ Evaluation Results Based on Portability

Criteria	Mean	Verbal Interpretation
Adaptability	4.71	Highly Acceptable
Installability	4.29	Very Acceptable
Replaceability	3.57	Very Acceptable
Overall Mean	**4.19**	**Very Acceptable**

Table 4.24 presents the evaluation results of fresh fish vendors based on portability, encompassing adaptability, installability, and replaceability criteria. Among the evaluated criteria, Adaptability stands out with a mean score of 4.71, marking it as “Highly Acceptable” for its capability to adjust to different conditions or requirements effectively. Installability follows with a score of 4.29, which is “Very Acceptable,” indicating ease of installation for the system. Replaceability scores 3.57, also has a verbal interpretation of “Very Acceptable,” demonstrating the device’s ability to be replaced when necessary.

The overall mean score of 4.19 reflects a verbal interpretation of “Very Acceptable” performance across all criteria assessed, highlighting the system’s strong adaptability, satisfactory installability, and reliable replaceability in various operational contexts.

Dried Fish Vendors' Evaluation Result

Table 4.25. Dried Fish Vendors' Evaluation Results Based on Functional Suitability

Criteria	Mean	Verbal Interpretation
Functional Completeness	5.00	Highly Acceptable
Functional Correctness	4.67	Highly Acceptable
Functional Appropriateness	4.67	Highly Acceptable
Overall Mean	**4.78**	**Highly Acceptable**

The results of the functional suitability-based evaluation of the dried fish vendors are shown in Table 4.25. The device's system functions to a degree that covers all the designated duties and user objectives, with a mean of 5.00 for functional completeness, which is interpreted as "Highly Acceptable." The average mean score for both functional correctness and functional appropriateness is 4.67, with a verbal interpretation of "Highly Acceptable," meaning that the device's system produces accurate results with the necessary level of precision and makes it easier to di its function. The overall mean of 4.78 for functional suitability indicates that the results are "Highly Acceptable."

Table 4.26. Dried Fish Vendors' Evaluation Results Based on Reliability

Criteria	Mean	Verbal Interpretation
Maturity	4.67	Highly Acceptable
Availability	4.33	Very Acceptable
Fault Tolerance	4.67	Highly Acceptable
Recoverability	4.33	Very Acceptable
Overall Mean	**4.50**	**Highly Acceptable**

The evaluation findings of the dried fish vendors based on reliability are shown above in Table 4.26. The highest average mean scores went to fault tolerance and maturity, both at 4.67 with a verbal interpretation of "Highly Acceptable". This mean that the device meets standard reliability requirements under normal operation and continues to function as intended even in the event of hardware or software faults. The average mean score for availability and recoverability was 4.33, with the verbal interpretation of "Very Acceptable". The device's reliability score was 4.50 overall, which means "Highly Acceptable," indicating that the system operates as intended within the allotted period.

Table 4.27. Dried Fish Vendors' Evaluation Results Based on Performance Efficiency

Criteria	Mean	Verbal Interpretation
Time Behavior	4.67	Highly Acceptable
Resource Utilization	4.67	Highly Acceptable
Capacity	5.00	Highly Acceptable
Overall Mean	**4.78**	**Highly Acceptable**

Table 4.27 displays the evaluation findings for the performance efficiency of the device. Capacity received the highest mean score of 5.00 and was verbally interpreted as "Highly Acceptable," meaning that the device's system's maximum limits satisfy the requirements. The average mean score for both time behavior and resource utilization is 4.67, which is interpreted as "Highly Acceptable." This indicates that the device's system response, processing time, and throughput rates meet the requirements and that they also satisfy the requirements when operating with a specific set of resources. With an overall mean of 4.78, the device's

performance efficiency is considered "Highly Acceptable," indicating that it performs well in relation to the amount of resources required under the given circumstances

Table 4.28. Dried Fish Vendors' Evaluation Results Based on Usability

Criteria	Mean	Verbal Interpretation
Appropriateness Recognizability	4.67	Highly Acceptable
Learnability	5.00	Highly Acceptable
Operability	4.67	Highly Acceptable
User Error Protection	4.67	Highly Acceptable
User Interface Aesthetics	4.67	Highly Acceptable
Accessibility	4.00	Very Acceptable
Overall Mean	**4.61**	**Highly Acceptable**

The device's learnability achieved the highest average mean of 5.00, interpreted as "Highly Acceptable," meaning that users may learn how to operate the equipment effectively. The evaluation results show that the average mean score for Appropriateness Recognizability, Operability, User Error protection, and user interface aesthetics is 4.67 with "Highly Acceptable" rating. The users can determine if the device is appropriate for their needs and has features that facilitate control and ease of use. In addition, the system has protections that prevent users from making mistakes, and the user interface makes it possible for users to interact in a way that is satisfying and pleasant. The evaluation's findings show that accessibility received a "Very Acceptable" rating with an average mean score of 4.00. As seen above, makes it apparent that the device's usability was evaluated as "Highly Acceptable" by the Dried Fish Vendors, with an overall mean score of

4.61. This measure pertains to the efficiency, effectiveness, and contentment that designated users can have when using the device.

Table 4.29. Dried Fish Vendors' Evaluation Results Based on Security

Criteria	Mean	Verbal Interpretation
Confidentiality	4.33	Very Acceptable
Integrity	4.00	Very Acceptable
Non-repudiation	4.00	Very Acceptable
Authenticity	4.67	Highly Acceptable
Accountability	4.33	Very Acceptable
Overall Mean	**4.27**	**Very Acceptable**

The results of the security-based evaluation of the dried fish vendors are shown in Table 4.29. The highest mean of the device for security is authenticity with mean of 4.67, which has a verbal interpretation of "Highly acceptable," meaning that device and system identity can be proved to be the one claimed. The device and system ensure that the data are accessible only to authorized users, with an average mean of 4.33 for confidentiality and accountability, which means "Very Acceptable." The average mean score for both integrity and non-repudiation is 4.00, with a verbal interpretation of "Very Acceptable". The device's security overall mean of 4.27 indicates that the results are "Very Acceptable".

Table 4.30. Dried Fish Vendors' Evaluation Results Based on Compatibility

Criteria	Mean	Verbal Interpretation
Co-existence	4.67	Highly Acceptable
Interoperability	4.33	Very Acceptable
Overall Mean	**4.50**	**Very Acceptable**

The results of the compatibility evaluation of the dried fish vendors are shown in Table 4.30. Device perform its functions efficiently while sharing a typical resources with other products, with an average mean of 4.67 for co-existence, with verbal interpretation of "Highly Acceptable." The mean score for Interoperability is 4.33, which is "Very Acceptable," meaning the device's components can exchange information to and use it. The overall mean of compatibility is 4.50 with verbal interpretation of "Very acceptable".

Table 4.31. Dried Fish Vendors' Evaluation Results Based on Maintainability

Criteria	Mean	Verbal Interpretation
Modularity	4.33	Very Acceptable
Reusability	5.00	Highly Acceptable
Analyzability	4.67	Highly Acceptable
Modifiability	4.33	Very Acceptable
Testability	5.00	Highly Acceptable
Overall Mean	**4.67**	**Highly Acceptable**

In Table 4.31, the device scored highest in reliability and testability with a mean score of 5.00, which means "Highly Acceptable." The device's analyzability received a score of 4.67, also classified as "Highly Acceptable," showing its effectiveness in the system. For modularity and modifiability, the device scored 4.33, with verbal interpretation of "Very Acceptable," meaning it can be modified effectively without compromising product quality. Overall its maintainability has an overall mean of 4.67 which means that the device is "Highly Acceptable".

Table 4.32. Dried Fish Vendors' Evaluation Results Based on Portability

Criteria	Mean	Verbal Interpretation
Adaptability	4.67	Highly Acceptable
Installability	4.00	Very Acceptable
Replaceability	3.33	Acceptable
Overall Mean	**4.00**	**Very Acceptable**

Table 4.32 displays the evaluation findings for the portability of the device. Adaptability received the highest mean score of 4.67 with a verbal interpretation of “Highly Acceptable,” indicating the device can adapt to different or evolving hardware, software, or other operational or usage environments. The average mean score for installability is 4.00, which indicates that the evaluated result of dried fish vendors are “Very Acceptable,” suggesting this device can be easily installed and uninstalled. The dried fish vendor evaluates the category of replaceability and has a mean score of 3.33, which means “Acceptable”. With an overall mean of 4.00, the device's portability has a verbal interpretation of “Very Acceptable”.

Table 4.33. Summary of Evaluation Results

Criteria	CpE Practitioners	Fresh Fish Vendors	Dried Fish Vendors
Functional Suitability	4.73	4.67	4.78
Reliability	4.70	4.32	4.50
Performance Efficiency	4.33	4.67	4.78
Usability	4.57	4.57	4.61
Security	4.00	4.29	4.27
Compatibility	4.90	4.50	4.50
Maintainability	4.48	4.51	4.67
Portability	4.53	4.19	4.00
Overall Mean	**4.53**	**4.46**	**4.51**
Verbal Interpretation	**Highly Acceptable**	**Very Acceptable**	**Highly Acceptable**

The Table 4.33 compares the evaluation scores given by CpE Practitioners, Fresh Fish Sellers, and Dried Fish Vendors across various criteria for a system or product. CpE Practitioners generally rate the system highest in reliability (4.7), compatibility (4.9), and portability (4.53). Fresh Fish Vendors find functional suitability most satisfactory (4.67), while Dried Fish Vendors give the highest scores in functional suitability (4.78), performance efficiency (4.78), and maintainability (4.67).

Overall, CpE Practitioners have the highest mean score of 4.53, interpreting the system as “Highly Acceptable”. Dried Fish Sellers closely follow with an overall mean of 4.51, also “Highly Acceptable”. Fresh Fish Sellers have the lowest overall mean at 4.46, still rating the system as “Very Acceptable”. This means that while all groups find the system satisfactory, CpE Practitioners are the most satisfied, particularly valuing reliability, compatibility, and portability, whereas Dried Fish Sellers highlight functional suitability and performance efficiency.

Project Benefits

Traditionally, fish sellers grappled with the dilemma of either selling their fish at reduced prices to prevent losses or storing excess supply for the following day, particularly during periods of oversupply like during summer. With the automatic fish dehydrator, sellers can efficiently dry their fish, mitigating the need for constant monitoring. Its capacity to dry up to 10kg of fish enables them to dry unsold fish conveniently within the device.

Automated fish dehydrators offer several advantages over traditional sun-drying methods, as shown in Table 4.34. The most significant benefit is the faster drying time. The device can dry an average twenty-one (21) gram fish within twelve (12) hours, whereas traditional drying can take up to three (3) days. Dehydrators also reduce the effort required for drying fish. Unlike traditional methods, which necessitate constant monitoring and flipping of the fish, dehydrators allow the user to set the drying process and walk away. Additionally, the device eliminates the need to worry about weather conditions, as the device provide a controlled environment.

Table 4.34. Traditional Fish Drying Result

Day	Picture		Weight	
	Tamban	**Galungongg**	**Tamban**	**Galungongg**
0			21 grams	19 grams
1			14 grams	13 grams
2			10 grams	11 grams
3			9 grams	8 grams

In addition to faster drying times and reduced effort, fish dehydrators offer enhanced hygiene and food safety. Traditional sun-drying exposes fish to dust, insects, and other contaminants, which can compromise the quality and safety of the dried product. Dehydrators, on the other hand, operate in a closed environment, minimizing contamination risks. Furthermore, the consistent and controlled drying conditions ensure uniform drying, which can enhance the texture and flavor of the dried fish. Dehydrators also consume less space compared to traditional drying methods, making them ideal for small-scale operations or limited storage areas.

Moreover, the device offers an automated shutdown after the dehydration process, ensuring convenience and peace of mind for sellers. Additionally, it provides real-time notifications via SMS, eliminating the need for frequent manual checks on the drying progress. Following the drying process, fish sellers can expand their market opportunities by selling the dried fish directly to customers or by specializing in dried fish sellers in the market, thereby maximizing their revenue potential.

A significant advantage of the device is its ability to extend the shelf life of dried fish. The developers undertook a detailed study to mimic the traditional storage practices employed by dried fish vendors, specifically by replicating the method of stacking the product in boxes.

As demonstrated in Tables 4.35 and 4.36, both Tamban and Galunggong varieties stored using this method exhibit a maximum shelf life of two weeks under optimal conditions. This represents a notable improvement over conventional storage methods, which often result in a shorter shelf life. The extended shelf life not only allows for a longer sales window for vendors but also significantly reduces the likelihood of spoilage.

Table 4.35. Observation on Dried Tamban Using the Device

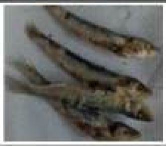
Photo	Day	Observation
	1 - 11	No significant changes
	12	Salt begins to form on the surface, especially around the areas where starts accumulate moisture.
	14	Salt crystals become more prominent, especially at the top surface of the fish.
	20	The dried fish become more brittle and fragile.

Table 4.36. Observation on Dried Galunggong Using the Device

Photo	Day	Observation
	1 - 10	No significant changes
	11	Salt begins to form on the surface, especially around the areas where starts accumulate moisture.
	14	Salt crystals become more prominent, especially at the top surface of the fish.
	18	The dried fish become more brittle and fragile.

Project Economic Feasibility

Fish vendors can utilize this innovative device after business hours to efficiently dry unsold fish inventory. This not only reduces waste but also allows them to potentially command slightly higher prices when reselling the dried fish. The initial investment for constructing the device, including electronic components and miscellaneous expenses, is ₱10,379.00. Additionally, fabrication by a professional aluminum worker would add ₱3,000.00 to the initial cost.

Figure 4.15. Maximum Power Consumption during Tests

The price of Tamban during April 2024 ranges from ₱40.00-₱60.00 per kilo in the afternoon, down from their original price of ₱70.00-₱80.00 in the morning. On the other hand, the price of Galunggong in the same season ranges from ₱70.00-₱100.00 per kilo in the afternoon, down from its original price of ₱100.00-₱120.00 in the morning. This indicates that the prices decrease as the day progresses and the fish remains unsold. If the fish is not sold by the end of the business day, its price the following day will be significantly lower due to the reduced quality of the fish.

Table 4.37. Total Budget for the Project

Expenses				
Item	**Price**	**No of items**	**Shipping**	**Total**
Heating Element(200W)	₱ 180.00	1	₱ 0.00	₱ 180.00
Heating Element(300W)	₱ 250.00	1	₱ 50.00	₱ 300.00
DHT22 sensor	₱ 191.00	1	₱ 0.00	₱ 191.00
Load Cell	₱ 29.00	4	₱ 0.00	₱ 116.00
HX711 amplifier	₱ 45.00	1	₱ 0.00	₱ 45.00
Porcelain Insulator	₱ 10.00	10	₱ 0.00	₱ 100.00
LCD Screen	₱ 273.00	1	₱ 0.00	₱ 273.00
SSR Relay	₱ 156.00	2	₱ 0.00	₱ 312.00
Buttons	₱ 5.00	3	₱ 0.00	₱ 15.00
Arduino Uno	₱ 449.00	1	₱ 0.00	₱ 449.00
Fans	₱ 200.00	2	₱ 0.00	₱ 400.00
Plywood (1/2 inch)	₱ 580.00	1	₱ 0.00	₱ 580.00
Aluminum Stucco Sheet	₱ 550.00	2	₱ 0.00	₱ 1,100.00
Aluminum Angle bar	₱ 350.00	3	₱ 0.00	₱ 1,050.00
Aluminum Tubular	₱ 350.00	4	₱ 0.00	₱ 1,400.00
Blind Rivet	₱ 200.00	1	₱ 0.00	₱ 200.00
Expanded Wire	₱ 576.00	1	₱ 0.00	₱ 576.00
Wheels	₱ 25.00	4	₱ 0.00	₱ 100.00
Stainless Round bar	₱ 180.00	5	₱ 0.00	₱ 900.00
Male and Female pins	₱ 8.00	4	₱ 0.00	₱ 32.00
Door handle(double)	₱ 29.00	1	₱ 0.00	₱ 29.00
Wire (24awg)	₱ 80.00	1	₱ 0.00	₱ 80.00
Insulation	₱ 240.00	1	₱ 0.00	₱ 240.00
Jumper wires	₱ 40.00	2	₱ 0.00	₱ 80.00
wire insulator	₱ 35.00	2	₱ 0.00	₱ 70.00
2x2(GI) angle bar	₱ 540.00	1	₱ 0.00	₱ 540.00
2.54mm wire cable Connector	₱ 22.00	1	₱ 0.00	₱ 22.00
PCB universal Board(8x12)	₱ 48.00	1	₱ 0.00	₱ 48.00
Wire (16AWG)	₱ 120.00	1	₱ 0.00	₱ 120.00
Sim800l V2 module	₱ 349.00	1	₱ 0.00	₱ 349.00
Simcard	₱ 60.00	1	₱ 0.00	₱ 60.00
Aluminum tape	₱ 113.00	1	₱ 0.00	₱ 113.00
Varnish	₱ 50.00	1	₱ 0.00	₱ 50.00
Lead	₱ 50.00	1	₱ 0.00	₱ 50.00
9v Adapter	₱ 118.00	1	₱ 58.00	₱ 176.00
LM25962 buck Converter	₱ 39.00	1	₱ 0.00	₱ 39.00
Hinges with screw	₱ 5.00	8	₱ 0.00	₱ 40.00
Cable Connector	₱ 25.00	1	₱ 0.00	₱ 25.00
Shrinkable tube	₱ 20.00	1	₱ 0.00	₱ 20.00
Cable Tie	₱ 39.00	1	₱ 0.00	₱ 39.00
Moldex	₱ 45.00	1	₱ 0.00	₱ 45.00
			Total	**₱ 10,379.00**

Operational Cost Analysis

The operational cost of the fish dehydrator primarily comprises electricity consumption and fish salting. During testing conducted in April 2024, the device reached a maximum power draw of 6.7 kWh. With an electricity price of ₱11.03 per kWh (as of April 2024), the cost of drying 10.20kg of fish would be ₱73.90. The cost of salt for fish salting is ₱40.00 for two (2) kilogram. Considering no additional factors like water usage, the total operational cost per drying cycle is ₱113.09.

Potential Profitability Analysis

A sample profitability calculation was performed for drying 10.20kg of Tamban fish. The initial cost of the fish was ₱50 per kg, resulting in a total cost of ₱500. After dehydration, the final weight of the dried fish is 4.59kg, with weight reduction of 55% of its original weight. Given a market price of ₱200 per kg for dried Tamban fish, the total revenue from this drying cycle would be ₱918. Subtracting the operational cost (₱113.09) and initial fish cost (₱500.00) from the revenue (₱918.00) yields a potential profit of ₱304.10 per drying cycle. This calculation is based on specific assumptions about fish prices and dehydration efficiency, and further research is needed to validate these across various fish size and market conditions.

Drying to Cover Investment

This calculation helps determine how many drying cycles are needed to recover an initial investment. This means that approximately 63.11 drying cycles are required to cover the initial investment of ₱13,379.00 with a profit of ₱304.10

per drying cycle. Since it can't complete a fraction of a drying cycle in practical terms, the user would need 44 cycles to fully cover the investment.

$$Drying\ to\ Cover\ investment = \frac{Initial\ Investment}{Profit\ per\ Drying}$$

$$Drying\ to\ Cover\ Investment = \frac{₱13{,}379}{₱304.10} \approx 44$$

Time to Cover Investment

Using the earlier calculation where 44 drying cycles are needed to cover the investment with a profit of ₱304.10 per cycle, and the number of drying per week is three (3) times, the calculation would be:

$$Weeks\ to\ Cover\ Investment = \frac{Drying\ to\ Cover\ Investment}{Dryings\ per\ Week}$$

$$Weeks\ to\ Cover\ Investment = \frac{44}{3} = 14.67\ weeks$$

It would take approximately 14.37 weeks to cover the initial investment of ₱13,379.00 if three (3) drying cycles are completed per week with 10kg of fish, with a profit of ₱304.10 per cycle.

Months to Cover Investment

$$Months\ to\ Cover\ Investment = \frac{Weeks\ to\ Cover\ Investment}{Average\ Weeks\ per\ Month}$$

$$Months\ to\ Cover\ Investment = \frac{14.67}{4.345} \approx 4\ months$$

Assuming a constant drying efficiency and fish weight and with profit of ₱304.10 per drying cycle, it would take approximately forty-four (44) drying cycles for the dehydrator to recover its initial investment cost of ₱13,379.00. This translates to 14.67 weeks or 4 months of operation. It's important to consider additional factors that might influence profitability, such as electricity cost, fish availability, and potential variations in drying efficiency for different fish sizes.

Project Schedule Feasibility

Table 4.38. Project Development Schedule

Description	Activity	Date Started	Date Finished	Duration
Plan	User Requirements	10/02/2023	10/17/2023	11 Days
	Software Requirements	10/17/2023	11/10/2023	25 Days
	Hardware Requirements	10/17/2023	11/10/2023	25 Days
Design	Design of Device	11/10/2023	11/28/2023	19 Days
	System Design	11/10/2023	12/10/2023	31 Days
Development	Materials Gathering	12/11/2023	01/12/2024	33 Days
	Building the Body	12/27/2023	01/25/2024	30 Days
	Wiring of modules	01/20/2024	02/15/2024	27 Days
	Programming	02/15/2024	03/06/2024	21 Days
Testing	Hardware Testing	03/06/2024	03/12/2024	7 Days
	Software Testing	03/12/2024	03/20/2024	9 Days
	Drying Testing	03/20/2024	04/19/2024	31 Days
Deployment	Deploying the Prototype	06/18/2024	06/18/2024	1 Day
Review	Visiting the Client	06/24/2024	06/24/2024	1 Day
Launch	Signing of MOU with the client	06/24/2024	06/24/2024	1 Day

The project development follows the agile methodology as seen in Table 4.38 above, which enables flexibility in adapting to changes during the development process. This approach allows for a more systematic approach and ensures that the project meets its requirements effectively. Initially, developers survey to gather essential data necessary for identifying the problem and understanding the general requirements for the solution. Further insight into the requirements is gained through interviews with the specific client. Subsequently, developers select the appropriate IDE, hardware, and other materials tailored to the project's requirements.

Deployment Result

Figure 4.16. Deployment of the Project

Approval from the Client

The initial phase of deployment involves obtaining client approval, which is crucial to ensuring support and collaboration between the school and community. This was done through securing a formal letters and talking with the beneficiary. This process took less than 30 minutes, along with the explanation of the device's function and how can it help them in their business.

Setting up the Device

The developers installed the device while explaining its functionalities to the beneficiaries. They conducted a thorough review of the device's functionality to ensure it was operating correctly and performing its intended tasks accurately. Each sensor was individually tested to verify the accuracy of the data it provided. Furthermore, during the setup process, the developers programmed the client's mobile number into the device, enabling it to send SMS notifications directly to the client.

Training

The developers then conducted a training session, explaining the necessary steps to use the device. This session lasted only one hour, as the device is designed for easy use and had been previously discussed during the evaluation. During the training, the developers demonstrated how to calibrate the device using the provided 500-gram weight, ensuring the user understood the proper calibration procedure.

Following the calibration training, the developers instructed the users on how to utilize the device for drying purposes. They emphasized the importance of following the manual and the on-screen instructions.

The next part of the training is giving the clients advice about how can they marinate the fish before the drying process. The client and his family were given chance to ask question to clarify everything before the end of the training. The client acknowledged the significance of using the device responsibly, recognizing the students' efforts to address the issue of unsold fish.

Handover of the Device

The handover of the device was overseen by Engr. Jomar C. Escobido, a representative from the College of Engineering. He discussed the agreement concerning the collaboration between the students and the clients, outlining the cooperation as part of the university's community extension program. This collaboration aims to enhance community engagement and support local initiatives through innovative solutions developed by the students. See *Appendix K.4* for additional documentation during deployment and *Appendix K.5* for the Memorandum of Understanding (MOU).

CHAPTER V

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents an in-depth summary of the results that the developer carefully analyzed. It includes a careful examination, well-recorded findings, and perceptive suggestions gathered after cautious research and examination.

Summary of Findings

The Arduino-based Tamban and Galunggong dehydrator has been completed. It was developed to address the challenges faced by retail fish vendors regarding unsold fish. Following tests of the device's functionality, it performed satisfactorily. In the evaluation using ISO 25010, the device was assessed by five (5) CpE practitioners, seven (7) fresh fish vendors, and three (3) dried fish vendors. These evaluators were selected based on their expertise and experience in their respective fields relevant to the device.

Based on the tests conducted, the device accurately measures the weight of fish when they are inserted into the dehydrator. However, after the drying process, there is an average of 3.93% discrepancy where the device reads a weight slightly heavier than the actual weight of the fish. This issue has been addressed by adjusting the final required weight for completing the drying process. Additionally, the drying time for Tamban varies based on the weight of each fish, with lighter fish drying more quickly.

Based on the drying tests, the device can dry 10kg of fish with an average weight of 16.24 grams in eleven (11) hours and fifty-one (51) minutes of drying. Fishes with an average of 21.8 grams were dried in twelve (12) hours and six (6) minutes. Lastly, the larger fish with an average weight of forty-eight (48) grams is dried for sixteen (16) hours and forty-two (42) minutes. The device also succeeded in notifying the user through SMS after the drying process.

Based on the evaluation, the device received a mean score of 4.53 from the CpE Practitioners, with an adjectival rating of “Highly Acceptable.” Similarly, it was appraised as “Highly Acceptable” by the dried fish vendors, achieving a mean score of 4.51. Lastly, the device was rated by the fresh fish vendors with a mean score of 4.26 with a verbal interpretation of “Very Acceptable”.

Conclusions

Based on the project findings, the following conclusions can be inferred:

1. The Arduino-based Tamban and Galunggong Dehydrator has shown functionality in accomplishing the subsequent functions:
   a) Monitored and regulated the temperature;
   b) Displayed the current temperature, humidity, and weight of the fish;
   c) Dried a maximum of 10kg of Tamban or Galunggong;
   d) Stopped the drying process automatically after completion;
   e) Notified the user the final weight of fish via SMS after the drying process.
2. The device obtained a highly acceptable evaluation among CpE practitioners and dried fish vendors, and a very acceptable evaluation among retail fish vendors with regard to the ISO 25010 criteria, which include functional suitability, reliability, performance efficiency, usability, security, compatibility, maintainability, and portability.

3. After deployment, the device met its intended goal. As a result, the client has accepted the device and is ready to use it in their business. The developers also received an acceptance letter from the client indicating that the device is an excellent solution for managing unsold fish in their business.

Recommendations

Based on the results of the testing and evaluation conducted with the device, the following recommendations are at this moment recommended:

1. To encourage fish sellers to adopt automated fish dehydrators within San Pablo City, aiming to minimize the impact of having unsold fish. This approach allows them to turn unsold fish into a value-added product instead of selling it for a lower price or disposing of it.
2. For future developers:
   a) Expand the functionality of the dehydrator to accommodate a wider range of fish species, catering to the diverse needs of users;
   b) Adjust the size of the dehydrator to ensure it fits the specific requirements of the user. By making the design scalable and customizable, users can accommodate varying amounts of fish beyond the prototype's capacity of 10kg;
   c) Introduce additional options for users to customize the drying process according to their preferences. For example, different drying settings for different fish;

d) Install an exhaust fan on one side of the device to reduce humidity, eliminate foul odors, and improve the efficiency of airflow direction;

e) Employ other sources of electricity, such as solar power and batteries to lessen electric consumption. This can also act as an emergency power supply in case of power outage.

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