Smart Utility for Precision and Accuracy (S.U.P.A.) Scooper: Design and Development of an Enhanced Grain Scoop with Integrated Weighing Scale

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BIOGRAPHICAL DATA

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BIOGRAPHICAL DATA

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BIOGRAPHICAL DATA

James Romulo Lagos Pabelic, The first child of Roxan L. Pabelic and Gil A. Pabelic was born on April 3, 2007, at DLSU Medical Center in Dasmarinas, Cavite.

He graduated from Buenavista Elementary School in the year 2019. He graduated junior high school in Governor Ferrer Memorial Integrated National High School in the year 2023. He is currently studying at CvSU - LSHS in the academic track of Science, Technology, Engineering, and Mathematics

BIOGRAPHICAL DATA

Bruce E. Ybañez was born on December 14, 2005 in Naic, Cavite. He is the only child of Mr. Angelito L. Ybanez and Mrs. Marilyn E. Ybanez. He is currently residing at Brgy. Agus-Os, Indang Cavite. He completed his elementary school education at Cavite State University - Child Development Center, where he graduated with honors.

In 2019, he started his secondary education at Cavite State University - Laboratory Science High School in Indang, Cavite. During his junior years at CvSU-LSHS, he was elected a few times for different organizations such as President of Barangay Sandigan (2022-2023) and Grade 10 Representative of Robotics Club (2022-2023). He pursued senior high school at the same school under the Academic track: Science, Technology, Engineering, and Mathematics. In the academic year 2023 to 2024, he was elected as the current Treasurer of Robotics Club and is now the president of the club for the academic year 2024 to 2025. He not only participated in different organizations but also actively competed during the annual Battle of the Bands held at CvSU-LSHS every acquaintance party.

He is planning to take a Bachelor of Science in Computer Science as his undergraduate degree to pursue his interest in the field of computer technology.

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PRANCIS LOUISE S. DIMAPILIS

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JAMES ROMULO L. PABELIC

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His family: Papa Angel, Mama Alyn, *Tito* Christian, *Tito* Toffer, *Nanay* Marivic, *Tita* Donna, Baby Mathia, and of course, her beloved *Lola* Lydia for their unending love and sacrifice that motivated the author to continue his studies and accomplish great things. The author owes his success to you.

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BRUCE E. YBAÑEZ

ABSTRACT

ANGCANAN, JAMES CKARL JC E., DIMAPILIS, PRANCIS LOUISE S., PABELIC, JAMES ROMULO L., YBAÑEZ, BRUCE E. Smart Utility for Precision and Accuracy (S.U.P.A.) Scooper: Design and Development of an Enhanced Grain Scoop with Integrated Weighing Scale. Capstone Thesis. Laboratory Science High School. Cavite State University, Indang, Cavite. April 2025. Adviser: Ms. Nemilyn A. Fadchar

This study was conducted from September 2024 to April 2025 at Cavite State University - Laboratory Science High School. The researchers aimed to design and develop the Smart Utility for Precision and Accuracy (S.U.P.A.) Scooper, an enhanced grain scoop with an integrated weighing scale, calculation, and accumulation functions. Addressing issues in traditional rice retailing methods, this innovation provides a solution that ensures precise measurement and transaction efficiency. The researchers utilized components such as an Arduino Uno, load cell, and LCD display with the prototype frame constructed from stainless steel. This product was tested for its accuracy, precision, battery life, and economic feasibility. Statistical analysis using percentage error and average deviation indicated high levels of accuracy, within a 3.05% margin and precision in weight measurement across varying loads. The scoop also maintained a satisfactory battery life under simulated daily usage. Economic analysis revealed the scoop's affordability and potential return on investment, making it a viable tool if further developed. The researchers concluded that the creation of a scoop with an integrated weighing scale with calculating functions is feasible, but is impractical for commercial use in its current state. The researchers recommended trying out alternative frame and internal design for the scoop without sacrificing its efficiency. The researchers also recommend testing other calibration tests to further test the durability, accuracy, and precision of the S.U.P.A scooper.

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James Ckarl JC E. Angcanan
Prancis Louise S. Dimapilis
James Romulo L. Pabelic
Bruce E. Ybañez

A capstone research outline submitted to the faculty of the Laboratory Science High School, College of Education, Cavite State University, Indang, Cavite in partial fulfillment of the requirements for CSRS 12 Capstone. Prepared under the supervision of Ms. Nemilyn A. Fadchar.

INTRODUCTION

Grain crops are an important source of fiber, vitamins, minerals, and other nutrients. There are many types of grain, such as wheat, oats, corn, etc. But most importantly rice, this type of grain is popular in Asian countries because of the climate in this region. According to Kogut (2024). Originally from tropical regions, rice is a warm-season crop that requires constant heat and humidity to grow. As well as the cultural significance of rice in Asian countries. It is no surprise then that the Philippines is one of the largest consumers of grains in the world, especially rice. In 2024, Balita, C. stated that; the Philippines consumed 16 million metric tons of rice in the marketing year of 2022-2023. Because of the constant demand, rice retail stores are a popular business in the Philippines.

In line with this, the rice industry plays a vital role in the Philippine economy, accounting for 25% of the consumer basket, the highest share among Asian countries (Ganbold, 2022). Rice production contributes 17% to the country's total agricultural output and provides employment for 2.4 million Filipino farmers (Philippine Statistics Authority, 2020). In local markets, rice is typically sold by the sack, with smaller portions scooped and weighed for customers. Retailers often use the scooping method, which involves measuring grains by the kilo to ensure precision and minimize wastage. This approach allows consumers to purchase rice in flexible amounts while supporting local businesses by making rice more accessible and affordable for Filipino households.

The goal of the research was to develop a scoop that has an integrated weighing scale, calculation, and accumulation feature. Additionally, the product was subjected to an economic analysis, where the researchers will evaluate its viability in light of these four factors.

Statement of the problem

Generally, the purpose of this study was to enhance the scoops used in rice retail shops. Integrating capabilities that help in rice retailing will benefit both the retailer and the consumer.

The study specifically answered these questions:

1. What is the feasibility of integrating a calculating and an accumulation function in addition to the weighing function?
2. What are the capabilities of the scoop in terms of its;
    a. accuracy in weight measurement
    b. precision in weight measurement
    c. battery life
3. What is the economic analysis of the product in terms of its production cost?

Objectives of the Study

In general, the goal of this study was to improve the scoops found in rice retail shops. Integrating functionalities that aid with rice retailing will benefit both the retailer and the customer.

Specifically, the aim of this study was to:

1. include calculating and accumulating functions in addition to the weighing capabilities of the scoop;

2. test and evaluate the scoop in terms of its:
    a. accuracy in weight measurement
    b. precision in weight measurement
    c. battery life
3. figure out the economic analysis of the product in terms of its production cost

Conceptual Framework of the Study

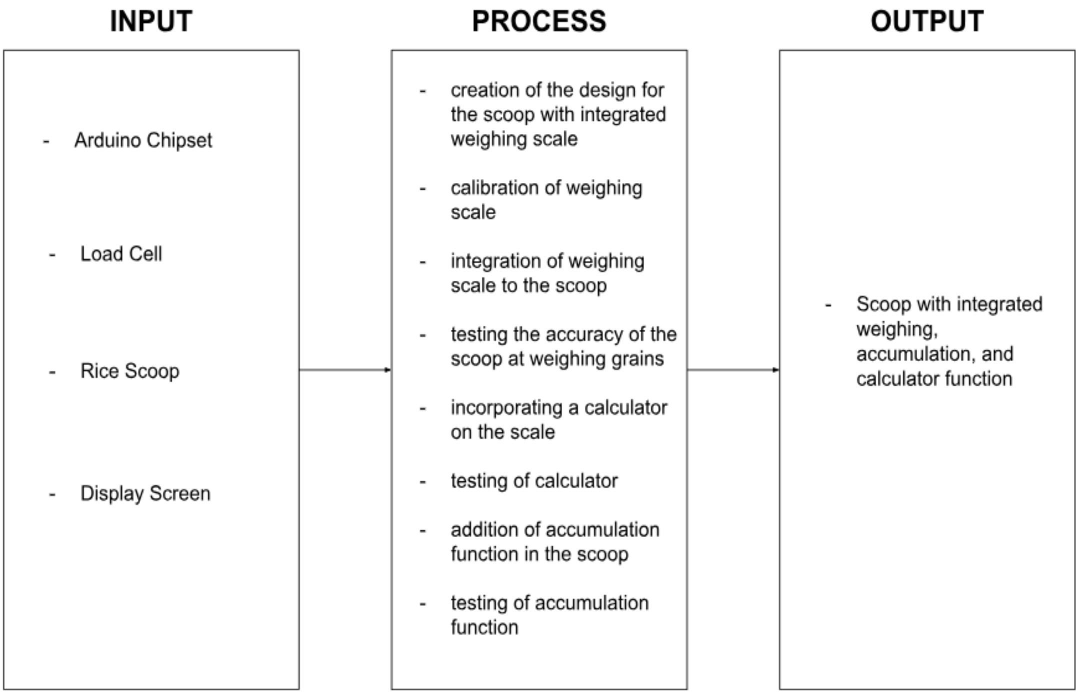

Figure 1. Research paradigm

The conceptual framework for this study was based on the Input-Process-Output model. It contains the materials that were used, the process of production, and the study's final output. The input consists of the materials that will be required to produce the intended output, such as the Arduino microcontroller and the load cell, which are critical components of the device. The processes mentioned must be completed with the utmost care to guarantee that the output results are the best possible. These include integrating the weighing functionality, the accumulating feature, and finally the calculator function. As well as, testing these functions to ensure that they work properly.

Significance of the Study

The findings of this study will provide valuable insights into the challenges and inconvenience that rice vendors in the Philippines will face during post-harvest retail operations. The study will contribute to a better understanding of how technology can address long-standing issues in the grain industry, particularly in small-scale retail settings. The study will benefit a variety of stakeholders, including vendors, consumers, and grain industries.

For **vendors**, this study will provide a practical solution to improve their business operations by reducing measurement errors and minimizing grain wastage, which will increase profitability. The product will enable vendors to offer more accurate services to their customers, potentially building stronger business relationships and increasing customer loyalty.

For **the grain industry,** this study will support the modernization of traditional retail practices. The increased efficiency and reduction in wastage will strengthen the local rice supply chain, improve resource management, and contribute to the industry's sustainability.

For **future researchers**, exploring similar topics or aiming to expand upon this study will yield valuable insights into the dynamics of vendor-consumer relationships and the impact of innovative tools in the grain industry.

Time and Place of the Study

This study was conducted at Cavite State University Main Campus, Laboratory Science High School in the municipality of Indang, Cavite. The data was gathered starting from the second semester of the school year 2024-2025.

Scope and Limitation of the Study

The study primarily focused on the integration of a weighing function, an accumulation function, as well as a calculator function in a rice scoop. In line with this, the researchers focused on finding the feasibility of integrating such functions in a rice scoop. In addition, the researchers tested the product in terms of its battery life and its capability to accurately measure weights. Furthermore, the product also went through economic analysis to see its commercial viability. However, this study is only limited to the scoops that are commonly used in rice retail stores, for the accommodation of the electronics. In addition, the maximum weight that the scoop could be handled would also need to be considered, in line with this the researchers have decided on the limit being five kilograms.

Definition of Terms

The following are key concepts, terminology, and terms used by the researchers throughout the study.

Arduino is an open-source electronics platform that features user-friendly hardware and software. It includes a microcontroller that can be programmed to perform a variety of tasks, making it suitable for adding electronic functions to devices. In this study, Arduino will be utilized to manage the weighing and calculation functions of the grain scoop, enabling precise measurements and effective data processing.

Load Cell is a device that converts force or weight into an electrical signal. It is important in weighing systems to provide accurate weight measurements. In this study, the load cell will be integrated into the grain scoop to ensure precise measurement of rice and other grains, allowing vendors to offer accurate quantities to consumers.

Economic Analysis is the process of evaluating the financial aspects of a product or project. It looks at the costs, benefits, and potential economic impact to see if it is worth investing in. In this study, economic analysis will compare the costs of making the grain scoop, such as materials and production, with benefits like improved accuracy, reduced waste, and better profits for vendors.

C++ is a generic programming language for building software. It is an object-oriented language, which emphasizes using data fields with unique attributes (a.k.a. objects) rather than logic or functions.

Weight is a consequence of the universal law of gravitation: any two objects, because of their masses, attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them .

Scooper is a specialized device designed to efficiently gather, lift, and transfer various materials from one location to another. It typically features a practical, often handheld design, allowing for ease of use and precision in handling substances, whether they are solid, semi-solid, or loose. Depending on its intended purpose, a scooper tool can vary in shape, size, and material, but its fundamental role remains consistent: to facilitate the smooth and effective collection and transportation of different substances.

Accumulation Function is an advanced feature integrated into the enhanced grain scoop that facilitates the automatic summation of successive weight measurements, providing a continuous total. This functionality eliminates the need for manual calculations, thereby reducing the likelihood of errors and improving operational efficiency.

Prototype is an initial model of a product that serves as the foundation for developing future versions (Cambridge Dictionary).

REVIEW OF RELATED LITERATURE

This chapter offers a compilation of related literature and studies discovered by the researchers. The analysis and literature in this chapter discuss several ideas, concepts, generalizations, findings, and developments in numerous research from the past to the present that are relevant to our current topic.

Grain Crops

Plants considered “grain crops” are those producing small, hard dry seeds or fruit consumed by man or his domesticated animals as a foodstuff, or processed for food or industrial purposes. “Grain crops” as a grouping, is, however, largely artificial. Plants producing useful grains have evolved in a number of plant families, and these families are not always closely related (Gray bosch, R. 2016). In addition, Grain crops are an important part of the human diet, accounting for a third of the consumed calories. Throughout human history, annual grain crops with high yields have been obtained through domestication (Soto-Gómez, D., & Pérez-Rodríguez, P. 2021). Human nutrition is closely related to grain consumption: rice, wheat, and maize are three basic pillars of the human diet (Neumann et al., 2010, as cited by Soto-Gómez, D., & Pérez-Rodríguez, P. 2021), and about 35% of human’s calories intake comes from these crops (Ross-Ibarra et al., 2007, as cited by Soto-Gómez, D., & Pérez-Rodríguez, P. 2021).

Grain crops such as wheat, rice, maize, and oats are vital to human diets due to their nutritional and practical benefits. They include vital carbohydrates, B vitamins, iron, magnesium, and fiber, which are necessary for metabolism, digestion, and general health. Whole grains include plenty of fiber, which helps with digestion and lowers the risk of chronic illnesses. Grains are inexpensive, easy to raise, and store, making them an essential component of food security for billions of people throughout the world.

Rice Retailing

A *bigasan* is a retail store that sells a variety of rice. In the Philippines, this is typically done through a simple storefront where bags of rice are opened as a display for customers. The name of the variety of rice and the corresponding price are shown on each bag. Customers need only tell the store’s staff what variety and how much rice they buy. The staff will then put the requested amount in a bag and weigh it before the customer. After the customer pays for it, then the transaction is complete. There are specialized rice businesses that sell only rice, but there are also retail outlets, such as sari-sari stores, that carry rice as part of their selection of products (Perez, 2024). Furthermore, according to JSL.co, (2017). Rice Retailing is a profitable business because rice is the staple food in our country. There are many rice varieties that consumers can choose from at low cost. The preferred varieties for daily meals are white, long-grained, and aromatic. Glutinous or sticky rice (*malagkit*) is used for native sweets.

The main priority of this research was to improve the quality of selling grains, especially rice by innovating the rice scoop used in these establishments by integrating a weighing function, accumulation function, and calculating function. To improve the service quality that would benefit the owner of these stores as well as the consumers.

C++

C++ is a general-purpose programming language that was developed by Bjarne Stroustrup as an enhancement of the C language to add an object-oriented paradigm. It is a high-level programming language that was first released in 1985 and since then has become the foundation of many modern technologies like game engines, web browsers, operating systems, financial systems, etc (GeeksforGeeks, 2025).

The researchers will use C++ as their main programming language in creating the product. Because it is a powerful and versatile language used in developing high-performance applications, operating systems, and embedded systems due to its efficiency, low-level control, and object-oriented capabilities.

Arduino

Arduino microcontroller board is an open source tool that is created for professionals and students to create and develop technologies and devices that can interact with its environment through the use of sensors. It is an easy to program tool and it can be updated anytime (Ismailov et. al., 2022).

The Arduino microcontroller board can be divided into two parts: hardware and software. Arduino uses a hardware called Arduino development board and the software it uses to develop the code is called Arduino Integrated Development Environment or Arduino IDE (Ismailov et. al., 2022). In its creation, Arduino IDE is only made to read C and C++ programming languages. But after some time, the developers of Arduino decided to add python as one of the programming languages that people can use to program the microcontroller.

The Arduino Co-founder Messimo Banzi stated some important reasons on why people should use the Arduino microcontroller over other microcontrollers. First, it has an active user community. If someone encounters a problem, they can ask on the community board for help and guidance. Second, Arduino is cheaper than its competitors. In comparison, On average, Raspberry Pi microcontroller costs around ₱3,000.00 while an Arduino only costs around ₱1,000.00. Third and last, consumers only need to pay for the Arduino hardware. The programming software of Arduino is free to use for anyone on their official website.

With all of that said, the researchers will use the Arduino microcontroller as one of the main components for the creation of the weighing scale due to the advantages it gives over other microcontrollers.

Weighing Scale

According to Active Scale Manufacturing Inc. (2023), A weighing scale is a device that is used to determine weight. Weighing scales can be divided into two primary types: spring scales and balances. Spring scales measure weight using Hooke's Law, which deforms in proportion to the weight placed on the load-receiving end. Balances are the oldest type of weighing device and measure weight using the principle of the lever.

The weighing scale that will be integrated into the rice scoop will be a spring scale, which is considerably easier to incorporate than a balance. In keeping with this, the researchers will employ a load cell to incorporate a spring scale into the rice scoop appropriately.

Numeric Keypad

According to Hanna, 2022. A calculator is a device that performs arithmetic operations on numbers. Basic calculators can do only addition, subtraction, multiplication and division mathematical calculations. However, more sophisticated calculators can handle exponential operations, square roots, logarithms, trigonometric functions and hyperbolic functions. Internally, some calculators perform all these functions by repeated addition processes.

The researchers will integrate only the basic calculating function in the rice scoop. As the researchers recognize that only the basic function would be needed to make the product as adding other functions to it would be redundant and increase costs.

Accuracy

The ability of an instrument to measure the accurate value is known as accuracy. In other words, it is the closeness of the measured value to a standard or true value. Accuracy is obtained by taking small readings. The small reading reduces the error of the calculation (BYJU, 2023)

The researchers will assess the product's capability in accurately measuring weight to ensure that the product made will be able to fulfill the conditions needed to satisfy the objectives of the study.

Precision

According to BYJU (2023), The closeness of two or more measurements to each other is known as the precision of a substance. If you weigh a given substance five times and get 3.2 kg each time, then your measurement is very precise but not necessarily accurate. Precision is independent of accuracy.

The researchers will assess the product's capability in precisely measuring weight to ensure that the product made will be able to fulfill the conditions needed to satisfy the objectives of the study.

METHODOLOGY

In this chapter, the researchers will discuss the materials and equipment used in the study, the research design of the study, and the process of creation for the product. This chapter also contains the data gathering procedures, the data analysis and the statistical analysis of the study.

Materials

- Arduino Uno set
- 16x2 LCD I2C display
- HX711 load cell amplifier
- 4x4 Keypad
- 50 kg load cell
- Stainless steel
- F to F jumper wires
- M to M jumper wires
- M to F jumper wires
- 9V battery
- Spring

The materials required for developing a scoop with a weighing scale include an Arduino Uno R3, which will serve as the central microcontroller for the system. A display screen is necessary to visually present the weight measurements, allowing for easy reading and monitoring. A 4x4 keypad is also included to enable user interaction, such as zeroing the scale and enabling input for price per kilo function. The 50kg load cell is a critical component for measuring weight, as it will detect the force applied by the scooped material with HX711 amplifier allowing the microcontroller to read the input. Stainless steel is chosen for the structural components of the scoop due to its durability and resistance to corrosion, ensuring long-term functionality. Finally, M to M, F to F, and M to F jumper wires were needed to connect all the components together, enabling communication and power distribution across the system.

Tools and Equipment

- C++
- Solder
- Soldering Iron
- Flux

In addition to the previously mentioned components, the development of the scoop with a weighing scale requires a few essential tools for assembly and electrical connections. C++ programming will be used for coding the microcontroller, allowing it to process input from the load cell and display the corresponding weight on the screen. Solder and a soldering iron are needed for making secure, reliable electrical connections between the various components, such as the load cell and the Arduino. The flux is used in the soldering process to ensure smooth and effective solder joints, preventing poor connections and ensuring long-term durability of the electrical circuits.

Research Design

Engineering design, also called technological design, is an iterative, systematic process for solving problems that involve creativity, experience, and accumulated disciplinary knowledge. As used in this framework, engineering design is a broad term, including methods such as architectural design, manufacturing design, industrial design, and software design. Furthermore, Much like scientific inquiry, engineering design is a dynamic process, not a rigid method. As engineering and science are often confused, it is helpful to draw a distinction. Scientific inquiry begins with a question and proceeds to generate and test hypotheses until the question is answered. In contrast, engineering design begins with a problem and proceeds to generate and test solutions until a preferred solution or solutions are reached. Whereas science seeks to understand, engineering seeks to meet people's needs (National Assessment Governing Board, 2014).

Research Method

The proposed project involved designing and building a prototype that integrates several components to measure weight and display the results for user accessibility. The design aimed to be both durable and effective, using stainless steel as the primary material for construction. The system will rely on an Arduino microcontroller to coordinate various components, while a load cell, digital display, and a numeric keypad will allow for data measurement, display, and user input.

To begin, the proposed design was constructed from stainless steel for durability and strength. Once the frame was built, an Arduino board was attached to serve as the main control unit for the system. A load cell, which is essential for measuring weight or pressure, was connected to the Arduino for data collection. Additionally, a digital display was integrated to visually present the measurement or any relevant data from the load cell. To allow for user interaction, a numeric keypad was also attached, enabling input for various functions or settings. The researchers then made a program that allows the arduino board to have a weight accumulation function, as well as a calculating function in the form of price per kilogram display. After assembling the hardware components, the next step involved coding the Arduino to ensure that it processes the data correctly and controls the various components. Furthermore, the researchers assessed the battery life of the integrated weighing scoop to determine sustainability for regular use. The battery test will be performed using the device at full-charge, simulating its function including activating the device, using the display screen, and its keypad function. The total time of operation will be continuously done until the device powers off. Finally, the product was evaluated in terms of accuracy in measuring weight, precision in measuring weight and production cost to ensure it meets the intended design objectives.

The researchers did 3 tests of measurement with varying weight. Those 3 tests will be repeated 40 times to test the accuracy and precision of the scoop. The researchers used rice grains as the independent variable, the measurements as the dependent variable, and the integrated scoop and traditional weighing scale as the controlled variable. The independent variable that was used for each of the tests are:

$\mathbf{T_1}$ = 0.55 kg of rice grains

$\mathbf{T_2}$ = 0.75 kg of rice grains

$\mathbf{T_3}$ = 1 kg of rice grains

The researchers compared the results of each test between the integrated scoop and traditional weighing scale by calculating its percentage error and average deviation. The accuracy and precision of the integrated scoop was also computed every after 10 tries to see if there are any changes in its capability to measure weight.

Proposed Design

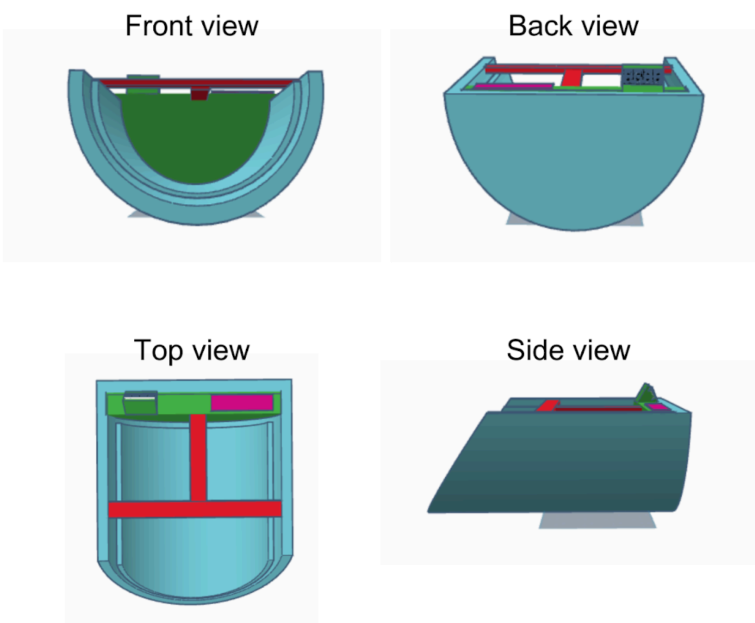

Figure 2. Proposed design of the integrated weighing scoop

For this research, the researchers developed a prototype of a scoop with an integrated weighing scale, designed to provide accurate measurements in various applications. The prototype features the following dimensions: a length of 11 inches

(27.94 cm), a width of 6 inches (15.24 cm), and a depth of 4 inches (10.16 cm), and will be capable of holding up to 1.5 kg of material. This design allows for a functional and compact tool that combines the precision of scale with the versatility of a scoop, enabling users to measure and transfer materials efficiently. The electrical components necessary for the weighing mechanism will be visibly integrated along the sides of the scoop, ensuring ease of access for maintenance and troubleshooting. By combining these two functions into a single device, the researchers aim to offer a solution that improves convenience and accuracy in contexts where both weighing and scooping are necessary.

Data Gathered

The researchers collected specific data points to evaluate the performance and feasibility of the S.U.P.A. scooper. The data points include the following:

Battery Life. The researchers measured the duration of how long the device will operate on a full single-charged use by simulating the device on regular usage including activating the integrated scale of the scoop and the usage of the display screen and keypad. Furthermore, the time from the initial power-on until the device shuts down due to battery depletion will be recorded.

Accuracy in Weight Measurement. The researchers evaluated the scoop's accuracy by using calibrated reference weights, ranging from values within the scoop's 1kg capacity. The reference weights will be placed on the scoop, while the displayed weight will be recorded by the researchers. This process was repeated multiple times to ensure the data's accuracy for light, medium, and heavy load.

Precision in Weight Measurement. The researchers weighed the same type of rice repeatedly under identical conditions. The readings were recorded by the researchers after each test. Moreover, the process was repeated for different types of rice and weights to ensure the consistency of the scoop. Furthermore, the data was analyzed using statistical measures including standard deviation and coefficient of variation to determine the repeatability of the weight measurements.

Production Cost. The researchers provided detailed records of expenditures during the study including the cost of raw materials and tools such as stainless steel, arduino components, load cell, display screen, keypad, wires, solder, soldering iron, and flux. Furthermore, any additional cost was documented by the researchers such as shipping fee or power consumption during the study. Finally, the total production cost was calculated by adding all expenses and providing a cost breakdown for transparency.

Analysis and Statistical Treatment of Data

For this study's analysis and statistical treatment of data, the researchers used the percentage error equation to find the accuracy of the data and average deviation equation to find the precision of the data. Break-Even Analysis was then used to determine the economic analysis of the product based on one of the given objectives of the researchers.

RESULTS AND DISCUSSION

This chapter presents the analysis and interpretation of the study's results, specifically the evaluation (1) of the feasibility of integrating a weighing, calculating, and accumulation function into the product. (2) of the weighing scale's battery life, accuracy, and precision. (3) of the economic analysis in making the product.

Prototype Development

The researchers built the circuit for the scoop which includes the necessary electronic parts and its wirings, as well as the hardware of the scoop which also serves as the shell for the circuit. The hardware was modified to allow the integration of the circuit without any strain to any of its parts.

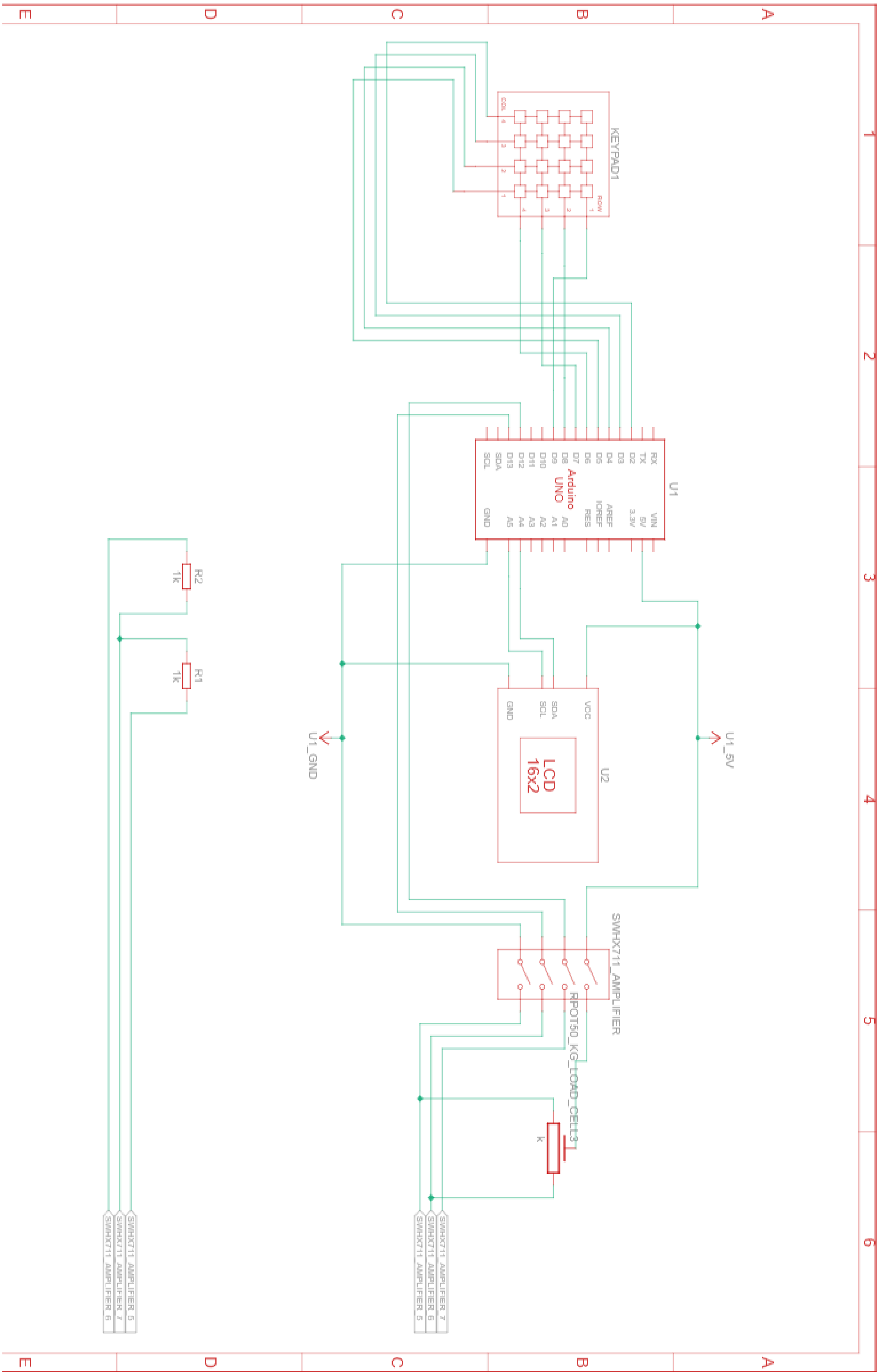

Figure 3.Schematic Diagram of the integrated weighing scoop

Figure 3 shows the layout of the inner circuit of the integrated weighing scoop. There are 5 main components that can be found in the inner circuit. Those 5 main components are namely; Arduino Uno R3 microcontroller, 4x4 keypad, 50 kg load cell, HX711 load cell amplifier, and a 16x2 LCD I2C display. First, the row pins of the keypad are connected to the 9, 8, 7, and 6 slots while the column pins are connected to the 5, 4 ,3, and 2 slots of the arduino uno board respectively. This allows the board to read the input coming from the keypad. For the wirings of the LCD I2C display to the board, the wirings are GND to GND, VCC to 5V, SDA to A4, and SCL to A5. The VCC to 5V and GND wirings allow the LCD display to power up and have a stable supply of power while the SDA and SCL pins allow the LCD display to read the program and show an alphanumeric display. Following that are the 50 kg load cell and HX711 load cell amplifier. The E+, E-, and A+ wires of the load cell were soldered to their respective HX711 amplifier slots. After that, additional wiring was added to the E+ and E- wires. Two 1 kilo ohm resistors were soldered to the E+ and E- wires and it was then joined together and was connected to the A- slot of the HX711 amplifier. After that, the DT, SCK, GND, and VCC pins of the HX711 amplifier were connected to the 13, 12, GND, and 5V slots of the arduino uno r3 microcontroller respectively.

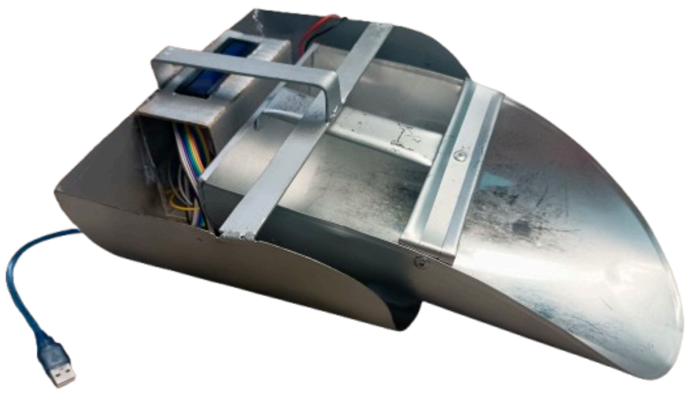

Figure 4. Design of the integrated weighing scoop

Figure 4 shows the design for the integrated weighing scoop. The final measurements of the weighing scoop are 14.3 inches (36.3 cm) for its length, 8.4 inches (21.3 cm) for its width, and 4.9 inches (12.5 cm) for its height. The electrical components were placed inside a box at the back of the main scoop with the LCD display on top of it. The 4x4 keypad was placed on the back of the scoop frame to allow ease of access while the battery holder was placed on the left of the scoop frame. This design utilizes two springs that hold the main scoop and the scoop frame together. These springs also allow the circuit to measure weight since the scoop touches the load cell at the bottom, applying pressure on it whenever an object with mass is placed on the scoop.

Program Development

The researchers made a program in C++ programming language for Arduino Uno R3 that includes weighing, calculating, and accumulation functions.

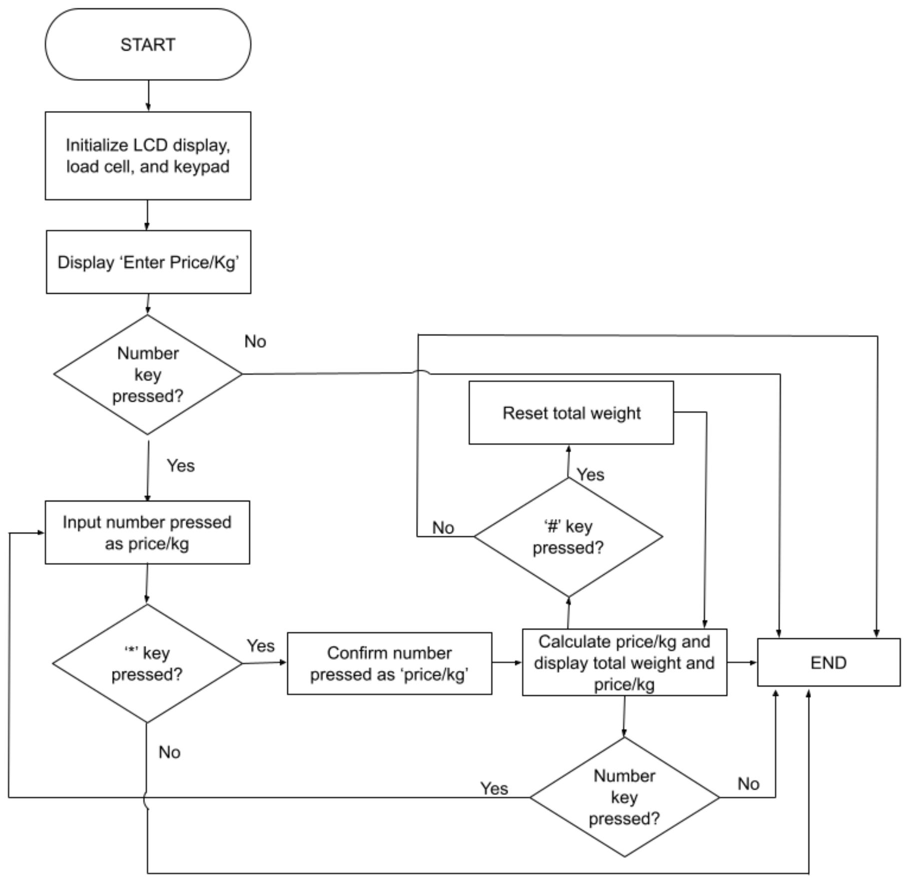

Figure 5. Program flowchart

Figure 5 shows the flowchart of the program that the researchers made for the integrated weighing scoop. As soon as you start the program, it will initialize all the interactive parts of the weighing scoop. It will then display ‘Enter Price/Kg’ on the LCD display as an indication to input a price. Whenever you press numbers, it will input that value as a temporary price per kg. By pressing the asterisk (‘*’) button, the program will set that input value as the price per kg. After that, it will display the total weight and the price per kg on the LCD display. The accumulation function is automatically turned on, but by pressing the number sign (‘#’) will reset the weight back to 0. To set a new price per kg, simply input a new value and press the asterisk button to set the new value as the price per kg.

Treatments

The researchers conducted three trials with three varying treatments to evaluate the product's accuracy and precision. For the first trial, the product was tested using T_1, which is 0.5kg of rice. The second treatment was tested using $T_{2,}$ with 0.75kg of rice, and the third treatment was conducted with 1kg of rice.

Results of Treatment 1

Table 1. Results of the weighing scoop for T_1

TREATMENT 1: 0.5 kg							
Test 1:	0.52 kg	Test 11:	0.52 kg	Test 21:	0.52 kg	Test 31:	0.51 kg
Test 2:	0.51 kg	Test 12:	0.52 kg	Test 22:	0.52 kg	Test 32:	0.49 kg
Test 3:	0.52 kg	Test 13:	0.52 kg	Test 23:	0.52 kg	Test 33:	0.51 kg
Test 4:	0.52 kg	Test 14:	0.52 kg	Test 24:	0.52 kg	Test 34:	0.52 kg
Test 5:	0.52 kg	Test 15:	0.52 kg	Test 25:	0.52 kg	Test 35:	0.51 kg
Test 6:	0.52 kg	Test 16:	0.52 kg	Test 26:	0.53 kg	Test 36:	0.51 kg
Test 7:	0.52 kg	Test 17:	0.52 kg	Test 27:	0.52 kg	Test 37:	0.51 kg
Test 8:	0.52 kg	Test 18:	0.52 kg	Test 28:	0.50 kg	Test 38:	0.53 kg
Test 9:	0.52 kg	Test 19:	0.52 kg	Test 29:	0.52 kg	Test 39:	0.47 kg
Test 10:	0.52 kg	Test 20:	0.51 kg	Test 30:	0.50 kg	Test 40:	0.50 kg

Average: 0.519 kg	Average: 0.519 kg	Average: 0.517 kg	Average: 0.506 kg
AVERAGE WEIGHT READING: 0. 51525 kg			

The data represents weight measurements from 40 tests, with Treatment 1 being 0.5kg. Most of the readings are close to this treatment, with many tests showing values around 0.52 kg. Some slight variations are seen, with a few tests recording weights lower than 0.5 kg, such as 0.47 kg in Test 39 and 0.49 kg in Test 32. On the higher end, there are a couple of tests with readings up to 0.53 kg. Despite these small fluctuations, the measurements consistently hover around Treatment 1, with the overall average of 0.51525 kg being very close to 0.5 kg. This suggests that the measurements are fairly consistent, with only minor deviations from Treatment 1.

Table 2. Percentage error of the weighing scoop for T_1

AVERAGE MEASURED VALUE		**PERCENTAGE ERROR**
Test 1-10:	0.519 kg	3.8%
Test 11-20:	0.519 kg	3.8%
Test 21-30:	0. 517 kg	3.4%
Test 31-40:	0. 506 kg	1.2%
Overall average:	0. 51525 kg	3.05%

The percentage errors for each group of tests reflect how close the measured weights are to 0.5 kg. For Tests 1-10, the average weight is 0.519 kg, resulting in a percentage error of 3.8%, indicating a slight overestimation of the true weight. This same percentage error is observed in Tests 11-20, with the average weight again being 0.519 kg. In Tests 21-30, the average weight drops slightly to 0.518 kg, leading to a slightly smaller percentage error of 1.2%, indicating the most accurate measurements in the dataset. Overall, the average weight across all tests is 0.51525 kg, with a total percentage error of 3.05%. This suggests that while the percentage errors show some fluctuations, the measurements generally stay slightly above the true value of 0.5 kg across all test groups, with the final group showing the smallest deviation.

Table 3. Average Deviation of the weighing scoop for T_1

AVERAGE MEASURED VALUE		AVERAGE DEVIATION
Test 1-10:	0.519 kg	0.0018 kg
Test 11-20:	0.519 kg	0.0018 kg
Test 21-30:	0.517 kg	0.0068 kg
Test 31-40:	0.506 kg	0.0116 kg
Overall average:	0.51525 kg	0.00765 kg

Table 3 shows the average deviation of each test group and the overall average deviation of treatment 1. Both test groups 1 and 2 have a 0.0018 kg average deviation, which indicates a low difference in values. Test group 3 has a higher average deviation of 0.0068 kg, and test group 4 has the highest average deviation of 0.0116 kg. The overall average deviation of treatment 1 is 0.00765 kg. The first two data sets showed the highest precision out of all the data sets, with the following precisions having a lower precision.

Results of treatment 2

Table 4. Results of the weighing scoop for T_2

TREATMENT 2: 0.75 kg							
Test 1:	0.69 kg	Test 11:	0.80 kg	Test 21:	0.80 kg	Test 31:	0.79 kg
Test 2:	0.80 kg	Test 12:	0.78 kg	Test 22:	0.80 kg	Test 32:	0.77 kg
Test 3:	0.80 kg	Test 13:	0.79 kg	Test 23:	0.80 kg	Test 33:	0.77 kg
Test 4:	0.80 kg	Test 14:	0.79 kg	Test 24:	0.80 kg	Test 34:	0.74 kg
Test 5:	0.79 kg	Test 15:	0.79 kg	Test 25:	0.69 kg	Test 35:	0.79 kg
Test 6:	0.79 kg	Test 16:	0.80 kg	Test 26:	0.79 kg	Test 36:	0.79 kg
Test 7:	0.79 kg	Test 17:	0.80 kg	Test 27:	0.77 kg	Test 37:	0.79 kg
Test 8:	0.79 kg	Test 18:	0.80 kg	Test 28:	0.76 kg	Test 38:	0.78 kg
Test 9:	0.79 kg	Test 19:	0.80 kg	Test 29:	0.80 kg	Test 39:	0.78 kg

Test 10:	0.79 kg	Test 20:	0.80 kg	Test 30:	0.74 kg	Test 40:	0.77 kg
Average: 0.781 kg		Average: 0.795 kg		Average: 0.772kg		Average: 0.777 kg	
AVERAGE WEIGHT READING: 0. 781306 kg							

The data for this next treatment shows weight measurements from 40 tests, all measured in kilograms. The values range from 0.69 kg to 0.80 kg, with the majority of readings falling between 0.77 kg and 0.80kg, which is close to Treatment 2 of 0.75 kg. The most common values in this data set are 0.79 kg and 0.80 kg, indicating that the majority of the tests recorded weights at or above Treatment 2. There are a few instances where the weights fall below 0.75 kg, such as Test 25 being 0.69 kg, Test 34 being 0.74 kg, Test 30 being 0.74 kg, and others that are closer to 0.77 kg.

The averages for different groups of tests range from 0.772 kg to 0.795 kg, with the overall average for all 40 tests being approximately 0.781 kg. This indicates that, while there are a few lower readings, the measurements are generally above the target weight of 0.75 kg, suggesting consistency in achieving weights that are slightly higher than the intended value.

Overall the majority of the weight measurements are slightly above the 0.75 kg target, with most values ranging between 0.77 kg and 0.80 kg. The overall average is approximately 0.781 kg, indicating consistency in achieving weights above the intended target, despite a few lower readings.

Table 5. Percentage error of the weighing scoop for T_2

AVERAGE MEASURED VALUE		PERCENTAGE ERROR
Test 1-10:	0.781 kg	4.13%
Test 11-20:	0.795 kg	6%
Test 21-30:	0.772kg	2.93%
Test 31-40:	0.777 kg	3.6%
Overall average:	0. 781306 kg	4.17%

The percentage errors for each group of tests in this dataset reflect how close the measured weights are to the true weight of 0.75 kg. For Tests 1-10, the average weight is 0.781 kg, resulting in a percentage error of 4.13%, indicating a slight overestimation of the true weight. In Tests 11-20, the average weight increases to 0.795 kg, leading to a higher percentage error of 6%, showing a greater deviation from the target weight. Tests 21-30 show a smaller average weight of 0.772 kg, with a reduced percentage error of 2.93%, indicating a slight improvement in accuracy. In Tests 31-40, the average weight is 0.777 kg, resulting in a percentage error of 3.6%. The overall average weight is 0.781306 kg, with an overall percentage error of 4.17%, reflecting a slight overestimation of the target weight across all the tests. Overall, the percentage errors show some variation, but the measurements tend to be consistently above the target weight of 0.75 kg.

Table 6. Average Deviation of the weighing scoop for T_2

AVERAGE MEASURED VALUE		AVERAGE DEVIATION
Test 1-10:	0.781 kg	0.0186 kg
Test 11-20:	0.795 kg	0.006 kg
Test 21-30:	0.772kg	0.028 kg
Test 31-40:	0.777 kg	0.0116 kg
Overall average:	0. 781306 kg	0.0175 kg

Table 6 shows the average deviation of each test group and the overall average deviation of treatment 2. In this treatment, test group 2 showed the lowest average deviation of 0.006 kg. It is then followed by test group 4 with 0.0116 kg average deviation and test group 1 with 0.0186 kg average deviation. Lastly, test group 3 showed the highest average deviation of 0.028 kg. The overall average deviation of treatment 2 is 0.0175.

Results of Treatment 3

Table 7. Results of the weighing scoop for T_3

TREATMENT 3: 1 kg							
Test 1:	1.04 kg	Test 11:	1.04 kg	Test 21:	0.92 kg	Test 31:	1.03 kg
Test 2:	1.04 kg	Test 12:	1.03 kg	Test 22:	0.97 kg	Test 32:	1.04 kg
Test 3:	1.04 kg	Test 13:	1.04 kg	Test 23:	1.01 kg	Test 33:	1.04 kg
Test 4:	1.04 kg	Test 14:	1.04 kg	Test 24:	1.03 kg	Test 34:	1.02 kg
Test 5:	0.94 kg	Test 15:	1.04 kg	Test 25:	1.04 kg	Test 35:	1.00 kg
Test 6:	0.85 kg	Test 16:	1.00 kg	Test 26:	1.00 kg	Test 36:	1.00 kg
Test 7:	0.99 kg	Test 17:	0.94 kg	Test 27:	0.94 kg	Test 37:	1.01kg
Test 8:	1.04 kg	Test 18:	1.00 kg	Test 28:	1.00 kg	Test 38:	0.99 kg
Test 9:	1.04 kg	Test 19:	1.04 kg	Test 29:	1.04 kg	Test 39:	0.99 kg
Test 10:	1.04 kg	Test 20:	1.04 kg	Test 30:	1.03 kg	Test 40:	1.00 kg
Average: 1.006 kg		Average: 1.021 kg		Average: 1.016 kg		Average: 1.012 kg	
AVERAGE WEIGHT READING: 1.01375 kg							

The data for Treatment 3 being 1 kg shows weight measurements ranging from 0.85 kg to 1.04 kg, with the majority of readings falling between 0.94 kg and 1.04 kg. The most common values are 1.04 kg and 1.00 kg, indicating that most test recorded weights at or above the target of 1 kg. A few tests showed lower readings, such as 0.85 kg and 0.92 kg. The averages for different groups of tests range from 1.006 kg to 1.021 kg, with the overall average for all 40 tests being approximately 1.01375 kg. This suggests that, while there are a few lower readings, the measurements are generally close to or slightly above the 1 kg target, indicating consistency in achieving weights near the intended value.

Table 8. Percentage error of the weighing scoop for T_3

AVERAGE MEASURED VALUE		PERCENTAGE ERROR
Test 1-10:	1.006 kg	0.6%
Test 11-20:	1.021 kg	2.1%
Test 21-30:	1.016 kg	1.6%

Test 31-40:	1.012 kg	1.2%
Overall average:	1.01375 kg	1.38%

The percentage errors for each group of tests in this dataset reflect how close the measured weights are to the true weight of 1 kg. For Tests 1-10, the average weight is 1.006 kg, resulting in a percentage error of 0.6%, indicating a very small overestimation of the true weight. In Tests 11-20, the average weight increases slightly to 1.021 kg, leading to a percentage error of 2.1%, showing a slightly larger deviation from the target. Tests 21-30 show a smaller average weight of 1.016 kg, with a percentage error of 1.6%, indicating a more accurate measurement. In Tests 31-40, the average weight is 1.012 kg, resulting in a percentage error of 1.2%. The overall average weight is 1.01375 kg, with an overall percentage error of 1.38%, suggesting a small overestimation of the true weight across all tests. Overall, the measurements are consistently close to the 1 kg target, with the percentage error remaining relatively low throughout the test groups.

Table 9. Average Deviation of the weighing scoop for T_3

AVERAGE MEASURED VALUE		AVERAGE DEVIATION
Test 1-10:	1.006 kg	0.0476 kg
Test 11-20:	1.021 kg	0.0246 kg
Test 21-30:	1.016 kg	0.0328 kg
Test 31-40:	1.012 kg	0.0164 kg
Overall average:	1.01375 kg	0.0309 kg

Table 9 shows the average deviation of each test group and the overall average deviation of treatment 3. Test group 4 showed the lowest average deviation of 0.0164 kg followed by test group 2 with 0.0246 kg average deviation. Test group 3 was then calculated to have an average deviation of 0.0328 kg and test group 1 has the highest average deviation of 0.0476 kg. The overall average deviation of treatment 3 is 0.0309 kg.

Battery Life

Table 10: Battery life of the product

TIME	RUNNING LIFE
Test 1	2:43:00
Test 2	2:44:31
Test 3	2:44:05
Average Running Life	2:43:52

The researchers conducted 3 tests on the battery life of the integrated weighing scoop if turned on indefinitely. The weighing scoop uses a non-rechargeable 9V battery. The 3 tests showed minimal difference on the total battery life of the integrated weighing scoop, with test 2 running the longest at 2 hours, 44 minutes, and 31 seconds. It is followed by test 3 with 2 hours, 44 minutes and 5 seconds, and test 1 with the shortest time at 2 hours and 43 minutes. The average of the 3 tests is 2 hours, 43 minutes, and 52 seconds. From the previous tests of the researchers, the time needed to properly scoop and weigh the product is around 15 seconds. This means that a 9V battery can last for around 655 scoops before needing a replacement if used for only 15 seconds per usage before turning off.

Based on the result of the study, the development of a scoop with weighing, accumulation, and calculating functions is feasible but requires rigorous testing and refinement to ensure proper function. Although the integrated scoop prototype developed in this study demonstrates the potential of such a tool, it is not yet fully operational. The researchers encountered challenges regarding its calibration and will need to try alternative calibration methods, which could not be implemented due to time constraints. Currently, the study provides a blueprint for future researchers who are interested in developing and innovating the traditional rice scoopers available in the market.

Economic Analysis

Table 11: Production cost of the integrated weighing scale

MATERIALS	AMOUNT	UNIT
LAFVIN R3 Project Super Starter Kit for Arduino UNO R3	1516	pesos
HX-711 Load Cell Amplifier/Digitizer Module	91	pesos
Arduino Nano ATmega328P CH340 Microcontroller	380	pesos
50 Kg-Weight Load Cell Sensor	61	pesos
30 cm Male to Male DuPont Wire Connector, 40pcs	68	pesos
30 cm Female to Female DuPont Wire Connector, 40pcs	68	pesos
Stainless Rice Scooper	200	pesos
Labor	400	pesos
Total	**2,784**	**pesos**

Table 11 presents the breakdown of the production cost for the integrated weighing scale, detailing the materials needed for assembly, their quantities, and prices. The main component, the LAFVIN R3 Project Super Starter Kit for Arduino UNO R3, which cost ₱1516, was used as the development board for the project. The HX-711 Load Cell Amplifier/Digitizer Module, priced at ₱91, was used to amplify and digitize the analog signals from the load cell. The Arduino Nano ATmega328P Microcontroller, costing ₱380, processed these signals and managed the overall operation of the system. The 50 kg-weight load cell sensor, which cost ₱61, was responsible for weight detection, while DuPont wire connectors, each costing ₱68, facilitated the necessary electrical connections between the components. A stainless rice scooper, priced at ₱200, was also included as part of the physical equipment for handling the objects. Labor costs for assembling the product totaled ₱400. The total production cost for manufacturing one unit of the integrated weighing scale came to ₱2,784, including all major components and labor expenses.

Table 12: Break-even analysis for recovery of investment in integrated scoop

	AMOUNT	**UNIT**
Markup	**10%**	
Original Price of Integrated Scoop	2,784.00	pesos
Selling Price of Integrated Scoop (with 10% markup)	3,062.40	pesos
Profit from Rice Business	325	pesos/day
Break-Even Average	9.43	days

This break-even analysis is conducted under the assumptions that fixed costs, specifically the initial investment in the integrated scoop, remain constant, the variable cost per unit does not change, the selling price per unit is maintained at a constant level with a 10% markup, and production equals sales, implying no inventory buildup. The time period covered in the analysis is measured in days, based on daily operational activities. The cost structure consists of a fixed cost amounting to PHP 3,062.40, representing the selling price of the integrated scoop after markup, while variable costs are not explicitly detailed but are assumed to be constant and incorporated within the daily profit calculation. Assuming that the fixed costs are constant, the variable cost per unit does not change, the selling price per unit is constant, and production equals sales, Table 12 presents the break-even point for a rice vendor’s investment in the integrated scoop, which costs PHP 3,062.40. This analysis calculates how many days the vendor will need to recover the full cost based on an average daily profit. According to the Philippine Statistics Authority, the average retail price of regular milled rice was PHP 48.51 per kilogram in the first phase of January 2025. The average daily profit of PHP 325 is based on a range of profits from PHP 150 to PHP 500. The break-even period is determined using the formula: Break-even Days = Investment Cost ÷ Average Daily Profit. Applying this formula, the break-even point is calculated by dividing the investment cost of PHP 3,062.40 by the average daily profit of PHP 325.00, resulting in approximately 9.43 days required to recover the investment. A sensitivity analysis indicates that if for example, the average daily profit decreases to PHP 250.00, the break-even period would extend to approximately 12.25 days, while a higher daily profit would reduce the number of days required. Based on the stated assumptions and computations, the investment in the integrated scoop would be recovered within approximately 9.43 days.

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

This section deals with the summary of findings, conclusions, and recommendations of the study.

Summary

The study entitled “Smart Utility for Precision and Accuracy (S.U.P.A.) Scooper: Design and Development of an Enhanced Grain Scoop with Integrated Weighing Scale” was conducted to create a rice scoop with an integrated weighing, accumulation, and calculating function. In addition, the study was conducted in order to evaluate if it is feasible to create a rice scoop with the mentioned functions. As well as conduct an economic analysis of the integrated rice scoop.

Additionally, the study provided valuable insights into the challenges faced by rice vendors in the Philippines during post-harvest retail operations and demonstrated how technological advancements could address these issues. The findings contributed to the modernization of small-scale grain retailing by improving measurement accuracy, reducing wastage, and enhancing business efficiency. Vendors can benefit from minimized losses and improved customer relations, while the grain industry gains from better resource management and a strengthened supply chain. The study may also serve as a reference for future researchers exploring vendor-consumer interactions and the role of innovative tools in the grain industry.

Moreover, the study aimed to enhance rice scoops used in retail shops by incorporating additional features to improve their functionality. Specifically, the research focused on integrating weighing capabilities along with calculating and accumulating functions to assist rice vendors. The study also evaluated the scoop’s performance in terms of accuracy, precision, and battery life in weight measurement. Furthermore, an economic analysis was conducted to assess the production cost and overall feasibility of the product for commercial use.

The production of the product was conducted at Guyam Malaki Indang, Cavite. and Agus-os Indang, Cavite. Meanwhile, the evaluation of the product was conducted at Agus-os Indang, Cavite during the month of January-March 2025. Three treatments with varying weights were employed to evaluate the weighing capability of the scoop: T_1 (Weighing 0.5 kg), T_2 (Weighing 0.75kg), and T_3 (Weighing 1kg). Each treatment was tested on the integrated scoop, the product showed exceptional precision in weighing the rice grains during the trials. However, in terms of accuracy, the product would often miss by a few decimals.

Conclusion

Based on the findings of the study, the researchers concluded that:

1. Integrating the calculation, accumulation, and weighing function in a rice scoop is feasible.
2. In terms of accuracy, the integrated weighing scoop showed that there is a definite room for improvement. While testing the integrated rice scoop the readings of the load cell would often miss by a few decimals. The error would generally be between 0.04 and 0.09, with the maximum being 0.15.
3. The scoop demonstrates reliable precision in weight measurement across all treatments, with consistent measurements that generally hover around or slightly exceed the intended target weight. While there are minor fluctuations, the overall data indicates that the scoop is precise and dependable for the given measurements.
4. The battery life of the integrated weighing scoop does not show any major differences between the 3 tests. The average battery life of the integrated weighing scoop is 2 hours, 43 minutes, and 52 seconds.
5. An average rice retailer may purchase the integrated scoop with a selling price of 3,062.40PHP and get the money he invested back in 9.43 days if they have an average daily profit of 325PHP.

6. With the findings of these studies, the researchers found that it is indeed feasible for the product to be created. However, the accuracy, economic analysis, and design of the product make it impractical for commercial use.

Recommendation

Based on the results of the study and the outcome of the product, the following recommendations are made:

1. The use of alternative materials is recommended to further lower the production cost of the scoop without compromising for less durability. This will help improve the economic feasibility of the product.
2. Adding another load cell for better accuracy of the readings. Improving the calibration process or trying different calibration methods are also suggested to reduce the errors in weight measurement.
3. It is encouraged to develop alternative designs that will make the integrated scoop more compact and portable, considering its electrical components, scooping function, and the ergonomic viability of the design.
4. It is recommended to try out different types of battery as a power source for the integrated weighing scoop without compromising on its ease of use.
5. It is encouraged to try out different calibration procedures to further test the accuracy and precision of the weighing scale over frequent usage and a longer timespan.

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APPENDICES

Appendix 1. Integrated weighing scoop program code

```
#include <HX711.h>
#include <Keypad.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 20, 4);

const int loadCellPinDout = 13;
const int loadCellPinSck = 12;

HX711 scale;

const byte ROWS = 4;
const byte COLS = 4;

char keys[ROWS][COLS] = {
  {'1', '2', '3', 'A'},
  {'4', '5', '6', 'B'},
  {'7', '8', '9', 'C'},
  {'*', '0', '#', 'D'}
};

byte rowPins[ROWS] = {9, 8, 7, 6};
byte colPins[COLS] = {5, 4, 3, 2};

Keypad keypad = Keypad(makeKeymap(keys), rowPins, colPins, ROWS, COLS);

float weight = 0;
float totalWeight = 0;
float pricePerKg = 0.0;
String inputString = "";

void setup() {
  Serial.begin(9600);

  lcd.begin(16, 2);
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("Enter Price/Kg");

  scale.begin(loadCellPinDout, loadCellPinSck);
  scale.set_scale();
  scale.tare();
}

void loop() {
  char key = keypad.getKey();

  if (key) {
    if (key >= '0' && key <= '9') {
      inputString += key;
      Serial.print("Input: ");
      Serial.println(inputString);
    }
```

```
    if (key == '*') {
      if (inputString != "") {
        pricePerKg = inputString.toFloat();
        Serial.print("Price per kg set to: ₱");
        Serial.println(pricePerKg);
        lcd.clear();
        lcd.setCursor(0, 0);
        lcd.print("Price/Kg: ₱");
        lcd.print(pricePerKg);
        inputString = "";
      }
    }

    if (key == '#') {
      totalWeight = 0;
      Serial.println("Accumulated weight reset.");
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Total Wt Reset");
      delay(1000);
      lcd.clear();
    }
  }

  weight = scale.get_units(10);
  if (weight < 0) weight = 0;

  totalWeight += weight;

  if (pricePerKg > 0) {
    float totalPrice = weight * pricePerKg;
    Serial.print("Weight: ");
    Serial.print(weight, 2);
    Serial.print(" kg, Total Price: ₱");
    Serial.println(totalPrice, 2);

    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Wt:");
    lcd.print(weight, 2);
    lcd.print("kg");

    lcd.setCursor(0, 1);
    lcd.print("₱");
    lcd.print(totalPrice, 2);
  }

  delay(200);
}
```

Appendix 2. Data collected from treatment 1

```
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.51 kg, Total Price: ₱2.57
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.59
Weight: 0.52 kg, Total Price: ₱2.59
Weight: 0.52 kg, Total Price: ₱2.59
Weight: 0.52 kg, Total Price: ₱2.58
Weight: 0.52 kg, Total Price: ₱2.59
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.61
Weight: 0.52 kg, Total Price: ₱2.61
Weight: 0.52 kg, Total Price: ₱2.61
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.58
Weight: 0.51 kg, Total Price: ₱2.57
Weight: 0.52 kg, Total Price: ₱2.58
Weight: 0.52 kg, Total Price: ₱2.59
Weight: 0.52 kg, Total Price: ₱2.60
Weight: 0.52 kg, Total Price: ₱2.61
Weight: 0.52 kg, Total Price: ₱2.62
Weight: 0.53 kg, Total Price: ₱2.64
Weight: 0.52 kg, Total Price: ₱2.62
Weight: 0.50 kg, Total Price: ₱2.52
Weight: 0.52 kg, Total Price: ₱2.58
Weight: 0.50 kg, Total Price: ₱2.52
Weight: 0.51 kg, Total Price: ₱2.57
Weight: 0.49 kg, Total Price: ₱2.46
Weight: 0.51 kg, Total Price: ₱2.57
Weight: 0.52 kg, Total Price: ₱2.59
Weight: 0.51 kg, Total Price: ₱2.56
Weight: 0.51 kg, Total Price: ₱2.53
Weight: 0.51 kg, Total Price: ₱2.57
Weight: 0.53 kg, Total Price: ₱2.64
Weight: 0.47 kg, Total Price: ₱2.37
Weight: 0.50 kg, Total Price: ₱2.48
```

Appendix 3. Data collected from treatment 2

```
Weight: 0.69 kg, Total Price: ₱3.46
Weight: 0.79 kg, Total Price: ₱3.96
Weight: 0.80 kg, Total Price: ₱3.98
Weight: 0.80 kg, Total Price: ₱3.98
Weight: 0.80 kg, Total Price: ₱3.99
Weight: 0.79 kg, Total Price: ₱3.94
Weight: 0.76 kg, Total Price: ₱3.82
Weight: 0.79 kg, Total Price: ₱3.97
Weight: 0.80 kg, Total Price: ₱3.99
Weight: 0.79 kg, Total Price: ₱3.97
Weight: 0.80 kg, Total Price: ₱3.98
Weight: 0.78 kg, Total Price: ₱3.92
Weight: 0.79 kg, Total Price: ₱3.95
Weight: 0.79 kg, Total Price: ₱3.95
Weight: 0.79 kg, Total Price: ₱3.97
Weight: 0.80 kg, Total Price: ₱3.99
Weight: 0.80 kg, Total Price: ₱3.99
Weight: 0.80 kg, Total Price: ₱4.00
Weight: 0.80 kg, Total Price: ₱4.01
Weight: 0.80 kg, Total Price: ₱4.02
Weight: 0.80 kg, Total Price: ₱4.01
Weight: 0.80 kg, Total Price: ₱4.01
Weight: 0.80 kg, Total Price: ₱4.01
Weight: 0.80 kg, Total Price: ₱3.98
Weight: 0.69 kg, Total Price: ₱3.46
Weight: 0.79 kg, Total Price: ₱3.93
Weight: 0.77 kg, Total Price: ₱3.85
Weight: 0.76 kg, Total Price: ₱3.80
Weight: 0.80 kg, Total Price: ₱3.98
Weight: 0.74 kg, Total Price: ₱3.70
Weight: 0.79 kg, Total Price: ₱3.95
Weight: 0.77 kg, Total Price: ₱3.84
Weight: 0.77 kg, Total Price: ₱3.84
Weight: 0.74 kg, Total Price: ₱3.71
Weight: 0.79 kg, Total Price: ₱3.97
Weight: 0.79 kg, Total Price: ₱3.95
Weight: 0.79 kg, Total Price: ₱3.94
Weight: 0.79 kg, Total Price: ₱3.94
Weight: 0.78 kg, Total Price: ₱3.92
Weight: 0.78 kg, Total Price: ₱3.92
Weight: 0.77 kg, Total Price: ₱3.87
```

Appendix 4. Data collected from treatment 3

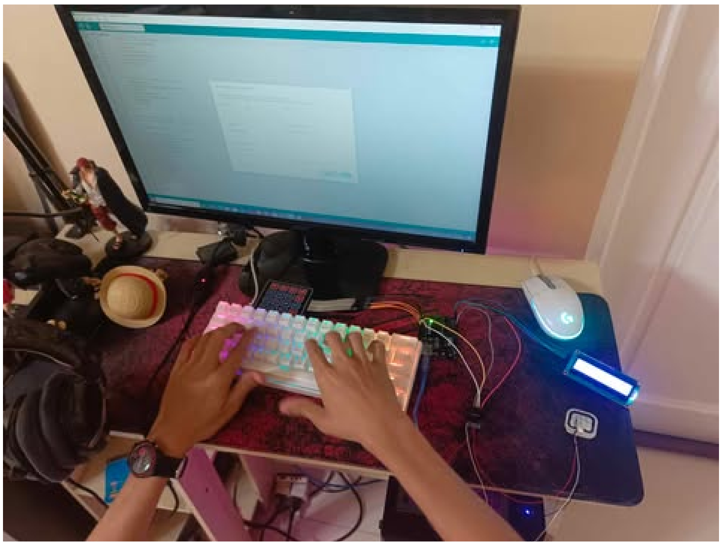
```
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.00 kg, Total Price: ₱5.01
Weight: 0.94 kg, Total Price: ₱4.69
Weight: 0.85 kg, Total Price: ₱4.23
Weight: 0.99 kg, Total Price: ₱4.94
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.19
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.03 kg, Total Price: ₱5.17
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.00 kg, Total Price: ₱5.00
Weight: 0.94 kg, Total Price: ₱4.71
Weight: 1.00 kg, Total Price: ₱4.98
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 0.92 kg, Total Price: ₱4.62
Weight: 0.97 kg, Total Price: ₱4.84
Weight: 1.01 kg, Total Price: ₱5.05
Weight: 1.03 kg, Total Price: ₱5.16
Weight: 1.04 kg, Total Price: ₱5.19
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.03 kg, Total Price: ₱5.15
Weight: 1.03 kg, Total Price: ₱5.17
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.04 kg, Total Price: ₱5.18
Weight: 1.02 kg, Total Price: ₱5.08
Weight: 1.00 kg, Total Price: ₱4.99
Weight: 1.00 kg, Total Price: ₱4.99
Weight: 1.01 kg, Total Price: ₱5.05
Weight: 0.99 kg, Total Price: ₱4.97
Weight: 0.96 kg, Total Price: ₱4.82
Weight: 0.99 kg, Total Price: ₱4.93
Weight: 1.00 kg, Total Price: ₱4.99
Weight: 0.97 kg, Total Price: ₱4.87
Weight: 0.97 kg, Total Price: ₱4.84
```

APPENDIX FIGURES

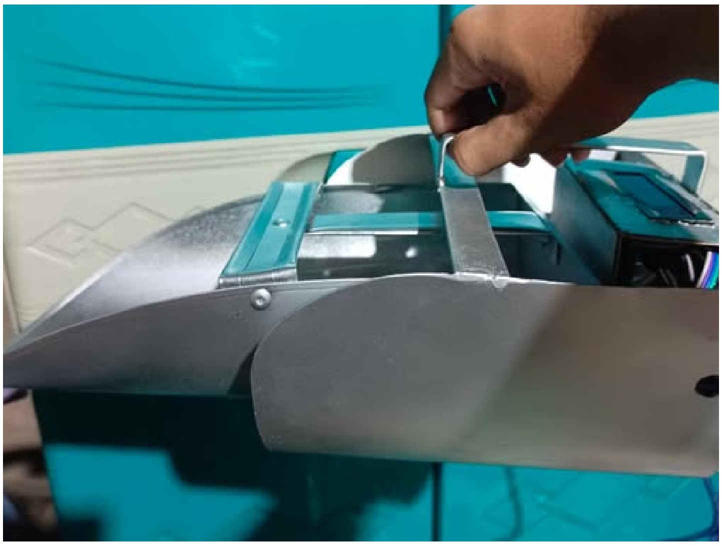
Appendix Figure 1. Materials for the creation of integrated weighing scoop

Appendix Figure 2. Checking of electronic parts

Appendix Figure 3. Creation of inner circuit



Appendix Figure 4. Testing of inner circuit and program



Appendix Figure 5. Creation of integrated weighing scoop prototype

Appendix Figure 6. 0.50 kg of rice grains measured using a traditional weighing scale

Appendix Figure 7. 0.75 kg of rice grains measured using a traditional weighing scale

Appendix Figure 8. 1.00 kg of rice grains measured using a traditional weighing scale

Appendix Figure 9. Testing of the integrated weighing scoop