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Hybrid multi-crop grain collector integrating mechanical sweeping, Arduino-based weighing and alert, and fan-assisted winnowing system

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Abstract

Agriculture is one of the most important sectors in the Philippines because it provides food, employment, and income that contribute to national growth and development. This study aimed to evaluate the performance of a Multi-Crop prototype in terms of speed, ease of operation, and conveyor transfer efficiency, as well as the accuracy of an Arduino-powered weighing scale and the efficiency of a fan-assisted winnowing system. The researchers developed a hybrid multi-crop grain collector integrating mechanical sweeping, Arduino-based weighing with alerts, and a fan-assisted winnowing system to help farmers collect sun-dried grains more quickly and efficiently, thereby reducing post-harvest losses. Each component has a specific function: The Arduino-powered weighing scale measures grains with a maximum capacity of 20 kilograms and includes a piezoelectric buzzer that alerts the user when the weight limit is reached. The weighing scale was proven to display accurate values comparable to traditional scales, and the buzzer functioned reliably at maximum capacity. The hybrid grain collector, powered by a DC motor and human force, lifts grains into a sack and has been shown to be faster, more user-friendly, and more conveyor-efficient than manual collection. The rechargeable fan-assisted winnowing system removes light impurities mixed with the grain; however, results indicate a significant difference in the amount of chaff before and after winnowing. Overall, this study demonstrates that the hybrid Multi-Crop prototype provides a faster, easier, and more efficient method of grain collection, reducing post-harvest losses and offering labor-saving benefits for farmers and agricultural workers.

Keywords: multi-Crop prototype, Arduino weighing scale, fan-assisted winnowing, post-harvest losses, agricultural machinery, grain collection efficiency

Hybrid multi-crop grain collector integrating mechanical sweeping, Arduino-based weighing and alert, and fan-assisted winnowing system

1. Introduction

Agriculture remained one of the most important sectors in the Philippines, providing food, employment, and income while contributing to national growth and development. According to Sunkad (2020), agriculture was not only used to provide food for humans and animals but also played an important role in supporting the country's national income. Growing incendiary crops accounted for the largest share of employment in the Agriculture, Forestry, and Fishing sector in 2020, according to the Annual Survey of Philippine Business and Industry (ASPBI), which reported 138,977 workers, most of whom were paid employees. Furthermore, according to the most recent report from the Philippine Statistical Authority (PSA), the value and production of agriculture had reached Php 437.53 billion, with fisheries accounting for 56% of that total. Despite this, the industry still faced several difficulties, especially during the harvesting stage, including worker shortages, restricted access to machinery, post-harvest losses, and climate-related damage. Major crops vital to the nation's food supply and economy, such as rice, corn, beans, and coconuts, were affected by these issues. Therefore, to increase the productivity and sustainability of Philippine agriculture, these problems needed to be addressed with creative solutions.

Traditional methods of grain collection, such as weighing and winnowing, were still widely used by many Filipino farmers, especially in rural areas where access to modern machinery was limited. Rice winnowing uses air flow to separate small rice husks, light debris, and small grains (Munir et al., 2018). Additionally, Shani (2024) stated that it was important to clean or winnow the grain by removing chaff and other debris before preparing it for food or as raw industrial material. These methods were performed manually using simple, low-cost materials and required the labor of many individuals. Collecting grains was time-consuming and required a lot of manual work: winnowing, transferring crops, collecting grains, and weighing them with a common weighing scale. Similarly, winnowing by hand or with other improvised tools often led to inconsistent grain cleanliness and quality, which could double the people's work. Innovative agricultural technologies such as Arduino-based systems, automation systems, and fan-assisted mechanisms helped improve post-harvest efficiency and reduce the manual labor burden on small-scale farmers. An example of this was the integration of Arduino-automated systems that minimized human error (Negrete, 2023). Additionally, the fan-assisted mechanism made the winnowing process more efficient, requiring less physical labor (Bajoria & Purohit, 2014). To conclude, these innovations provided more efficient systems for small-scale farmers, saving time and physical labor.

This study introduced a multi-crop grain collector powered by a DC Motor and mechanical sweeping brooms, modified with an Arduino Nano-powered weighing scale with a piezoelectric buzzer alarm and a rechargeable, fan-assisted winnowing system to improve efficiency, accuracy, and usability compared to traditional post-harvest handling methods. Unlike in other models, where the collector, weighing scale, and winnower were separated, our prototype combined all three to improve ease of operation. Its special features included automation via an Arduino and a DC Motor, as well as enhanced portability, since it is on wheels. This study aimed to create, develop, and test a hybrid multi-crop grain collector integrating mechanical sweeping, Arduino-based weighing and alert, and fan-assisted winnowing system.

Statement of the Problem - The study aimed to develop and test the effectiveness of a hybrid multi-crop grain collector integrating mechanical sweeping, Arduino-based weighing and alerting, and a fan-assisted winnowing system, and to evaluate efficiency, accuracy, and usability. Specifically, it sought to answer the following questions: (1) What is the level of performance of the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan Assisted Winnowing System in terms of speed, ease of operation, and conveyor transfer efficiency? (2) What is the level of accuracy of the Arduino-powered weighing scale in terms of measurement and alarm? (3) Is there a significant difference in the amount of chaff mixed with the grains before and after using the fan-assisted winnowing system in terms of Rice grains and mung beans?

Statement of Hypothesis - This study aimed to test the following hypothesis: There is no significant difference in the amount of chaff mixed with the grains before and after using the fan-assisted winnowing system for rice grains and mung Beans.

Significance of the Study - The development of this device modernized grain collection by combining a hybrid grain collector, an Arduino Nano-powered weighing scale, and a rechargeable, fan-assisted winnowing system into a single portable unit. It delivered precise measurements, cleaner outputs, and sustainable operation, helping farmers boost productivity and reduce post-harvest losses. The findings were significant in the following: First, for the farmers, this device reduced physical strain and saved time through its automated weighing and fan-assisted cleaning systems. It ensured more precise measurements and cleaner grains, directly improving market value and supporting better income for farmers. By automating labor-intensive tasks, the device lessened physical fatigue and the risk of injury for agricultural workers. It increased daily throughput and created more predictable workloads, which supported fairer compensation and better working conditions. For the local community, the technology improved grain quality. It reduced post-harvest losses, strengthening food security and encouraging the adoption of sustainable, easy-to-use mechanical and electronic tools in rural areas. For the agricultural technology sector, the project served as a hands-on demonstration of how renewable energy, microcontroller programming, and mechanical design can be combined to solve real-world agricultural problems. Lastly, for future researchers, this study provided a foundation for further research on hybrid grain-processing devices by documenting the prototype design, performance, and practical challenges encountered.

Scope and Delimitation of the Study - This study focused on the development, construction, and evaluation of a multi-crop grain collector equipped with a DC motor–powered conveyor, a mechanically driven broom mechanism, an Arduino Nano–based weighing scale, and a rechargeable fan-assisted winnowing system. The project aimed to provide small-scale farmers with a portable, cost-efficient, and sustainable post-harvest tool capable of collecting, cleaning, and weighing grains. The prototype was tested using palay (rice) and mung beans to assess its capability for multi-crop handling and its performance across its major subsystems: grain collection, weighing, and winnowing. The research covered the design, assembly, data collection, and testing of the prototype using the specified components from August 2, 2025, to February 2026.

The weighing system used an Arduino-controlled load cell with a piezoelectric buzzer serving as a weight-limit alarm. In contrast, the winnowing subsystem used a rechargeable fan to remove light impurities such as chaff, husks, and dust. The evaluation assessed the weighing scale's accuracy, ease of operation, the speed and efficiency of the grain collection mechanism, the effectiveness of the winnowing process, and the device's overall usability. Testing and data collection were conducted over 2 days in San Jose, during which selected respondents assessed the prototype's usability. For the technical sections of the evaluation, the researchers responded based on direct observations to maintain objectivity and avoid bias. However, the study was subject to several delimitations. It did not include long-term durability testing, extended field deployment, or large-scale commercial application of the device. The Arduino microcontroller was utilized exclusively for the weighing subsystem.

In contrast, the conveyor was powered by a DC motor, and the rotating sweep mechanism relied on human-assisted force transmitted through sprockets and chains. The rechargeable fan used for winnowing had limited runtime, limiting its use to short-duration activities. The prototype was intended solely for small- to medium-scale farming and excluded functions related to industrial post-harvest processing. The scope was confined to post-harvest operations, including grain collection, cleaning, and weighing. It did not cover grain storage, moisture content analysis, packaging, or the separation of impurities, including heavier contaminants such as stones. Environmental testing was conducted only under fair-weather conditions, excluding extreme temperatures, rain, strong winds, and other environmental factors that could affect device performance. The study focused solely on evaluating the prototype's technical functionality and operational efficiency in controlled, short-term experimental settings.

2. Methodology

Research Design - This study used an experimental and developmental research design to examine the accuracy and efficiency of the hybrid multi-crop grain collector with an Arduino-powered weighing scale and alarm and a rechargeable fan-assisted winnowing system. The developmental aspect of the study involved designing, constructing, and improving the prototype. At the same time, the experimental method enabled the researchers to test the prototype's accuracy, efficiency, and usability. Through this method, the researchers were able to determine how Arduino innovation upgraded the efficiency of the cleaning procedure and the accuracy of weighing. The study included examining the prototype with *palay* (rice) and mung beans to determine its effectiveness across different crops. This was designed to condition the researchers to provide accurate results and to deliver suggestions for future studies, to improve sustainable, automated post-harvest devices for small-scale farmers.

Participants of the Study - The study involved 20 farmers and farm owners who operated grain production and post-harvest operations in San Jose. The respondents participated in testing and evaluating the Hybrid Multi-Crop Grain Collector prototype, which includes mechanical sweeping, an Arduino weight measurement system, an alert system, and a fan-powered winnowing device. Farmers served as study respondents because they are the primary users who benefit from agricultural machinery and post-harvest technologies, making their feedback vital for assessing the device's performance in real-world farming environments. According to Pingali (2007), farmers serve as essential agents who bring agricultural technologies into use, as their direct farming experience enables them to assess whether innovations deliver real-world agricultural value. The study involved 20 farmers and farm owners who operated grain production and post-harvest operations in San Jose. The respondents participated in testing and evaluating the Hybrid Multi-Crop Grain Collector prototype, which includes mechanical sweeping, an Arduino weight measurement system, an alert system, and a fan-powered winnowing device. Farmers served as study respondents because they are the primary users who benefit from agricultural machinery and post-harvest technologies, making their feedback vital for assessing the device's performance in real-world farming environments. According to Pingali (2007), farmers serve as essential agents who bring agricultural technologies into use, as their direct farming experience enables them to assess whether innovations deliver real-world agricultural value.

Data Gathering Procedure - The data-gathering procedure for the study "A Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan-Assisted Winnowing System" used a quantitative, experimental approach to test the device's accuracy and efficiency. Before experimenting, the researchers prepared and calibrated the Arduino nano-powered weighing scale using standard weights to ensure accuracy. A pilot test was done to check the system's operation and reliability. To determine If the use of the prototype was much faster than the traditional way of grain collection and the ability of the conveyor to transfer the grain properly into the sack, they determined the performance level of the prototype in terms of ease of operation and conveyor transport efficiency, using a survey questionnaire and letting the twenty (20) participants, composed of farmers and farm owners to operate and observe the prototype. The speed was measured using a stopwatch, and the cleaned grains were weighed using both the Arduino scale and a standard weighing device to assess accuracy. The winnowing efficiency was determined by comparing the weight of the cleaned output to the input weight. Five (5) trials per crop per method were conducted under similar weather conditions, and all data were recorded on prepared sheets and encoded for analysis.

Research Process

Stage 1 Preparation and Gathering of Materials

To achieve successful results in developing the hybrid multi-crop grain collector integrating mechanical sweeping, Arduino-based weighing and alerting, and a fan-assisted winnowing system, the researchers used the materials shown in the images below. A) For the Grain Collector: Bearing, Motor chain, Plastic broom brush, Conveyor roller, Sprockets, Yoga Mat, Rubber wheels, DC motor, Tarpaulin, Timing chain sprocket, motor timing chain, and Sack. B) For the Winnowing System: Rechargeable fan, Fan switch, Rechargeable fan battery, and Rocker switch. C) For the Arduino nano-powered weighing scale with alarm: HX711 Load cell amplifier, Jumper wires, Organic light-emitting diode (OLED), Load cell, Piezoelectric buzzer, Arduino nano, Arduino nano expansion board, 3 cell 18650 battery holders, 18650 rechargeable battery, Buck converter, Charger, Motor driver, and Momentary button. D) For the Casing and Accessories: Stainless steel square tube, Galvanized flat steel, Plastic filament, PVC pipe, and Bolts and nuts

Stage 2: Building and Development of the Project

The researchers created a sketch and a 3D model of the Hybrid Multi-Crop Grain Collector prototype, showing its dimensions, structural framework, mechanical components, and overall system design. The sketch also included the conveyor layout, mechanical sweeping mechanism, Arduino-based weighing circuit, fan-assisted winnowing system, and electronic components. This served as the basis for assembling the components and visualizing how the integrated grain collection, weighing, and cleaning system would function. After creating the initial sketch of the proposed prototype, the researchers proceeded to construct the device, a process that took four months. The main frame was built from stainless-steel square tubes to ensure durability and stability. Mechanical components, including the bearing, bike chain, sprocket, DC motor, conveyor roller, and yoga mat, were installed to enable smooth grain collection and transport. The electronic system was then assembled, integrating the Arduino Nano, load cell sensor, HX711 amplifier, OLED display, rechargeable fan, piezoelectric buzzer, and jumper wires. These components were first tested on a breadboard before being permanently mounted onto the structure. The rechargeable battery was connected to power the system during the operation. Once all components were securely installed, the researchers conducted preliminary testing to ensure proper alignment, accurate weighing, and effective winnowing performance before proceeding to the experimental stage.

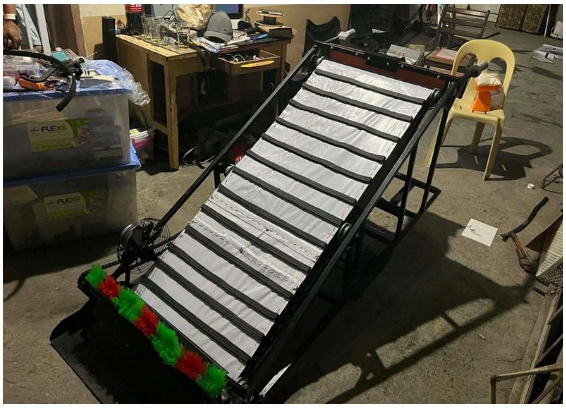

Figure 1. Actual Product of the Grain Collector

Stage 3: Experimental Stage, Observation and Data Recording

To evaluate whether the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan-Assisted Winnowing System is functional, the researchers began by assembling the fully constructed prototype using the prepared mechanical and electronic components. The load cell was installed beneath the weighing platform, while the Arduino Nano, HX711 amplifier, OLED display, rechargeable fan, and piezoelectric buzzer were connected to complete the system circuit. The researchers then placed measured quantities of rice grains and mung beans into the collection area to test the mechanical sweeping and conveyor system. The grains passed through the weighing section to display the weight and activate the alert system once the weight limit was reached. As the grains moved toward the outlet, the fan-assisted winnowing system was activated to generate airflow and separate chaff from the grains. The researchers observed the system's response, recorded weight readings, and measured the degree of impurity removal to evaluate overall functionality and performance. The study took 2 days to complete.

Statistical Treatment of the Data - The researchers used mean computation, experiments, and a paired-samples t-test to statistically analyze data from testing the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan-Assisted Winnowing System. These statistical tools helped determine the performance level, accuracy, and effectiveness of the developed prototype in terms of speed, ease of operation, conveyor transfer efficiency, weighing accuracy, buzzer reliability, and winnowing performance. The study employed both descriptive and inferential statistics. For descriptive statistics, the weighted mean was used to determine the prototype's performance level based on respondents' evaluations of speed, ease of operation, and conveyor transfer efficiency. The weighted mean was also used to assess the system's usability and overall performance. For inferential statistics, a paired t-test was applied to determine whether there was a statistically significant difference in the amount of chaff mixed with grains before and after using the fan-assisted winnowing system for both rice grains and mung beans. The computed t-value and corresponding p-value were analyzed to determine whether the observed reduction in grain weight after winnowing was statistically significant. The decision rule was based on a 0.05 level of significance ($\alpha = 0.05$). A p-value less than 0.05 indicates a statistically significant difference between the weight of grains before and after winnowing, confirming the effectiveness of the fan-assisted winnowing system. Conversely, a p-value greater than 0.05 indicates that there is no statistically significant difference. By combining weighted-mean computation and paired t-tests, the researchers quantitatively assessed the operational efficiency and functional reliability of the hybrid multi-crop grain collector, ensuring the prototype's performance was evaluated systematically and data-driven.

Ethical Considerations - The researchers ensured that all experimental procedures were performed safely and responsibly. All prototype testing was conducted within a controlled environment, using proper protocols for handling mechanical and electrical components to prevent accidents, injuries, or equipment damage. No human or animal subjects were exposed to risk, as all data collected focused solely on the mechanical performance, accuracy, and efficiency of the prototype. Respondent participation in the usability evaluation was voluntary, and participants were informed of the study's purpose before completing the evaluation form. No personal or identifying information was collected. All data gathered was used exclusively for academic research and was kept confidential. Furthermore, the researchers ensured that all written outputs, attributions, and References strictly followed the guidelines and standards set by the American Psychological Association (APA) 7th edition, upholding academic integrity and avoiding plagiarism throughout the study.

1. Results and Discussions

Table 1

Performance level of the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan-Assisted Winnowing System in reducing the collection time

Number of Trials	Observation for the Traditional collection	Observation for the Grain Collector
1	1	0
2	0	1
3	0	1
4	0	1
5		1

Legend: 1 – fast 0 – slow

Table 1 presents a comparison of the performance of the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan-Assisted Winnowing System with the traditional grain collection method in terms of speed. The results indicate that the prototype performed faster in four of five trials, while the traditional method was slower in those same trials. Although the traditional method appeared fast during the first trial, the prototype consistently achieved a "fast" rating in subsequent trials. This pattern suggests that the developed system provides more stable and efficient time performance compared to manual grain collection. The repeated fast observations highlight the prototype's capability to reduce collection time, thereby improving operational efficiency. These findings imply that integrating mechanical sweeping, conveyor transfer, and automated processes significantly enhances speed and consistency in grain collection. The improved performance aligns with the findings of Santosh et al. (2019), who emphasized that traditional manual grain collection is labor-intensive and time-consuming. In contrast, mechanized grain handling systems significantly increase efficiency and productivity. Therefore, the results support the claim that the Hybrid Multi-Crop Grain Collector effectively increases collection speed and performs better than the conventional method, particularly as the number of trials increases.

Table 2

Performance level of the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan Assisted Winnowing System in making the prototype easy to use

Indicator	Weighted Mean	Verbal Description
1. The multi-crop prototype is easy to operate.	3.65	Very High
3. The machine controls are easy to understand.	3.30	Very High
4. Minimal effort is required to operate the machine properly.	3.45	Very High
Overall Mean	3.47	Very High

Legend: 3.26-4:00 Very High, 2.51-3.25 High, 1.76-2.50 Low Level, 1.00-1.75 Very Low

Table 2 presents the performance level of the Hybrid Multi-Crop Grain Collector Integrating Mechanical Sweeping, Arduino-Based Weighing and Alert, and Fan-Assisted Winnowing System in terms of ease of operation. The results indicate that the respondents strongly agreed that the prototype is easy to operate, that its controls are understandable, and that minimal effort is required to operate it properly. The overall evaluation reflects a high level of usability, suggesting that the system is user-friendly and practical for agricultural applications. The consistent positive assessment across all indicators demonstrates that the prototype design successfully considered operator convenience and functional simplicity. These findings imply that integrating mechanical components with an Arduino-based automated system enhances not only operational efficiency but also ease of use. The results align with those of Ren et al. (2025), who emphasized that modern mechanized and integrated grain-handling systems significantly improve reliability, usability, and productivity in post-harvest operations. The strong agreement among respondents supports the conclusion that the developed prototype is manageable, efficient, and suitable for actual field implementation, thereby reinforcing its potential as an effective technological innovation in grain collection and processing.

Table 3

Performance level of the Conveyor in transferring the Grains Properly

Indicator	Weighted Mean	Verbal Description
1. The conveyor smoothly transfers grains without interruptions.	3.45	Very High
2. The conveyor efficiently moves grains from one process to another.	3.40	Very High
3. Minimal grain spillage occurs during conveyor transfer.	2.90	High
Overall Mean	3.25	High

Legend: 3.26-4:00 Very High, 2.51-3.25 High, 1.76-2.50 Low Level, 1.00-1.75 Very Low

Based on Table 3, the indicator "The conveyor smoothly transfers grains without interruptions" had a weighted mean of 3.45, indicating a very high level. In contrast, "The conveyor efficiently moves grains from one process to another" obtained a weighted mean of 3.40, which was also interpreted as a very high level. Meanwhile, the indicator "Minimal grain spillage occurs during conveyor transfer" had a weighted mean of 2.90, indicating a high level. The overall weighted mean of 3.25, interpreted as high, indicates that the respondents generally agreed that the conveyor system effectively transfers grains properly and supports efficient prototype operation. These findings indicate that the conveyor mechanism of the Hybrid Multi-Crop Grain Collector can transport grain smoothly and efficiently between processing stages. The high ratings for uninterrupted transfer and efficient movement suggest that the conveyor roller, DC motor, and mechanical transmission system successfully facilitated controlled grain flow. Although grain spillage received a slightly lower rating, it remained within an acceptable range, indicating that the system continued to be effective at minimizing grain losses compared to manual handling. This demonstrates that the conveyor improves operational efficiency, reduces handling time, and ensures continuous grain processing. This result supports the findings of Kumar and Kalita (2017), who emphasized that proper mechanized handling and transport of grains during post-harvest operations are critical for reducing grain losses and maintaining grain quality.

Additionally, Nath et al. (2024) highlighted that adopting modern post-harvest technologies improves efficiency, reduces labor requirements, and enhances consistency in grain-handling operations. Furthermore, Shrestha (2017) and Nguyen et al. (2019) reported that mechanized grain-handling and cleaning systems significantly improve processing efficiency and reduce the limitations of manual handling by ensuring continuous, controlled grain movement. These studies support the present findings, as the respondents agreed that the conveyor system improved the efficiency and reliability of grain transfer within the prototype.

Table 4

The accuracy level of the Load cell in providing the exact weight measurement of rice grains in kilograms

Number of Trials	Weight Displayed on the Traditional Weighing Scale	Observation	Weight Displayed on the Arduino Powered Weighing Scale	Observation
1	4kg	1	4kg	1
2	3kg	1	3kg	1
3	2kg	1	2kg	1
4	0.5kg	1	0.5kg	1
5	2.5kg	1	2.5kg	1

Legend: 0 – Not accurate 1 – Accurate

The table shows the load cell's accuracy in measuring the weight of rice grains in kilograms. Based on the results in Table 4, the weight displayed on the Arduino-powered weighing scale matched that of the traditional weighing scale in all five (5) trials: 4 kg, 3 kg, 2 kg, 0.5 kg, and 2.5 kg. This shows no difference in accuracy between the two measurements, indicating that the load cell provided accurate, precise weighing readings. There is an indicator that shows 0 for inaccurate and 1 for accurate. The consistent results across all five trials confirm that the Arduino-powered weighing scale can reliably measure rice grain weight, making it effective for automated grain weighing and monitoring in post-harvest operations. This result supports the recent study by Kulkarni et al. (2020), which found that properly calibrated load cell sensors integrated with microcontrollers can provide precise and reliable digital weight measurements comparable to standard weighing devices, which explains why the Arduino-powered weighing scale in the prototype produced accurate, identical results to the traditional weighing scale.

The data in the table shows the load cell's accuracy in measuring the weight of mung beans in kilograms using both the traditional weighing scale and the Arduino–Powered Weighing Scale. It shows that, as in Table 5, where we tested the load cell's accuracy using rice grains, the two measurements yield the same result. The weight displayed on the traditional weighing scale in the first trial is 1.3kg, the same as the Arduino-powered weighing scale. The second-to-last trial also shows the same measurements for the traditional and Arduino-powered weighing scales. Therefore, there is no difference in the weight measurement of mung beans between the traditional and Arduino-powered weighing scales. This result is also supported by Kulkarni et al.

(2020), who state that load cell sensors calibrated with microcontrollers can provide accurate digital weight measurements. The consistent results from the two weighing devices across all five (5) trials demonstrated that the Arduino-powered weighing scale provides a reliable measurement of mung bean weight.

Table 5

The accuracy level of the Load cell in providing the exact weight measurement of mung beans in kilograms

Number of Trials	Weight Displayed on the Traditional Weighing Scale	Observation	Weight Displayed on the Arduino Powered Weighing Scale	Observation
1	1.3kg	1	1.3kg	1
2	1.5kg	1	1.5kg	1
3	1.11kg	1	1.11kg	1
4	1.6kg	1	1.6kg	1
5	1.23kg	1	1.23kg	1

Legend: 0 – Not accurate 1 – Accurate

Table 6

Accuracy level of the Piezoelectric buzzer in producing sound

Outcome	Frequency (f)	Percentage (%)
Produced sound (1)	4	80%
No sound (0)	1	20%
Total	5	100%

Legend: 1 – produced a sound , 0 – did not produce a sound

Table 6 presents the piezoelectric buzzer's percentage accuracy when the programmed maximum weight of 20 kilograms was reached. In five trials, the buzzer was successfully activated in four (80%), while one trial (20%) produced no sound. These results indicate that the buzzer exhibited high accuracy and reliability in responding to the Arduino-based system's programmed condition, making it an effective alert mechanism when the maximum weight limit is reached.

Table 7

Accu T-Test: Paired Two-Sample for Means

Weight of the rice grains with chaff before and after winnowing

Indicators	Variable 1	Variable 2
Mean	1.54	1.26
Variance	0.208	0.173
Observations	5	5
Pearson Correlation	0.959437456	
Hypothesized Mean Difference	0	
df	4	
t Stat	4.801960384	
P(T<=t) one-tail	0.004317896	
t Critical one-tailed	2.131846786	
P(T<=t) two-tail	0.008635793	
t Critical two-tailed	2.776445105	

*Significant at p≤0.05

The paired-samples t-test results for rice grains show that the mean weight decreased from 1.54 kg before winnowing to 1.26 kg after winnowing, resulting in a mean reduction of 0.28 kg. The computed t-value of 4.80 exceeds the critical t-value of 2.776 (two-tailed), and the p-value of 0.0086 is lower than the 0.05 level of significance. Therefore, the null hypothesis is rejected. This result indicates that the fan-assisted winnowing system significantly reduced the amount of chaff mixed with the rice grains. The decrease in weight suggests that the system effectively removed lighter impurities, improving the cleanliness and market quality of the rice grains. This finding supports the study of Shrestha (2017), which explained that mechanical winnowing systems using controlled airflow effectively separate lighter chaff from heavier grains, resulting in cleaner grain output.

Table 8

T-Test: Paired Two-Sample for Means

Weight of the mung grains with chaff before and after winnowing

Indicator	Variable 1	Variable 2
Mean	1.3	1.116
Variance	0.035	0.03858
Observations	5	5
Pearson Correlation	0.993293814	
Hypothesized Mean Difference	0	
df	4	
t Stat	17.08397111	
P(T<=t) one-tail	3.44279E-05	
t Critical one-tailed	2.131846786	
P(T<=t) two-tail	6.88558E-05	
t Critical two-tailed	2.776445105	

*Significant at p≤0.05

The paired-samples t-test results for mung beans indicate that the mean weight decreased from 1.30 kg before winnowing to 1.116 kg after winnowing, with a mean difference of 0.184 kg. The computed t-value of 17.08 is substantially higher than the critical value of 2.776 (two-tailed), and the p-value of 0.0000689 is far below the 0.05 level of significance. Thus, the null hypothesis is rejected. This indicates a highly significant difference in the weight of mung beans before and after winnowing. The extremely low p-value provides strong statistical evidence that the fan-assisted winnowing system was highly effective in removing chaff and other light impurities from mung beans. This result aligns with the findings of Kumar and Kaita (2017), who reported that airflow-assisted grain cleaning technologies significantly improve grain purity by removing lightweight contaminants.

3. Conclusions

Based on the study's findings, the researchers conclude the following: At the Performance level of the Multi-Crop Prototype, the Hybrid Multi-Crop Grain Collector demonstrated faster performance than the traditional method of grain collection. The prototype consistently reduced collection time across most trials, demonstrating that integrating mechanical sweeping and conveyor transfer significantly enhances operational efficiency. The respondents strongly agreed that the prototype is easy to operate, has understandable controls, and requires minimal effort during use. This indicates that the system was successfully designed with user-friendliness and practicality in mind, making it suitable for small-scale farmers. Lastly, the conveyor system transferred grains smoothly and efficiently between processes with minimal spillage. Although slight grain loss was observed, the overall performance rating confirms that the conveyor mechanism reliably supports continuous and efficient grain movement.

Regarding the accuracy of the Arduino-powered weighing scale, it produced measurements identical to those of the traditional weighing scale in all trials for both rice grains and mung beans. This confirms that the load cell and HX711 amplifier provide accurate, precise digital weight readings, making the system reliable for post-harvest weighing operations. The piezoelectric buzzer functioned effectively, activating when the preset weight limit was reached. This confirms that the alert system reliably notifies users when the sack reaches maximum capacity, preventing overloading and improving operational control. For the Significant Difference in the Amount of Chaff Before and After Winnowing, there is a statistically significant difference in the weight of rice grains before and after using the fan-assisted winnowing system. The weight reduction indicates that the system effectively removed lighter impurities, such as chaff and dust. There is also a statistically significant difference in the weight of mung beans before and after winnowing. The highly significant result confirms that the fan-assisted airflow mechanism efficiently separated lighter contaminants from the grains.

Recommendations - The researchers suggest the following, based on their conclusions: To further improve conveyor transfer efficiency, adjustments to conveyor alignment and speed control, or the addition of side barriers, may be implemented to minimize grain spillage and ensure smoother grain transfer. For the agricultural technology sector to further improve the reliability of the piezoelectric buzzer alert system, proper wiring, secure connections, and optimized Arduino programming should be implemented to ensure the buzzer consistently produces sound across all trials. To further improve the effectiveness of the fan-assisted winnowing system, the airflow intensity and fan speed may be adjusted to ensure that only lighter impurities are removed while preventing the loss of usable grains during the cleaning process. To further improve the prototype's overall performance, future researchers may conduct additional trials and testing under different agricultural conditions to identify additional areas for improvement and enhance the system's efficiency and reliability.

4. References

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