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Ergonomic Design and Development of A Seed Packing Aid for Rice Farmers

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Abstract. *Rice milling is a vital agribusiness subsystem that produces rice and by-products such as seeds. UD. Sri Rejeki, a small-scale mill, still relies on manual seed packing using plates, which is repetitive, inefficient, and ergonomically risky. This study developed a vacuum-based ergonomic packing tool for rice seeds. Quality Function Deployment (QFD) identified worker needs, Rapid Upper Limb Assessment (RULA) evaluated posture, usability testing assessed tool performance, and the Mann-Whitney test compared workload before and after implementation. Design attributes were based on worker requirements, posture, and benchmarking. Usability testing showed three workers completed five tasks with a System Usability Scale (SUS) score of 70.8 (Grade C, "Good"). RULA indicated reduced posture risk from 7 (high) to 4 (low). The Mann-Whitney test confirmed a significant workload reduction after tool adoption. In conclusion, the vacuum-based ergonomic packing aid improved efficiency, reduced workload, and enhanced worker safety in small-scale rice seed packaging.*

Keywords: *ergonomic seed packing tool, rice milling, quality function deployment, rapid upper limb assessment, usability testing, work posture*

I. INTRODUCTION

Rice is one of the most strategic food commodities in Indonesia, playing an essential role for both producers and consumers. In 2019, Indonesia's harvested rice area reached 10.68 million hectares with an estimated paddy production of 54.60 million tons, equivalent to 31.31 million tons of rice for consumption (Badan Pusat Statistik, 2019). The rice agribusiness system consists of several subsystems, from input supply to marketing, with rice milling industries acting as a crucial intermediary that converts paddy into rice and by-products such as rice seeds. As part of the national rice supply chain, rice milling industries significantly influence productivity and food security.

Based on their type, rice milling enterprises are categorized into three groups: maklon (service-based), non-maklon (self-owned production), and combined. The majority of rice milling units in Indonesia are small-scale enterprises, accounting for 94.13% of the industry (BPS, 2012), many of which have operated since the 1960s–1980s (Sawit, 2011). UD. Sri Rejeki, established in 2000 in Purworejo, Central Java, is a small-scale non-maklon rice milling business that produces rice seeds with a daily output of 500 kg to 1 ton, packed in 5–20 kg bags.

Despite this production capacity, the seed packaging process remains conventional. Workers manually pour seeds into sacks using plates, followed by weighing and sealing. This repetitive activity, performed for eight working hours daily, exposes workers to fatigue and musculoskeletal complaints. A preliminary survey using the Nordic Body Map revealed common pain in the neck, shoulders, back, waist, wrists, and legs among packaging workers, indicating ergonomic risks in current practices.

To address these issues, an ergonomic intervention is required in the form of a seed packing tool that minimizes repetitive manual movements and improves worker comfort. This study proposes the design of a vacuum-based seed packing aid equipped with a stand and wheels for mobility. The design approach applies Quality Function Deployment (QFD) to translate worker requirements into technical specifications, supported by ergonomic evaluation using the

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Rapid Upper Limb Assessment (RULA), usability testing, and statistical comparison.

Previous studies on rice milling industries have primarily focused on post-harvest processing efficiency, machine performance, and rice quality improvement, while limited attention has been given to ergonomic risks in small-scale seed packaging activities. Furthermore, research on ergonomic interventions in seed packing tools for rice milling workers, particularly integrating usability evaluation and non-parametric statistical analysis, remains scarce.

This study contributes to the field by introducing a novel vacuum-based ergonomic seed packing tool designed through QFD and evaluated using RULA, usability testing, and Mann-Whitney analysis. The research demonstrates how integrating ergonomic principles into equipment design can reduce musculoskeletal risks, improve usability, and enhance productivity in small-scale rice seed packaging operations.

II. RESEARCH METHOD

This study employed a mixed-method approach consisting of field observation, literature review, survey-based data collection, and experimental testing. The methodological steps are as shown at Figure 1.

Initial Observation and Problem Identification. A preliminary field observation was conducted to gather concrete information regarding workers' complaints and needs in rice seed packing activities. Problems were then

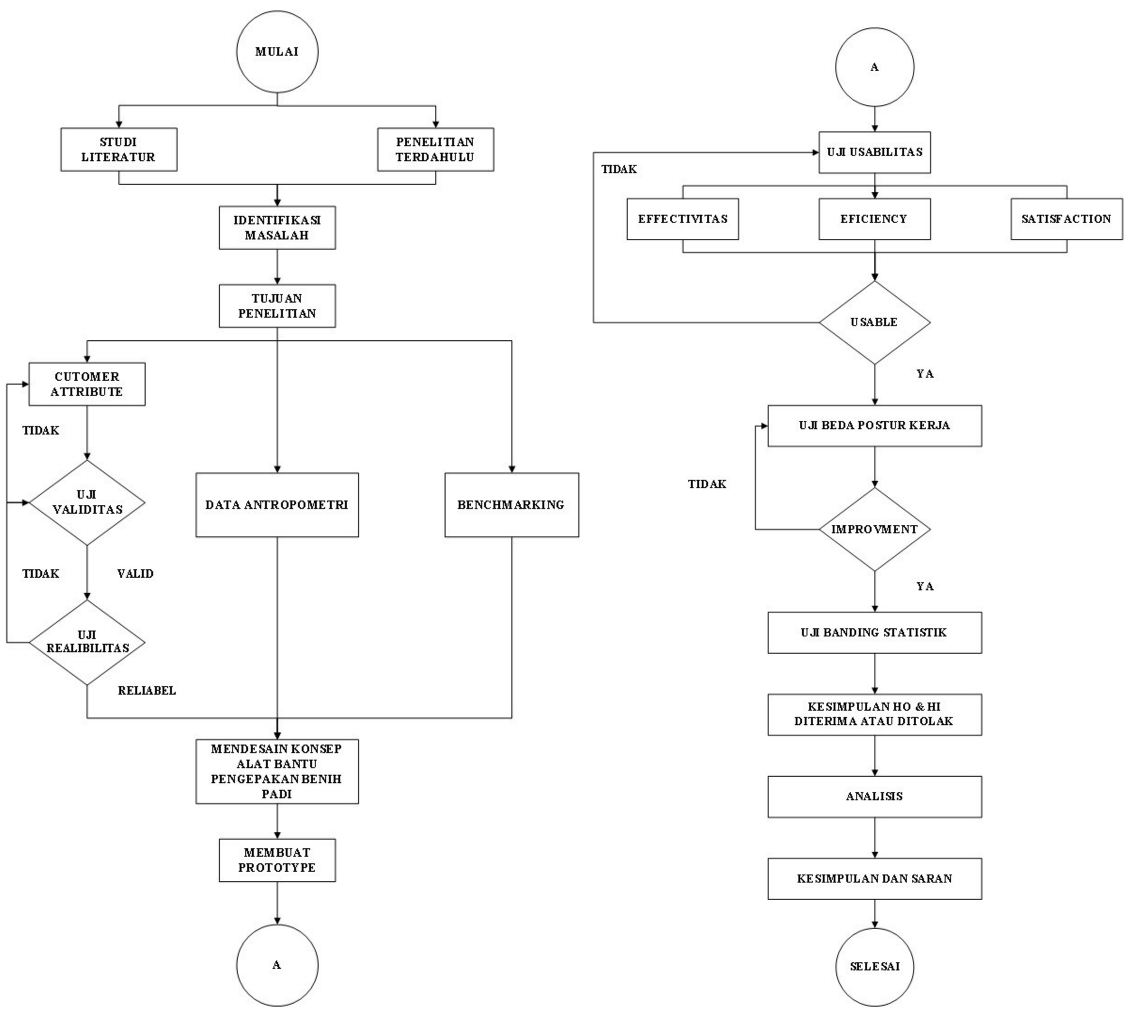

Figure 1. Flowchart Diagram

identified and formulated as the basis for designing an ergonomic packing tool.

Data Collection. Two types of data were used:

1. Primary data, obtained through interviews, questionnaires, and usability testing. A preliminary questionnaire with 24 items across 8 attributes was distributed to 3 rice seed packing workers to test validity and reliability. A validated questionnaire was then applied for Quality Function Deployment (QFD) analysis. Nordic Body Map was also used to assess musculoskeletal complaints.
2. Secondary data, obtained from previous studies, technical reports, and relevant online resources, served as supporting references.

Interviews and Questionnaires. Semi-structured interviews with three workers identified eight customer attributes: ease of use, posture improvement, mobility, workload reduction, faster packing process, productivity enhancement, easy maintenance, and low power consumption. These attributes were integrated into the survey instrument.

Validity and Reliability Testing. Validity was assessed using Pearson's product moment correlation, while reliability was tested with Cronbach's Alpha, ensuring acceptable levels of accuracy and consistency before proceeding to QFD analysis.

Anthropometric Data. Anthropometric measurements were applied to ensure the tool design dimensions were adapted to users' physical characteristics.

Quality Function Deployment (QFD). The House of Quality (HOQ) was constructed through the following stages:

1. Identification of customer needs (What), categorized into must-be, one-dimensional, and attractive requirements.
2. Determination of technical descriptors (How) responding to customer needs.
3. Development of relationships between What and How matrices using weighting scores (9 = strong, 3 = moderate, 1 = weak).
4. Analysis of interrelationships among How elements to avoid design conflicts.
5. Prioritization of customer requirements through importance ratings and improvement ratio calculations.

Benchmarking. The design was benchmarked against existing tools to evaluate functionality, innovation, and adaptability, using the Plan–Search–Observe–Analyze–Adapt framework.

Prototype Development and Testing. A prototype of the ergonomic seed packing tool was developed and tested. Usability testing was conducted to assess effectiveness, efficiency, and satisfaction. Postural analysis was carried out using Rapid Upper Limb Assessment (RULA) before and after tool implementation.

Statistical Analysis. A comparative experiment was conducted with three workers to evaluate differences before and after using the tool. The Mann–Whitney U test was employed to test the hypothesis of workload reduction.

Conclusion and Recommendations. Findings from QFD analysis, usability testing, and statistical comparison were synthesized to propose recommendations for improving the design and implementation of the ergonomic rice seed packing tool.

III. RESULT AND DISCUSSION

RULA (Rapid Upper Limb Assessment)

The Rapid Upper Limb Assessment (RULA) was conducted to evaluate workers' postures during the rice seed packing process. Postural analysis was performed by capturing working postures at different phases of the activity and coding them into two groups: **Group A** (upper arm, lower arm, wrist, and wrist twist) and **Group B** (neck, trunk, and legs).

The RULA coding for Group A showed elevated scores in the upper arm and wrist movements, indicating repetitive and constrained postures. Group B results highlighted significant strain on the neck and trunk, with additional static loading observed in the lower back. The final RULA score obtained from the analyzed postures was **7**, which indicates that the activity is at a high risk level and requires immediate ergonomic intervention.

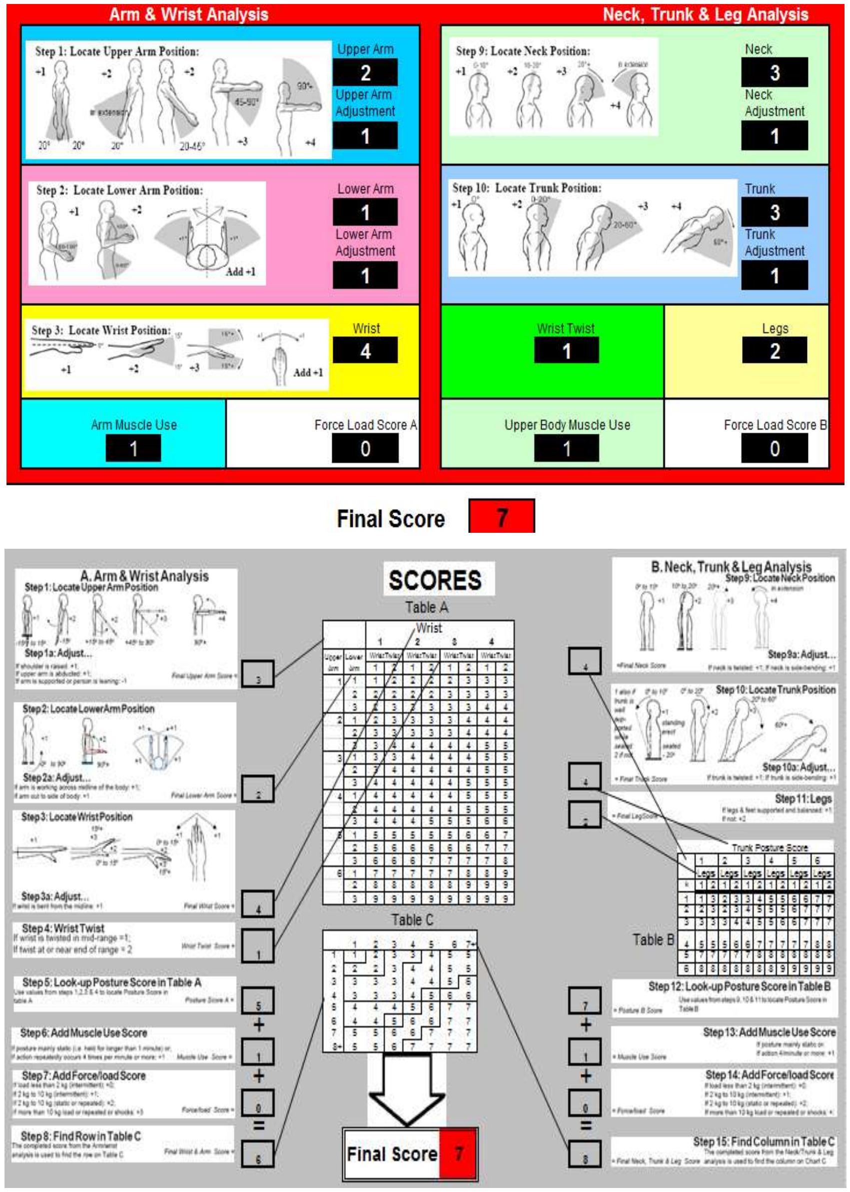

Figure 2. RULA Score Before Improvement

The RULA findings confirm that the conventional rice seed packing process exposes workers to high musculoskeletal risks. The repetitive nature of lifting, pouring, and adjusting bags of seeds contributes to increased strain on the upper limbs and trunk. Similar studies have also reported that repetitive manual material handling activities without ergonomic tools significantly increase the likelihood of musculoskeletal disorders (MSDs).

The score of **7** falls within the "Action Level 4," meaning that the task requires urgent ergonomic redesign. This result is consistent with workers' self-reported complaints from the Nordic Body Map survey, particularly in the neck, shoulders, wrists, and lower back. The alignment between subjective complaints and objective postural risk assessment reinforces the necessity of intervention.

The proposed ergonomic packing tool—integrating a suction mechanism and mobile support—addresses these high-risk postures by reducing repetitive manual scooping and lowering excessive trunk bending. By minimizing repetitive strain and improving posture, the tool is expected to reduce the RULA score significantly, thus enhancing both worker comfort and productivity.

House of Quality (HOQ) Matrix

The House of Quality (HOQ) was developed to align workers' requirements with the technical specifications of the ergonomic rice seed packaging tool. Data were obtained from anthropometric measurements, worker questionnaires, and benchmarking of the current packaging method. The questionnaire revealed key dissatisfaction factors, such as repetitive movements, high physical workload, and inefficient processes, which were then translated into design requirements.

The main worker needs identified include ease of use, improved working posture, portability, reduced workload, faster packaging process, increased productivity, ease of maintenance, and low power consumption. Among these, improving posture, reducing workload, and enhancing process efficiency were rated with the highest priority (importance score 5.0).

Technical requirements derived from these needs include handle dimensions based on anthropometry, frame and material selection, suction fan performance, motor power, operational speed, and trolley wheels for mobility. Target values were set at the maximum scale (5) to ensure optimal performance. The improvement ratio indicated that ease of maintenance and energy efficiency require the most significant enhancement, while sales point analysis confirmed posture improvement, workload reduction, and process acceleration as key selling factors.

The calculation of raw weight and

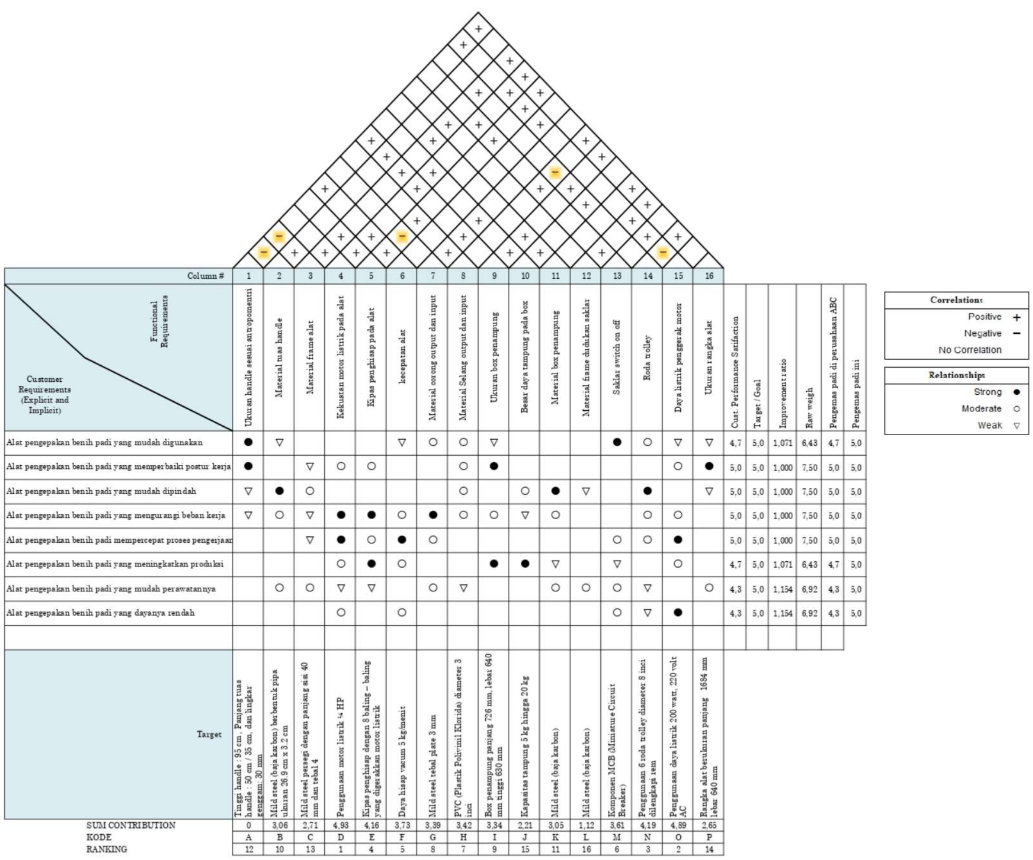

Figure 3. House of Quality

normalized raw weight showed that posture improvement, portability, workload reduction, and process efficiency each contributed the highest relative weight (0.132). Finally, the relationship matrix between *what* (worker needs) and *how* (technical specifications) demonstrated strong correlations, confirming that the proposed ergonomic tool addresses critical worker requirements effectively.

Design Details

The ergonomic rice seed packaging tool was designed with 14 integrated components, each contributing to functionality, usability, and mobility. The main system consists of a **fan cover and output funnel**, which houses the impeller and connects the input and output hoses, ensuring a continuous flow of seeds. The **electric motor (¼ HP)** drives the **suction fan turbine**, fabricated from mild steel, to generate airflow for seed transfer. At the inlet side, a **cover funnel** and **input hose** (PVC, 3 inches, flexible) allow the device to reach various working positions, supported by an **input funnel** fabricated from 3 mm plate steel.

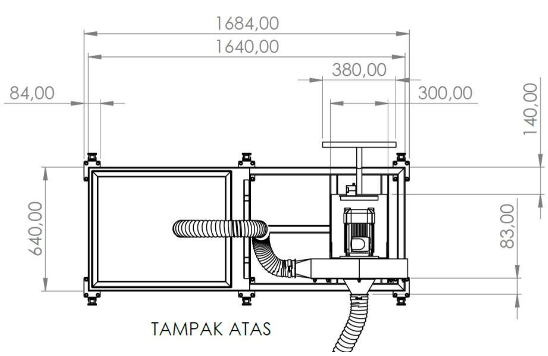

Figure 4. Top View of Design

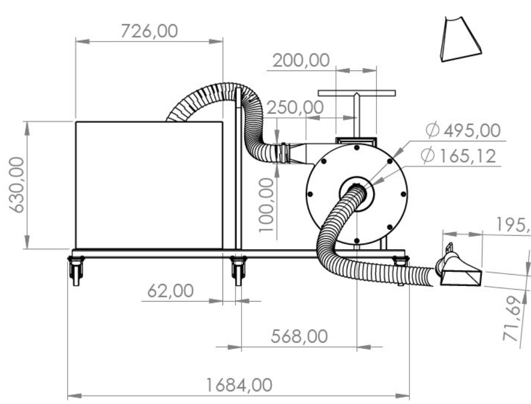

Figure 5. Front View of Design

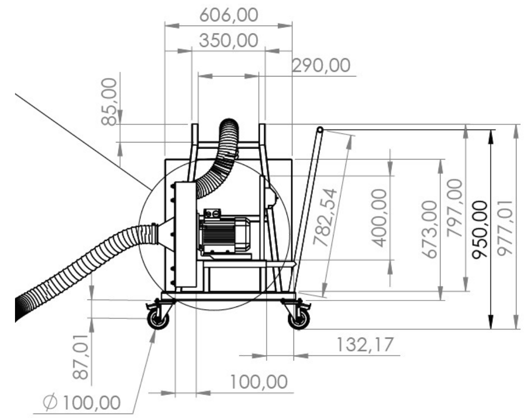

Figure 6. Side View of Design

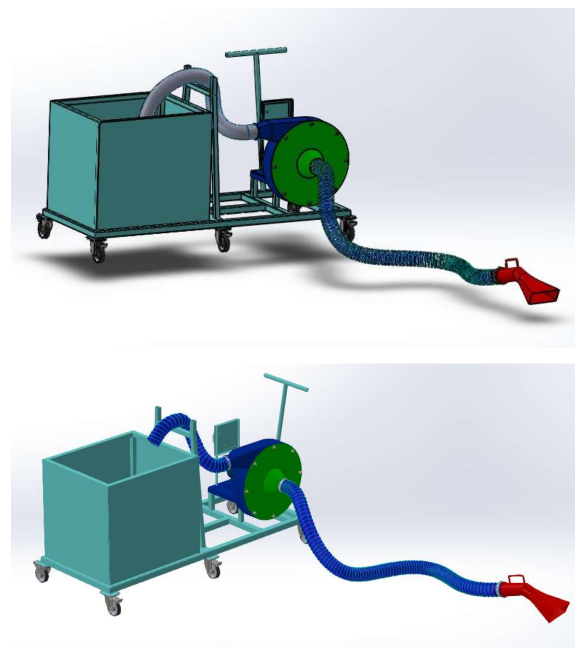

Figure 7. Detailed Design of the Equipment

For mobility, the tool is equipped with **six trolley wheels (8 inches)** and a **T-shaped handle**, enabling operators to move and reposition the device with reduced physical effort. The **main frame** (40 × 40 × 4 cm, mild steel) serves as the structural base, supporting all major components, including the **seed storage box** with a maximum capacity of 20 kg, and auxiliary frames for the **output hose** and **switch unit**. Power operation is controlled by an **on/off MCB switch** mounted on a dedicated frame for operator accessibility. Finally, the **output hose** (PVC, 3 inches) directs seeds into the packaging container.

This modular design ensures efficient suction, ergonomic handling, and reduced operator workload while maintaining structural durability and ease of operation.

Prototype of the Tool

The rice seed packaging tool prototype was developed based on the finalized design specifications and engineering drawings. The prototype integrates all 14 components described in the design details, ensuring functionality, ergonomics, and durability. The construction utilized mild steel for structural components, PVC hoses for input–output flow, and a ¼ HP electric motor for fan operation.

Visual documentation of the prototype is

Figure 8. The Rice Packaging Tool Prototype

Figure 9. Top Side View of the Rice Packaging Tool Prototype

Figure 10. Right Side View of the Rice Packaging Tool Prototype

Figure 11. Left Side View of the Rice Packaging Tool Prototype

provided in Figures 3, illustrating multiple perspectives of the device, including right- and left-side views. These images demonstrate the compact and mobile structure of the tool, supported by a six-wheel trolley system and a T-shaped handle for ease of transportation. The prototype successfully reflects the conceptual design and enables subsequent usability and ergonomic testing.

Usability Testing

The usability evaluation was conducted through interviews and questionnaires, focusing on three key components: effectiveness, efficiency, and satisfaction. This approach follows established frameworks (Nielsen, 2001; Mifsud, 2015) to ensure comprehensive assessment of user interaction with the rice seed packaging prototype

Figure 12. Trial of The Rice Packaging Tool Prototype

Effectiveness

Effectiveness was measured based on the number of tasks successfully completed by users without errors. Table 4.26 summarizes the results, where most tasks achieved a 100% success rate. Only the task of inserting seeds into the packaging recorded a 33% error rate, indicating the need for design refinement in this stage of operation. The overall success rate was calculated using Equation (1), demonstrating that the prototype is highly effective for practical operation.

Efficiency

Efficiency was assessed using a time-based measurement, where the completion time for each task was recorded for three participants (Table 4.27). Tasks such as moving the tool and storing packaged seeds were completed rapidly, while tasks involving seed insertion and cleaning required longer durations, reflecting higher physical and operational demands.

Additionally, suction capacity was calculated to quantify system performance. With a motor speed of 1400 rpm, the airflow velocity reached 3.72 m/s, resulting in a suction capacity of approximately 0.6 kg/min. However, this rate is considered suboptimal for large-scale operation. Analytical projections suggest that performance could be enhanced by increasing motor rotation speed to 11,500 rpm and reducing the hose diameter to 2 inches, thereby improving both airflow velocity and throughput.

Satisfaction

User satisfaction was measured through qualitative feedback regarding tool usability, ergonomics, and operational convenience. Overall, respondents indicated that the tool was easy to operate, mobile due to the six-wheel system, and efficient for small-scale seed packaging. Nonetheless, suggestions for improvement included enhancing suction power and optimizing seed input to minimize error rates.

Postural Analysis Using RULA

The postural differences before and after using the rice seed packaging prototype were assessed using the Rapid Upper Limb Assessment (RULA) method. Table 4.31 illustrates the working activity, where workers transferred rice seeds into a plastic box in a sitting position while holding the hose with the right hand. This posture generated discomfort in the right hand, buttocks, and both knees.

For Group A, the upper arm formed an angle of 20–45° with a score of 2 (+1 if the shoulder was raised), the lower arm angle ranged between 60–100° with a score of 1 (+1 if the shoulder was raised), while the wrist remained neutral (0–10°) with a score of 1. Wrist twist was stable (score 1), with no repetitive motion (score 0) and low load (<10 kg, score 0).

For Group B, the neck angle was 0–20° (score 2), the trunk also 0–20° (score 2), and the legs were in an unbalanced position (score 2). The activity was not repetitive (score 0) and the load was <10 kg (score 0).

The final RULA scores obtained were 4 for Group A and 3 for Group B, corresponding to an overall action level of 2 (Table 4.32). This indicates a low-risk level, where corrective action is recommended in the future but is not urgently required.

A clear improvement was observed after the implementation of the prototype. In Group A, wrist posture improved from a score of 4 to 1 due to the elimination of wrist twisting. In Group B, the neck score decreased from 4 to 2 and the trunk score from 4 to 2, indicating a more neutral position without forward bending.

In conclusion, the RULA score of 4 places the activity in Action Level 2, suggesting a small risk that requires corrective measures in the long term. Thus, the use of the prototype successfully reduced musculoskeletal risk, particularly in the wrist, neck, and trunk regions, enhancing ergonomic feasibility for seed packaging tasks.

Statistical Comparison Test

A comparative analysis was conducted on three workers involved in rice seed packaging using the Man Whitneyy Test questionnaire before and after implementing the packaging tool. The Mann–Whitney non-parametric test was applied with the following hypotheses:

H_0: There is no reduction in workload after using the rice seed packaging tool.

H_1: There is a reduction in workload after using the rice seed packaging tool.

The test results (Table 4.31) show that the mean rank for the "before" group was 34.50, while the "after" group was 22.50. The Mann–Whitney U value was 224.000 with **Z = -2.875** and a significance level of **p = 0.004** (< 0.05). Since the calculated Z (-2.875) is greater than the critical value of Z (-1.96) and the significance value is below 0.05, **H_0 is rejected and H_1 is accepted**.

These results indicate a statistically significant difference in workload perception before and after the introduction of the packaging tool. Thus, the prototype effectively reduces the subjective workload of workers, supporting its usability and ergonomic benefits.

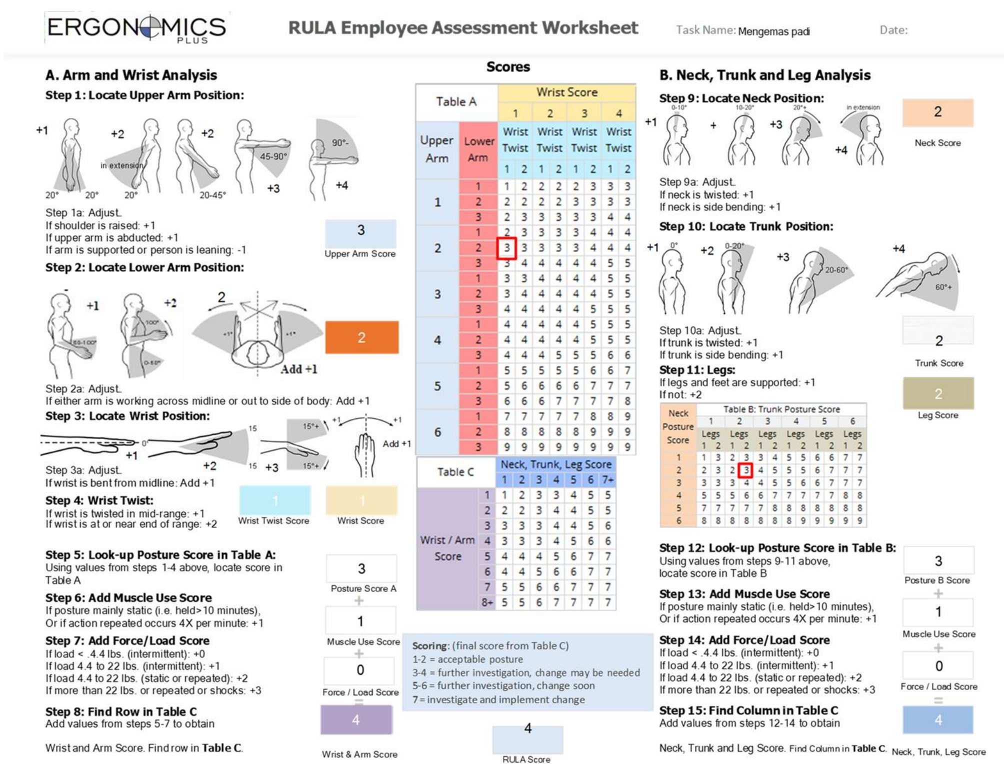

Figure 13. RULA Score After Improvement

IV. CONCLUSION

This study designed and evaluated a prototype rice seed packaging tool to enhance ergonomics and reduce musculoskeletal risks. The tool was developed based on customer attributes, worker postural analysis, and benchmarking. The specifications included a 95 cm carbon-steel handle, a vacuum system with a suction capacity of 0.749×10^{-5} m^3/s, an 8-blade fan, and a plastic container box with a capacity of 5–20 kg. Usability testing showed that workers successfully performed all assigned tasks, achieving a SUS score of 70.8 (Grade C, Good). Nevertheless, the current vacuum performance remains limited, highlighting the need for further motor optimization.

Postural assessment using RULA demonstrated a reduction in ergonomic risk from a high level (score 7) to a lower level (score 4). In addition, statistical analysis using the Mann–Whitney test confirmed a significant decrease in perceived workload after the implementation of the tool ($p < 0.05$). These results indicate that the prototype improves usability, reduces ergonomic risk, and alleviates workload in rice seed packaging activities.

This study was limited by a small number of participants, which restricts the generalizability of the findings. Future research should involve a larger sample size to provide more robust statistical evidence. Moreover, design optimization could include cost-based attributes, improved suction capacity through higher motor speed (11,500 rpm) and larger hose diameter, and refinement of working posture ergonomics. Such improvements will contribute to a more efficient, ergonomic, and scalable rice seed packaging solution.

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