Improving Post-Harvest Rice Drying Efficiency through a Low-Cost Halogen Dryer Design for Rural Communities

Supun Sadeepa and Roshan Thilakarathna*
Department Mechanical and Manufacturing Technology, Faculty of Technology, Wayamba University of Sri Lanka.
fot209185@kul.wyb.ac.lk, roshant@wyb.ac.lk

ABSTRACT

Small-scale rice farmers in Sri Lanka often depend on traditional sun-drying methods, which are inefficient, weather-dependent, and contribute to significant post-harvest losses. This research focuses on the conceptual design and evaluation of a low-cost wet rice dryer using halogen lamps as the heat source, aimed at improving drying efficiency before milling. Field surveys were conducted to identify the common challenges faced by rural farmers, including uneven drying, weather interruptions, and grain rejection by millers due to high moisture content. Based on the survey results, key user requirements were identified, including low operating cost, simple structure, and potential for multi-crop drying. Based on the survey results, key user requirements were identified, including low operating costs, a simple structure, and the potential for multi-crop drying. A conceptual design was developed accordingly, with a drying chamber and tray system optimized for 1 cm thick rice layers. The full assembly was modeled in 3D using CAD software, allowing for virtual evaluation of airflow, heat source positioning, and accessibility.

Finite Element Analysis (FEA) was applied to simulate the mechanical response of the tray under typical loads, confirming its structural soundness. Preliminary thermal experiments were conducted using a controlled test box setup to evaluate the heating performance of a 1000W halogen lamp. The system successfully achieved drying temperatures up to 82°C, which are suitable for surface moisture reduction. Temperature trends were recorded over time, and manual quality checks showed promising results for further development. These findings indicate the technical feasibility of the design and its potential to improve post-harvest efficiency in rural settings. The study provides a foundation for future stages of prototype fabrication, sensor integration, and field validation.

KEYWORDS: *halogen lamp dryer, low-cost design, post-harvest technology, prototype development, rice moisture reduction, small-scale rice processing, wet rice drying*

1 INTRODUCTION

Rice *(Oryza sativa)* plays a vital role in the diets of millions of people worldwide. It is especially important in Sri Lanka as the staple food and a source of livelihood for many farming communities. From cultivation to consumption, rice undergoes several stages of processing, and drying is one of the most critical. Proper drying preserves rice quality, prevents spoilage, and prepares the grain for milling (Thakur *et al*., 2024). However, for many small-scale farmers, especially in rural areas, access to reliable and efficient drying methods remains a challenge.

In Sri Lanka, it is still common to see farmers rely on open sun drying, where rice is spread on the ground in open areas. This method is highly dependent on weather conditions and often results in uneven drying, contamination, and grain loss due to insects, birds, or rainfall. When rice is not dried adequately, it cannot be milled effectively, as high moisture content can lead to mechanical issues in milling machines, such as clogging, blade damage, or system failure. According to Chua *et al*. (2003), many millers refuse to process wet rice, forcing farmers to bear significant post-harvest losses.

Recognizing this problem, this research aims to design and develop a low-cost wet rice dryer that can be fabricated using locally available materials and operated by small-scale farmers. The proposed dryer is intended to reduce moisture content in rice before milling, using a controlled heating system powered by halogen lamps. The project also explores ways to improve drying performance by enhancing airflow and properly insulating the chamber (Wang *et al*., 2025).

https://doi.org/10.54389/QBYH9996

By offering a practical and affordable solution, this research seeks to support rural agricultural communities by minimizing grain loss and improving the overall efficiency of the rice milling process. The work combines design, fabrication, and experimental testing to create a prototype dryer that is both accessible and effective.

2 METHODOLOGY

The methodology of this research followed a structured process, beginning with a field survey and data collection from local farmers to identify challenges related to drying wet rice under small-scale conditions (Xangsayasane *et al*., 2019). Based on the insights gathered, design considerations were defined, focusing on energy efficiency, low cost, and user-friendly operation as mentioned (Nath *et al*., 2024). A conceptual layout of the dryer was then developed to guide structural planning and heat source arrangement. This was followed by detailed 3D modelling using CAD software, in which each component, such as the frame, heating unit, and tray system, was designed and assembled digitally for compatibility and precision (Mihret *et al*., 2023). Each design and development stage was aligned with practical constraints and existing literature on small-scale post-harvest technologies.

2.1 Survey and Data Collection

To initiate the research process, a field survey was conducted targeting small-scale rice farmers and local mill operators. A total of eight (08) subjects participated in the survey to gather relevant insights. The below Table 3 shows the sample of the field survey. The primary aim of this research was to understand the practical difficulties faced during the post-harvest phase, particularly in drying of wet rice before milling. Data was collected through informal interviews and direct observations in rural farming areas, where many farmers rely on open sun drying methods, which are weather-dependent and often ineffective (Dissanayaka *et al*., 2020).

Most respondents reported that wet rice often leads to machine damage during milling or to complete rejection by mill owners, resulting in financial loss and waste, as explained in this (Introduction of Rubber Roller Milling Machine for Improving the Domestic Milled Rice Quality, n.d). The survey also revealed that the average daily quantity of rice processed ranges from 40 to 50 kg, but, individual milling instances are typically around 5 kg per batch. This information was critical in determining the design capacity and layout of the proposed drying system. The feedback collected directly shaped the direction of the conceptual and structural design to ensure the final solution would be practical, affordable, and well-suited to the local context.

Table 1: Survey Data Collection Sample

Question point	Description
Subject 01	
1. Rice flour amount per day	20kg - 30kg
2. Price for 1kg of rice flour	80/= - 100/=
3. Method of drying	Dry on a cloth
4. Time for drying the wet rice	30min
5. Challenges faced when drying the wet rice	Weather issues, uneven drying
6. Problems faced while milling wet rice?	Grain breaking, machine clogging
7. How does wet rice threshing affect machine breakdowns during rice threshing?	When milling the wet rice flour
8. If designing a dryer, what features should it include?	Multi-food drying, that is, drying other foods using this dryer.
9. Are you willing to spend money on a dryer?	15000/= - 20000/=
10. How will it affect your business if rice is dried by a machine rather than the rice drying method you are using?	The drying time of wet rice is usually 30 minutes, so its milling efficiency can be increased. If so, this method is a very suitable solution for that.
11. Would you consider using this machine if it could dry other crops or foods other than rice?	That is a good idea for this mechanism.
12. How do you measure the moisture content of the rice you take for drying?	Wet rice is heavier than normal. Also, if you touch wet rice with your hand, the rice will stick to your hand. They use that method to measure moisture.
13. What is the average moisture content of the rice before you dry it?	No
14. Do you monitor the moisture content of the rice after drying it? If yes, how?	Yes, He touched the rice. If you keep the rice in your hand while taking it out of the rice. Then he decides that the rice is dry. Otherwise, the rice is not dry.
15. Who are you primarily producing rice flour for?	For business

2.2 Design consideration and Conceptual design

The wet rice dryer was designed with a focus on efficiency, low cost, and ease of use. Controlled heat sources like halogen lamps were selected to ensure even drying, while a moisture monitoring system is planned to avoid over-drying, as explained in this (Chua *et al*., 2003). Food-grade and durable materials were chosen to improve safety and lifespan (Kim, 2013). The overall structure was kept simple to allow easy maintenance and local fabrication, according to review (Bunyawanichakul, 2006) . The below figures 1(a) and 1(b) illustrate the conceptual design and some main components of the machine, providing a clear understanding of its structure and overall drying process.

2.3 3D model designing

A 3D model of the wet rice dryer was developed to visualize and validate the design before fabrication. Each component, such as the frame, trays, and heating unit, was modelled separately and assembled to ensure proper fit and function. This process helped identify design improvements early, particularly in airflow and heat distribution, according to reviewed this (Bennamoun *et al*., 2003). The final model supports both construction and future optimization.

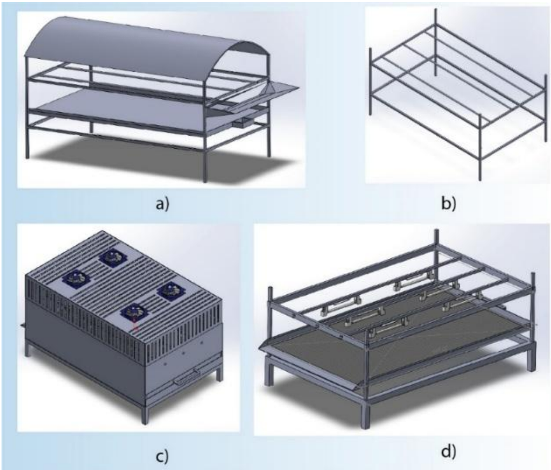

Figure 1.Conceptual sketch and 3D design of the proposed machine.

(a) Conceptual design of the dryer; (b) conceptual design of the halogen light bar; (c) 3D design of the final proposed dryer; (d) base part of the dryer with tray and light bars.

According to Figure 1(a) and (b), all major components of the dryer were designed and assembled. The 3D model of the rice dryer was fully completed, with each part, such as the frame, trays, and lamp holders, designed individually to ensure accuracy and compatibility. Once all components were finalized, they were assembled into a complete model to visualize the overall structure and functionality. The design was refined based on insights gained from earlier experiments, allowing for practical improvements in airflow and lamp positioning. Halogen lamps were selected as the heating source due to their high heat output, fast response, and cost-effectiveness, making them suitable for small-scale drying. A power rating of 1000 W per lamp was chosen to achieve rapid heating to the target temperature range while maintaining efficient energy use.

3 RESULTS & DISCUSSION

3.1 Calculation of design

In this study, BG 352 rice was selected as the preferred variety for rice flour production due to its suitability for industrial milling applications (Pathiraje et al., 2010). When evaluating material properties, two key density values were considered: bulk density and true density. The bulk density of rice typically ranges from 0.77 to 0.87 g/cm^3, while the true density, which refers to the mass per unit volume of the rice grain itself (excluding air spaces), ranges from 1.17 to 1.41 g/cm^3. In contrast, bulk density accounts for the air gaps between grains when stored or handled in bulk. For design calculations in this research, the bulk density value was selected and converted to 800 kg/m^3 to suit volume and mass estimations within the drying chamber.

New Tray Area Calculation

1. Volume Needed

$$V = \frac{5kg}{800kg/\text{m3}} \tag{1}$$

$$= 0.00625\,m3$$

2. Tray Area Calculation (for 1.2 cm layer thickness)

$$A = \frac{V}{Layer\ thickness} \tag{2}$$

$$A = \frac{0.00625\,m3}{0.012}$$

$$= 0.520\,m2$$

Possible Tray Dimensions m^3

- 70 cm × 88 cm (0.7 m × 0.9 m)
- 103.6 cm ×0.593 cm (1.036× 0.593 m)

The selected tray is 104 cm × 595 cm (1.04 mm 0.595 mm)

According to Eqs. (1) and (2) calculation was carried out. Accordingly, the total area is = 0.614 m^2. This area is considered as sufficient for the rice in the tray.

3.2 Survey result

To ensure the proposed dryer meets the real needs of end users, a field survey was carried out among small-scale rice farmers and mill operators. The objective was to gather practical insights on current drying methods, common challenges, and typical processing capacities. The data collected from this survey served as the foundation for shaping the design requirements and functional goals of the dryer.

Based on the field survey findings, several important factors related to small-scale rice drying and milling were identified. The typical drying thickness used by farmers was around 1 cm or less, and the average drying time using traditional sun drying methods was approximately 30 minutes. Respondents reported that the average quantity of rice milled per day was around 50 kg, with an individual consumption of about 5 kg per person per session. Additionally, the average temperature of rice before milling was approximately 30°C. When discussing affordability, the survey indicated that the average acceptable cost for a locally built drying machine was around LKR 27,000, making low-cost solutions like the proposed dryer both feasible and relevant for the target users. According to the survey, Authors were able to record different temperature from dry rice samples and the below figure 2 illustrates the survey results of temperatures for four selected subjects.

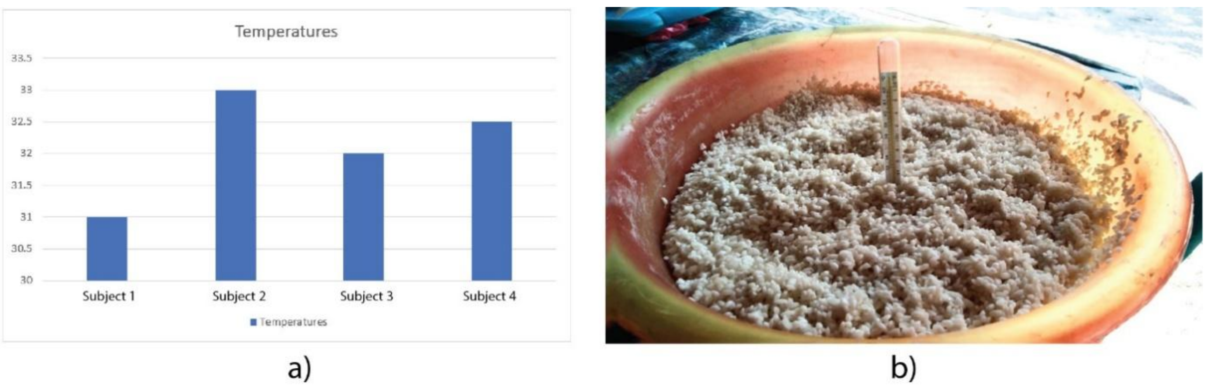

Figure 2. Survey results of temperatures for four selected subjects. (a) Different rice sample temperature levels; (b) method of wet rice temperature measurement.

During the survey, temperature data of wet rice samples were collected from four different locations. It was observed that the temperature varied slightly across areas, ranging from 30°C and 33°C. As shown in Figure 2 (b), the recorded temperatures were used to create a graphical representation, which highlights a maximum temperature of **33°C** and a minimum of 31°C. The measurements were taken using a standard thermometer, as illustrated in Figure 2. (b).

3.3 Experiments and testing

The paragraphs below describe the experiments conducted by the authors to evaluate the performance of halogen lamps in achieving the required drying temperature.

Experiment 01

An experimental setup was prepared to evaluate the heating efficiency of the halogen lamps used in the drying system according to below figure 3(a). In the first experiment, a 1000W halogen lamp was tested, and the setup successfully achieved a maximum temperature of 82°C. These initial results demonstrated the lamp's ability to generate sufficient heat within a short period. Based on this outcome, further experiments are planned to optimize the heating conditions and determine the optimal parameters for efficient, uniform rice drying.

Experiment 02

An experimental setup was developed to evaluate the heating efficiency of the halogen lamps used in the dryer design according to Figure 3. (a). In the initial trial, a 1000W halogen lamp was tested, and the system successfully reached a maximum temperature of 80.7°C, indicating strong heat generation potential according to Figure 3. (b). For this experiment, the ambient room temperature was recorded at 32.5°C according to Figure 3. (d). To simulate actual drying conditions, as shown in figure 3(c), a 100g rice sample was prepared by soaking it in water for 40 minutes, after which the excess water was drained before placing the sample into the insulated test chamber. These preliminary results will guide future experiments focused on optimizing lamp performance and determining the optimal conditions for moisture removal during the drying process.

During heating, temperature measurements were taken at regular intervals to monitor the drying performance. The experiment began by placing the prepared rice sample evenly inside an insulated box, maintaining a uniform thickness of 1 cm across the surface according to figure 3(e). A 1000W halogen lamp was then activated as the heat source. The initial temperature of the box was recorded at 32.5°C, and over the course of 5 minutes, as shown in figure 4(b). The temperature gradually increased. By the end of the heating period, the final temperature reached 68.3°C, indicating a significant and consistent rise in thermal energy within the chamber suitable for the rice drying process.

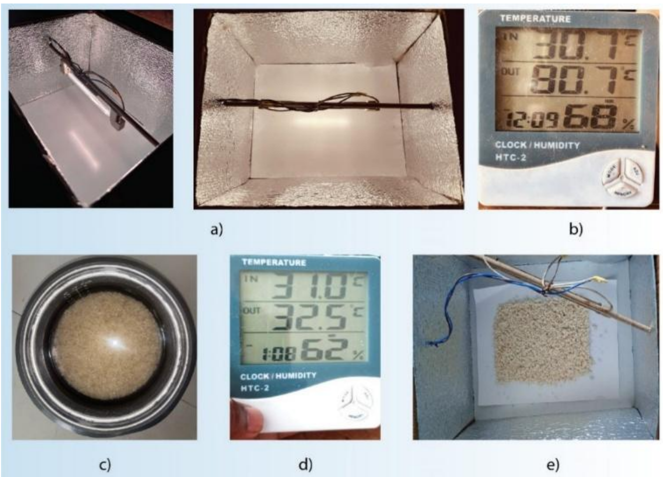

Figure 3. Results of Experiments 1 and 2 (a) Testing the experimental dryer box with different light intensities; (b) experimental box reaching maximum temperature; (c) rice soaking; (d) rice soaking temperature; (e) 1 cm thickness of rice sample during the drying process.

Quality Check

After turning off the halogen lamp, the dried rice sample was manually inspected, as shown in Figure 4. (a) The rice was found to be neither sticky nor wet to the touch, indicating that effective surface drying had been achieved. Based on this manual evaluation, the drying quality was considered satisfactory for the intended application.

Observations & Results

During the experiment, a steady increase in temperature was observed within the first five minutes of operation. The halogen lamp effectively provided sufficient heat for removing surface moisture from the rice sample. No signs of overheating or burning were detected, indicating that the drying process was controlled and safe under the tested conditions.

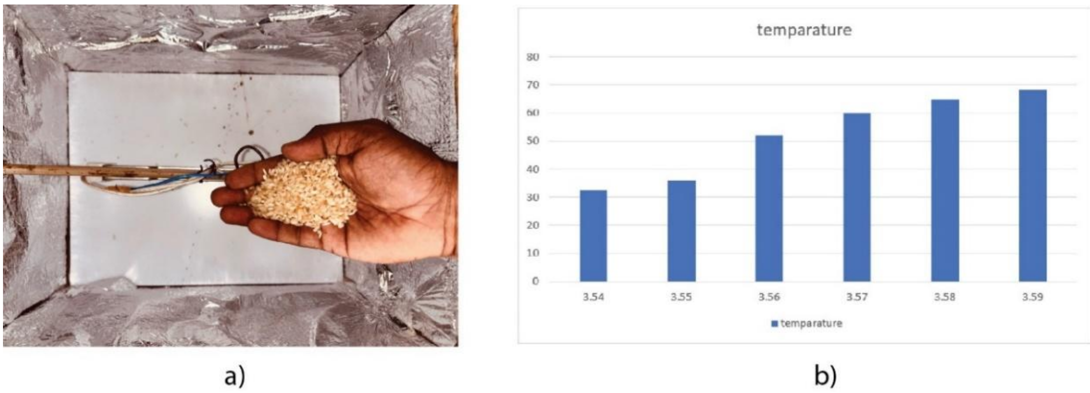

Figure 4.Temperature monitoring results. (a) Inspection of the rice sample after the drying process; (b) temperature changes over time.

3.4 Phototype and Testing

In this experiment, the rice sample was soaked as shown in **Error! Reference source not found.**(c). After soaking, the sample was placed in the experimental box at a thickness of 1 cm, as illustrated in **Error! Reference source not found.**. The halogen lamp was then switched on, and the drying process was initiated while monitoring the temperature using a measuring instrument, as shown in Figure 2(b). Temperature and time readings were recorded and presented in Figure 4(b). After 5 minutes of drying, the condition of the rice sample was examined, as depicted in Figure *4*(a).

Phototype Testing 01

This was the first performance test conducted after the prototype was developed. The aim of this first performance test was to evaluate the dryer's ability to reduce the moisture content of soaked rice efficiently while monitoring temperature and moisture trends. A 100 g rice sample was soaked in water for 1 hour, resulting in an initial moisture content of approximately 40%. The sample, with an initial temperature of 29 °C, was evenly spread on the drying tray Figure *5*(e). Halogen lamps served as the heat source, and temperature and moisture content were continuously measured using a thermocouple and moisture sensor connected to an Arduino Nano. Data were logged in real time to Excel for analysis.

The drying process lasted 18 minutes, during which the temperature increased steadily to 60 °C and the moisture content decreased to an expected 14%. Manual quality checks confirmed that the rice was dry and free from surface moisture Figure *5*(b), and the final moisture content was recorded

Figure 5(c). The complete prototype used in this test is shown in Figure 5(d). The graphical data demonstrated a consistent temperature rise accompanied by a corresponding decrease in moisture, confirming the dryer's effective performance.

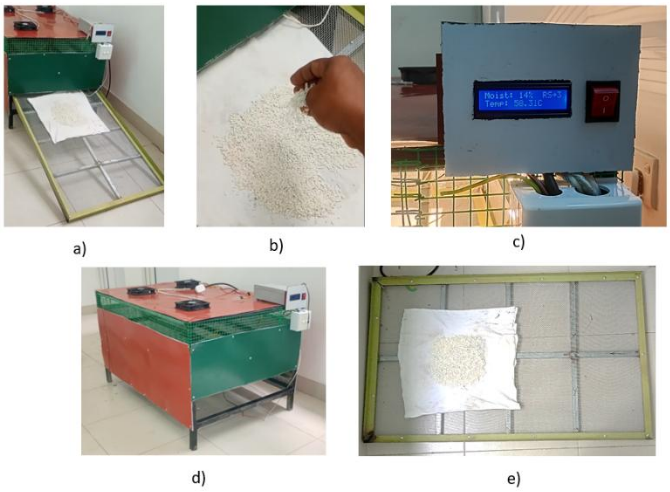

Figure 5.Testing the rice sample on the phototype dryer. *(a) Rice sample on the drying chamber; (b) Quality checking the rice sample;(c) Final moisture content level after drying; (d) Final phototype of dryer; (e) spreading rice sample on dryer*

Phototype Testing 02

Following the initial prototype evaluation, a second performance test was carried out to assess the dryer's operation under full-load conditions. In this test, a 5 kg rice sample was soaked in water for 2 hours **Error! Reference source not found.**(d). After soaking, the water was drained, and the rice was evenly distributed on the drying tray **Error! Reference source not found.**(c). The initial temperature and moisture content were recorded as 29 °C and 42%, respectively. The drying process was initiated using four halogen lamps as the heat source. Temperature and moisture content were continuously monitored using a thermocouple and a moisture sensor connected to the Arduino Nano, with real-time data logging to Excel. The process continued until the moisture content reached the target range of 14%.

The total drying time recorded was 42 minutes, during which the temperature rose steadily while the moisture content decreased, as shown in ***Error! Reference source not found.***(b). A manual quality check was conducted at the end of the process, **Error! Reference source not found.**(a), confirming that the rice was dry, non-sticky, and suitable for milling. This test demonstrated that the dryer maintained effective performance and drying uniformity even under maximum load conditions.

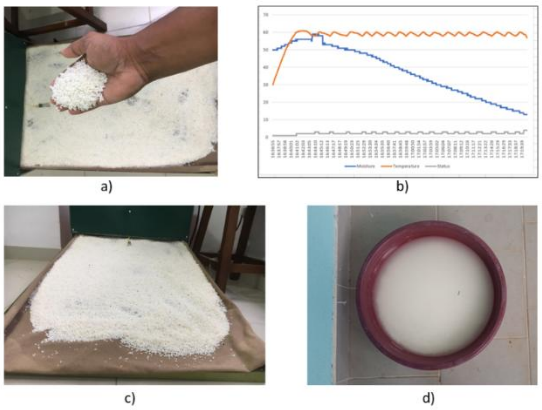

Figure 6: Testing the rice sample of maximum capacity (a) checking the drying quality of rice sample; (b) Temperature vs moisture content graph; (c) Place the rice on drying tray; (d) soaking rice sample

3.5 Simulation of Drying Tray

To ensure the structural integrity of the drying tray, a simulation was carried out using SolidWorks simulation tools. The tray was modelled using steel material, with a 50 N force applied to simulate the load during drying, and fixed supports at the rail positions to reflect actual mounting conditions. As illustrated in Figure 7(a), the setup accurately represented the tray's behavior under stress. The simulation yielded a maximum stress of 98,530 N/m², well below the steel's yield strength, confirming the structural safety of the design. The maximum displacement observed was 0.275 mm, and the strain was minimal. The detailed results are shown in the displacement diagram Figure 7(b), strain distribution diagram Figure 7(c), and stress diagram Figure 7(d**)**. These results confirm that the tray design is both stable and mechanically suitable for use in the drying system.

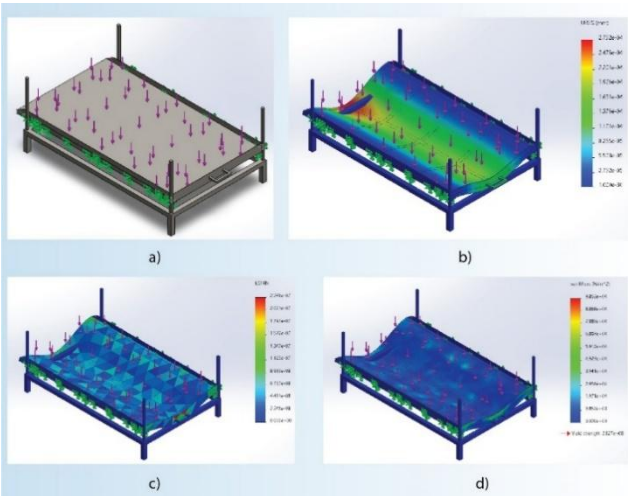

Figure 7. Finite Element Analysis (FEA) of the dryer tray. (a) Force distribution on the tray; (b) displacement results; (c) strain results; (d) stress results.

4 CONCLUSION & FUTURE WORK

This study presented the design and development of a cost-effective wet rice dryer to address the practical issues faced by small-scale rice processors. The system was designed with simplicity, affordability, and functionality in mind. It uses halogen lamps as the heat source and features a manually accessible tray system for ease of use. Field surveys confirmed the need for such a device, especially in rural areas where weather-dependent drying methods often lead to grain loss and reduced milling efficiency.

Initial experiments showed that the prototype could reach the required drying temperatures in a short time, and the drying quality met acceptable standards during manual evaluation. Based on these outcomes, further enhancements are planned, including optimizing drying efficiency and increasing drying capacity to meet larger processing demands. Additionally, the current quality assessment method after drying relies on manual evaluation; future work will focus on developing an objective, measurable quality detection system. Other improvements will include adding controlled airflow using exhaust fans and integrating moisture sensors to automate the drying process more precisely. Additional testing with larger samples will also be carried out to evaluate performance and long-term reliability. Overall, this system shows promise as a practical and affordable solution for improving post-harvest rice handling at the small-scale level.

5 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of all lecturers and laboratory technicians of the Department of Mechanical and Manufacturing Technology, Faculty of Technology, Wayamba University of Sri Lanka, in completing this work. Furthermore, the authors express their sincere gratitude to the editors and anonymous reviewers for their insightful suggestions and constructive comments, which have greatly improved the quality of this research paper.

REFERENCES

Bennamoun, L., & Belhamri, A. (2003). Design and simulation of a solar dryer for agriculture products. *Journal of Food Engineering*, *59*(2–3), 259–266. doi: 10.1016/S0260-8774(02)00466-1

Bunyawanichakul, P. (2006). *DEVELOPMENT OF A CYCLONE RICE DRYER*.

Chua, K. J., & Chou, S. K. (2003). Low-cost drying methods for developing countries. In Trends in Food Science and Technology (Vol. 14, Issue 12, pp. 519–528). Elsevier Ltd. doi: 10.1016/j.tifs.2003.07.003

Dissanayaka, D. M. S. K., & Wijayaratne, L. K. W. (2020). Common Agricultural Practices and Post-Harvest Losses in Trincomalee, Sri Lanka. In Journal of Tropical Forestry and Environment (Vol. 10, Issue 02).

Introduction of Rubber Roller Milling Machine for Improving the Domestic Milled Rice Quality. (n.d.). Retrieved from https://www.researchgate.net/publication/380929315

Kim, M. H. (2013). Review on Rice Flour Manufacturing and Utilization. *Journal of Biosystems Engineering*, *38*(2), 103–112. doi: 10.5307/jbe.2013.38.2.103

Mihret, Y. C., Delele, M. A., & Hailemesikel, S. T. (2023). Design, development, and testing of rice-husk fueled mixed-flow rice dryer for small-scale rice producer farmers. *Heliyon*, *9*(7). doi: 10.1016/j.heliyon.2023.e18077

Nath, B., Chen, G., O'Sullivan, C. M., & Zare, D. (2024). Research and Technologies to Reduce Grain Postharvest Losses: A Review. In Foods (Vol. 13, Issue 12). Multidisciplinary Digital Publishing Institute (MDPI). doi: 10.3390/foods13121875

Pathiraje, P. M. H. D., Madhujith, W. M. T., Chandrasekara, A., & Nissanka, S. P. (2010). The Effect of Rice Variety and Parboiling on in vivo Glycemic Response. In Tropical Agricultural Research (Vol. 22, Issue 1).

Thakur, A., Singh, A., & Bharat, N. K. (2024). Conservation and development of rice germplasm for natural farming. In Climate-Smart Rice Breeding (pp. 45–61). Springer Nature. doi: 10.1007/978-981-97-7098-4_3

Wang, Y. J., Li, Y. F., Pan, S., Qin, M. Y., Yuan, Y. D., Yuan, W. J., & Li, C. (2025). Rice drying quality using gas-catalytic infrared equipment: an experimental study. *IOP Conference Series: Earth and Environmental Science*, *1500*(1), 012047. doi: 10.1088/1755-1315/1500/1/012047

Xangsayasane, P., Vongxayya, K., Phongchanmisai, S., Mitchell, J., & Fukai, S. (2019). Rice milling quality as affected by drying method and harvesting time during ripening in wet and dry seasons. *Plant Production Science*, *22*(1), 98–106. doi: 10.1080/1343943X.2018.1544463