Experimental Performance of a Passive Greenhouse Solar Dryer for Paddy

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Abstract- *Sun drying is a popular post-harvest operation to maintain the quality of rice during the storage period. Farmers use different treatments and thicknesses for sun drying of paddy in Ampara district, Sri Lanka. A study was conducted to evaluate the drying treatments' suitability and effectiveness as practiced by local paddy farmers during the drying process. The grain with an initial moisture content of 28% (dry basis) was sun-dried with three types of drying treatment and three levels of thickness of grain. This experiment was conducted between 8.30 am and 4.30 pm at the South Eastern University of Sri Lanka in August 2020. Two dryers were fabricated, and it was found that the duration of drying of paddy from 28% to 13% moisture content on a dry basis was 300 to 660 minutes depending upon the drying treatments and thickness. The thermal storage greenhouse dryer is reasonable at shallow thickness with less time to reach the necessary moisture level than other drying treatments. A thermal storage greenhouse can be utilized for drying paddy at 4 cm thickness for 420 minutes. It was found that with an increase in the thickness of paddy from 2 cm to 6 cm, the drying time increases. A statistically significant interaction was obtained between drying treatments and thickness level on moisture removal of paddy. Therefore, the moisture removal rate differs from the paddy's drying treatments and thickness under thermal storage passive type greenhouse.*

Keywords: drying, drying rate, thickness, moisture

I. INTRODUCTION

Dying is a method that reduces grain wetness content to a level wherever it's safe for storage. Drying is the most crucial operation once gathering a rice crop. Delays in drying, incomplete drying, or ineffective drying can reduce grain quality and lead to losses. Drying and storage connected processes and might typically be combined in-store drying. Storage of incompletely dried grain with the next than acceptable wetness content can fail what storage facility is employed. Additionally, the longer the required grain storage amount, the lower the specified grain wetness content should be 14% (Purohit, Kumar and Kandpal, 2006). Solar drying involves the drying of the product inside a closed structure. The top surface of the drying is made transparent so that the radiations can be absorbed (Bala and Debnath, 2012) Various sorts of solar dryers are designed, developed, and tested within entirely different countries' regions for drying paddy. The two most dryers are natural convection dryers and compelled convection dryers. The air circulation is established by buoyancy induce air circulation and compelled convection dryers within natural convection dryers. The air circulation is provided by fan-operated either by electricity module or fossil fuels. Solar thermal technology may be a technology that is speedily gaining acceptance as associate energy-saving measures in agriculture applications. It is most well-liked to different alternative sources of energy like wind and sedimentary rock due to its inexhaustible, most popular, and non-polluting. Solar air heaters are simple devices to heat air by utilizing alternative energy. It is being used in several applications requiring low to moderate temperature 80°C, like crop drying and air heating (Fudholi *et al.*, 2018).

The effectiveness of drying varies because of many factors like selection, gathering strategies, initial and final wetness substance, and drying strategies(Iguaz *et al.*, 2003). Sun-drying will increase the broken rice rate at the edge of the grain temperature gets to a high fault (Iguaz *et al.*, 2003). Among these factors, the ultimate wetness substance could be an essential issue deciding the self-life of rice throughout storage and alternative post-harvest practices because respiration within the grain at high grain status causes deterioration. High wetness content promotes the persecutor and malady attack within the grain. In distinction, if the wetness content in paddy is simply too low, the grains thus fragile once being polished. This could result in a better fraction of broken kernels. Keeping the paddy at acceptable wetness content will prolong storage time and forestall mould growth (Cheenkachorn, 2007). Therefore, the desired wetness content is 12-14% for storage and 10-13% for an edge.

The thickness of paddy on the drying surface is another essential factor that determines the moisture removal of paddy. Most farmers are practicing different thickness levels according to the quantity of paddy, weather conditions, and availability of the labor without an understanding of the drying performances. Too thin layers tend to heat up very quickly, negatively affecting the head rice recovery. On the other hand, deep layers create dry grains on the top and wet grains on the base, which re-adsorbs moisture on subsequent stirring leads to high broken grains (Iguaz *et al.*, 2003)Thus, the paddy has to be dried in optimum thickness during the sun drying operation. Paddy is dried with different conditions in the Ampara district, one area with higher paddy production in Sri Lanka. Different drying treatments and thicknesses have been used traditionally depending on the quantity, labor availability, and surface area. However, the performance of drying under these conditions has not been studied. Therefore, the objectives of this study were to determine the suitable drying treatments and the optimum drying depth during sun-drying methods practiced by local paddy farmers in the Ampara District. To determine suitable drying techniques and the optimum drying thickness during sun drying, greenhouse without thermal drying, and greenhouse with thermal drying.

II. RESEARCH METHODOLOGY

A. *Sample collection and experimental site*

Freshly harvested paddy varieties AT 362 and BG94-1 commonly grown in the region were used in this study. Paddy harvested by combine harvester was procured from the paddy field at Malwaththa farm at Ampara district, Sri Lanka, during the *Yala* season. The grain sample was immediately transported from the paddy field to the experimental site. Without thermal storage bed and thermal storage bed, the sun-drying experiment was conducted between 8.30 am to 4.30 pm in February 2021 at the South Eastern University of Sri Lanka. (7°18'00.3"N and 81°51'41.8"E)

B. *Experimental design*

The different drying treatments were identified based on the open sun drying, without thermal storage bed and thermal storage bed greenhouse. This experiment was designed as a factorial randomization complete block design with different drying varieties and different drying thickness with three replications. Three levels of grain thickness, 2cm, 4cm, and 6cm, were prepared within one-meter square (1m^2) wooden frames, and AT 362 and BG94-1 used as different varieties.

C. *Development of solar greenhouse dryer*

A greenhouse with an effective floor coverage of 4 m^2× 5 m^2 was constructed of PVC pipe and a UV film covering. After, an air vent was provided at roof level with a compelling opening of 0.4 m^2 for natural convection. The greenhouse was kept at an east-west orientation during the experiments. After constructing the solar greenhouse dryer, the thermal storage unit is stored inside the dryer to maximum efficiency. The sand was used as a sensible heat storage material. Sensible storage is the most robust and easiest to set up, so it appears better adapted to the technical constraints in Sri Lanka. Furthermore, this type of technology is the most suitable for this particularly isolated region, based on locally available materials. Indeed, sensible storage media can include water, rocks, or even soil in the case of a geothermal field (Bala and Debnath, 2012).

D. *Sand storage*

The sand were put inside the greenhouse dryer. The length of the drying bed was 3 m, the height of the sand bed was 12 cm, and the width of the drying bed was 2 m. Black soil were used for the experiment because it absorbs more heat during the daytime. The drying area was made with 1 m^2 wooden frames and high-density polyethylene bags.

E. *Data collection*

To analyze the performance of the proposed system, various parameters were calculated, including moisture content, temperature, and relative humidity. The moisture content of the grain was measured hourly using a calibrated digital grain moisture meter (model: LDS-1H) after stirred by hand raking. The atmospheric temperature and relative humidity were recorded at one-hour intervals during the drying. All the experiments were carried out in triplicate.

F. *Data analysis*

All data were subjected to analyze the variance and significant differences (0.05) among the treatments using SPSS version 26 for windows and R software

III. RESULTS AND DISCUSSION

A. Effects of different level of thickness on moisture removal with two varieties of paddy

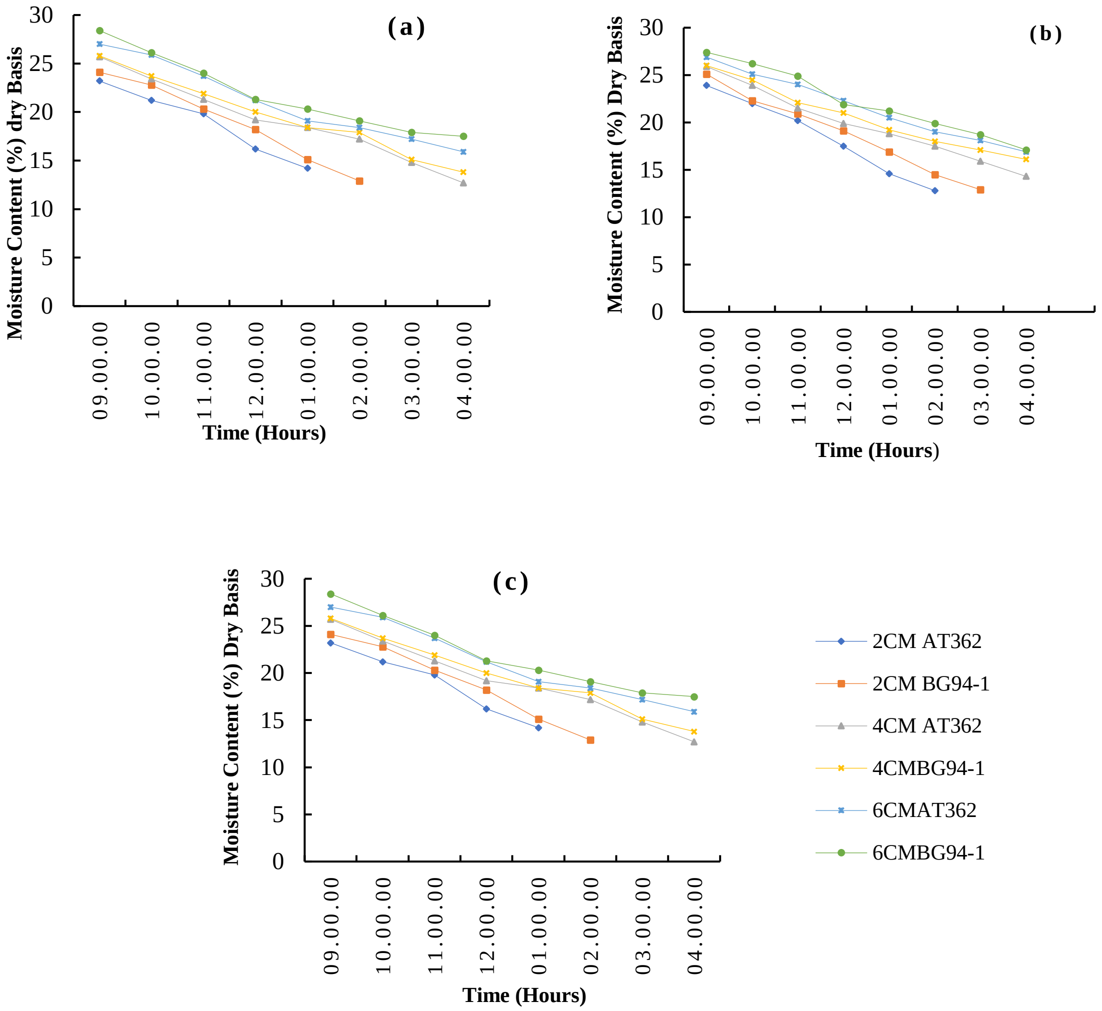

Figure 01: Moisture removal with different level of thickness (a) open sun drying, (b) greenhouse without thermal, and (c) greenhouse with thermal

This study has shown that drying AT362 paddy variety at 2cm thickness presented the best mill recovery, whole variety, and thickness levels. However, drying the paddy at these thicknesses takes (5hours) to reach the final moisture content. This becomes evidence because paddy dried at these drying thicknesses experienced the lowest fissure level. Farmers are busy on the farm and in their families, and hence, such an extended drying time may not be acceptable. This research continued with the research work to reduce the drying time of paddy. The paddy was dried at 2cm, 4cm, and 6cm in thickness. Results show that reduced thickness took less drying time to reach the 14 % (dry basis) final moisture content. There is no significant variation in the moisture content change of paddy variety using AT362 and BG94-1 in all the thickness levels. All paddy depths received the same quantity of solar radiation per unit area. At the same time, the deeper thickness needed more time to reach the recommended milling moisture content.(Nguyen-Van-Hung *et al.*, 2019) Reported that 7 to 8 days of drying is required for 7cm thickness. A similar study conducted in the Philippines said that the recommended paddy drying thickness using the open sun drying method is 2 to 4 cm. Therefore, a suitable thickness of drying paddy and efficient drying rate in open sun drying, greenhouse without thermal and greenhouse with thermal drying was 2cm thickness with AT362 variety.

B. Effects of different drying treatments on moisture removal with two varieties of paddy

paddy and moisture content change also showed not significant (p=0.273) interaction with moisture content change in this experiment. That means the difference in mean moisture content

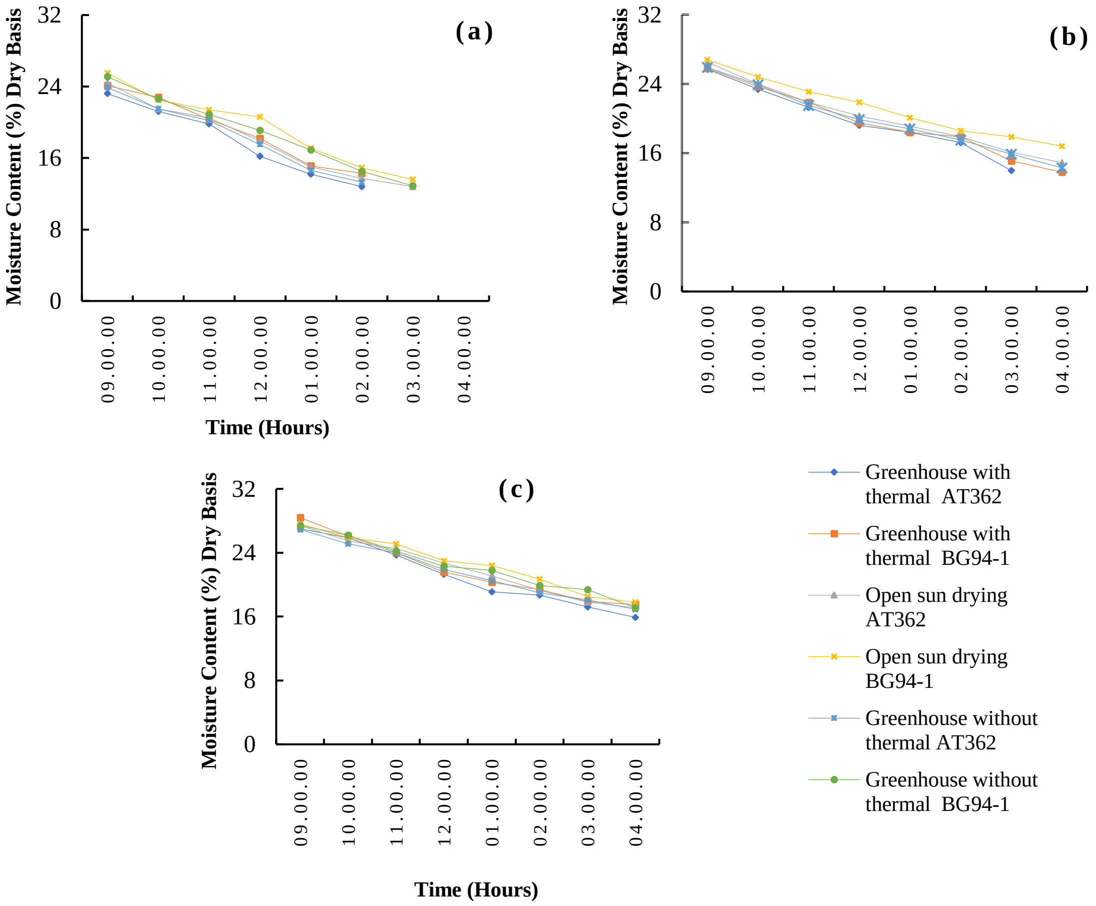

Figure 02: Different drying treatments on paddy moisture removal

C. Interaction effects of drying treatments, thickness, and time on moisture removal

Interaction effect of paddy varieties (AT 362 and BG 94-1), thicknesses (2cm, 4cm, and 6cm), and treatments (open drying, greenhouse without thermal storage and greenhouse with thermal storage) after moisture content change in four hours (day 1 9.00 am to 1.00 pm). Interaction between drying treatments and thickness on moisture content change was found as significant (p=0.000). The relationship between thickness and moisture content change also showed a significant ($p<0.05$) interaction with moisture content change. And the relationship between drying treatments and moisture content change also showed a significant (p=0.039) interaction with moisture content. Similarly, the relationship between a variety of paddy and moisture content change also showed not significant (p=0.273) interaction with moisture content change in this experiment relationship between a variety of change in paddy variety between AT 362 and BG 94-1 (p=0.207). The postdoc test using Duncan's multiple range (alpha= 0.05) results indicated no significant variation in the moisture content change using different treatments open drying, greenhouse without thermal storage, and greenhouse with thermal storage. Similarly, there was no significant variation in the moisture content change of paddy variety using AT 362 and BG 94-1 in all the thickness levels. Therefore, different drying treatments and thickness levels showed the moisture content change under 2 cm thickness and paddy variety AT 362.

D. Effect of atmospheric temperature and relative humidity for paddy drying

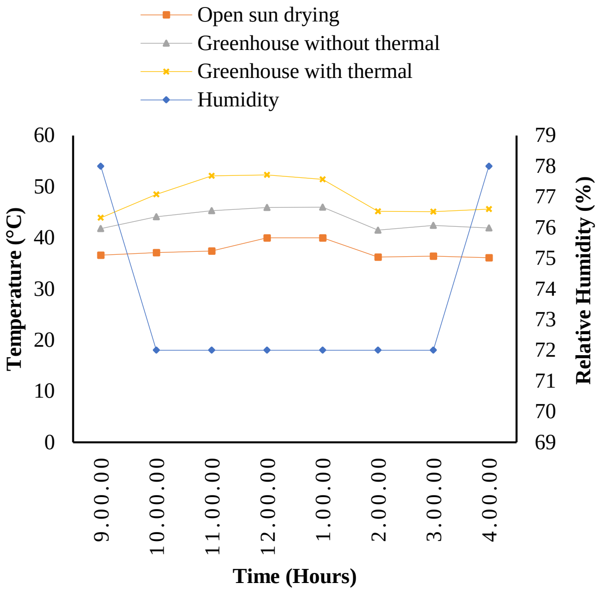

Figure 03: Variation of atmospheric temperature and relative humidity

The variation of atmospheric temperature in the experimental site during the sun drying, greenhouse without thermal, and greenhouse with thermal drying operations were recorded. Accordingly, temperature ranges between 29°C - 60°C, respectively. Around 12% of moisture content was removed from the paddy between 9.00 am to 4.00 pm in the treatments. If it is zero in larger populations, there is an 0% probability of finding this in the sample. The results demonstrated a significant effect of a greenhouse without thermal temperature compared to open sun drying temperature. The main reason for fast initial moisture removal before noon was due to high atmospheric temperature and low relative humidity in the experimental site. This was supported by (Pirasteh *et al.*, 2014) was external wetness would readily evaporate when the paddy is open to hot air. Still, interior moisture evaporates gently as it has to transfer away from the kernel to the exterior due to surface forces. According to (Panyoyai, Wongsiriamnuay and Khamdaeng, 2014), the mechanism of water evaporation in the material occurs through heat and mass processes simultaneously. The time is taken to reach the paddy's required moisture content ranges from 5 to 9 hours, depending on the air temperature in the experimental site. Better temperature regulation was achieved in the dryer with thermal storage greenhouse. When the solar intensity radiation was low at the end of the day, a near about constant was performed in the greenhouse thermal storage drying. This is a fact due to the release of sensible energy. In this study greenhouse, thermal storage drying was found suitable with less time to attain the required temperature level than open sun drying and greenhouse without thermal storage.

IV. CONCLUSION

Drying performance significantly varies with the drying treatments and thickness of the paddy. The time requirements to reach the required moisture content with a greenhouse with thermal and greenhouse without thermal were 240 to 720 minutes, respectively from 28% initial moisture content (dry basis). Greenhouse with thermal was found suitable at shallow thickness with a less amount of time compared to other drying treatments. In contrast, open sun drying treatment is not suitable for the high thickness of paddy. The time required to reach the required moisture content has increased with the increasing thickness level open sun drying, greenhouse with thermal and greenhouse without thermal treatments. There is no significant trend observed in open sun drying and greenhouse without thermal treatments with thickness. Greenhouse without thermal and greenhouse with thermal can be used for sun drying of paddy at 6 cm thickness with 240 minutes' duration under a sunny day. A statistically significant interaction was obtained between drying treatments and thickness level on moisture removal of paddy. The performance of existing solar dryers can still be improved upon especially in the aspect of reducing the drying time and probably storage of heat energy within the system by increasing the size of the solar collector or base area. Also, meteorological data should be readily available to users of solar products to ensure the maximum efficiency and effectiveness of the system. Technical improvement is necessary; the Capacity of the drier needs to be increased and should be affordable to the farmers. The electrical energy produced by solar panel can be used when sunlight is not available and temperature sensor and moisture sensor can be used which can control over heating of paddy.

REFERENCES

Bala, B. K. and Debnath, N. (2012) 'Solar Drying Technology: Potentials and Developments', *Journal of Fundamentals of Renewable Energy and Applications*, 2, pp. 1–5. doi: 10.4303/jfrea/r120302.

Cheenkachorn, K. (2007) 'Drying of rice paddy using a microwave-vacuum dryer', *In proceedings of Euro Congress Chemical Engineering Copenhagen,* (September), pp. 16–20.

Fudholi, A. *et al.* (2018) 'Solar Drying Technology in Indonesia: an Overview', *International Journal of Power Electronics and Drive Systems (IJPEDS)*, 9(4), p. 1804. doi: 10.11591/ijpeds.v9.i4.pp1804-1813.

Iguaz, A. *et al.* (2003) 'Modelling effective moisture difusivity of rough rice (Lido cultivar) at low drying temperatures', *Journal of Food Engineering*, 59(2–3), pp. 253–258. doi: 10.1016/S0260-8774(02)00465-X.

Nguyen-Van-Hung *et al.* (2019) 'Best practices for paddy drying: case studies in Vietnam, Cambodia, Philippines, and Myanmar', *Plant Production Science*, 22(1), pp. 107–118. doi: 10.1080/1343943X.2018.1543547.

Panyoyai, N., Wongsiriamnuay, T. and Khamdaeng, T. (2014) 'Experimental study on the thermal performance of thermosyphon heat exchanger for rough rice drying', *International Conference on Science, Technology and Innovation for Sustainable Well-Being*, 6(January).

Pirasteh, G. *et al.* (2014) 'A review on development of solar drying applications', *Renewable and Sustainable Energy Reviews*, 31, pp. 133–148. doi: 10.1016/j.rser.2013.11.052.

Purohit, P., Kumar, A. and Kandpal, T. C. (2006) 'Solar drying vs. open sun drying: A framework for financial evaluation', *Solar Energy*, 80(12), pp. 1568–1579. doi: 10.1016/j.solener.2005.12.009.