Original Article

Comparative Investigation on Drying Efficiency of the Solar Dryer Using Iron as the Absorber Plate Against the Stainless Steel Absorber Plate for Drying Copra

Qadir Hasbi K M A[1], T. Shaafi[2]

[1]Research Scholar, Department of Agricultural Engineering, Saveetha School of Engineering, Saveetha Institute of Medical And Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India, Pincode: 602105.
[2]Project Guide, Department of Agricultural Engineering, Saveetha School of Engineering, Saveetha Institute of Medical And Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India, Pincode: 602105.

Abstract

Aim: To study and compare the drying efficiency of stainless steel with iron as the absorber plate for drying coconut. **Materials and Methods:** The sample size for the groups were determined as 20 for each group, a total of 40 for the groups using a simple sample size calculator, with G power of 80% by keeping threshold 0.05, confidence interval 95% and enrollment ratio as 1. Coconut samples placed on stainless steel absorber plate are depicted as the control group, and the coconut samples placed on iron absorber plate are the experimental group. The coconut samples were collected from the solar dryer setup after drying for two days and the moisture content of both the groups were determined using a hot air oven with formula. **Results:** The results show that the mean reduction value of moisture content for iron is 23.98%, whereas the reduction value of moisture content for stainless steel is 30.77% for coconut samples. The independent samples t-test was done which revealed that both the groups are statistically significant with p value of 0.046 for the reduction of moisture content. **Conclusion:** The evaluation of the drying efficiency in terms of moisture content reduction for iron and stainless steel as the absorber plate was experimentally studied and found that the novel iron absorber plate has lower drying efficiency than stainless steel absorber plate.

Keywords: Solar dryer, Copra, Stainless Steel, Novel Iron Absorber Plate, Moisture Content, Drying Efficiency.

DOI: 10.47750/pnr.2022.13.S04.098

INTRODUCTION

The aim of this study is to compare and analyse the drying efficiency of the iron and stainless steel absorber plate in drying coconut. One of nature's wonders is the coconut tree which is also praised as kalpavriksha in India (Ahuja, Ahuja, and Ahuja 2014). In the world, India holds the third place in coconut cultivation after the Philippines and Indonesia, from which nearly 30% of the coconut is processed into copra to extract coconut oil (Deepa et al. 2015). As the demand and price for coconut varies, it's vital to add value and extend their shelf life to avoid deterioration, it is done by a process called drying, which removes the product's moisture content thereby preventing spoilage (Alonge and Adeboye 2012). Coconut oil has a number of uses in food, toiletry, industrial and other applications (Joshi et al. 2020). The process of drying demands a significant quantity of energy. Hence using solar energy for drying reduces the need and utilization of non-renewable sources of energy (Nukulwar and Tungikar 2021). Replacing solar energy in the field of drying eliminates the use of conventional sources of energy by 27% - 80% (Ayyappan 2018). The solar dryers which are used for agricultural products are proven to be the most energy efficient ones (Kumar, Sansaniwal, and Khatak 2016).

176 and 596 research articles were published in Science direct and Google scholar respectively. The most cited articles suggested the following datas regarding open solar drying and a solar dryer. The quality of copra dried at different temperature in a cabinet drying were analysed and compared with open sun drying and it was found that the copra dried at 70°C gives an oil yield of 67% whereas the least amount of oil yield was given by the copra dried at 90°C of 40.1% and sun dried copra gave an oil yield of 63.1% (Deepa et al. 2015). The heat transfer coefficient value for different crops such as green peas, onion, potato slices, green chillies etc based on linear regression techniques and experimental datas were found which is used for designing a dryer (Anwar and

Tiwari 2001). For the manufacture of high quality copra, the drying properties and quality of copra produced in a natural circulation solar tunnel dryer were investigated and the copra quality was found to be 84.66% milling copra grade 1 when compared to open sun drying which was 53% (Ayyappan and Mayilsamy 2010). A kiln is constructed according to the CRI specification, the test performance is evaluated for the constructed kiln and compared with open sun drying which resulted in the following conclusion: 1. Open solar drying is appropriate for small holders which receive more solar radiation and have a lengthy day time, 2. Kiln drying is applicable for large scale processing, 3. In comparison to kiln drying, open solar drying led to a lower net loss, 4. Relatively open sun drying has high drying efficiency (Thanaraj, Dharmasena, and Samarajeewa 2007). The several thermal factors of open solar drying of crops like green peas, onions, cauliflower, potatoes, white gram and green chillies were investigated (Jain and Tiwari 2003). Among the most cited articles the best article is “Quality Analysis of Copra Dried at Different Drying Air Temperatures” (Deepa et al. 2015).Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar et al. 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021)

Based on the existing literature study, the following problems such as poor drying efficiency, poor quality of dried food products, and an energy intensive drying process were identified. Hence the aim of this study is to compare the novel iron absorber plate with stainless steel absorber plate for its drying efficiency of coconut which helps the copra traders and farmers in choosing the right absorber plate material for the solar dryer.

Materials And Methods

In an attempt to compare the drying efficiencies of the two absorber plates namely stainless steel and iron, a solar dryer setup was constructed and kept under the meteorological conditions of Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai (latitude 13.02°N, longitude 80.01°E). The moisture content of the samples was tested in the highway engineering laboratory at Saveetha School of Engineering using a hot air oven. The sample size was taken as 20 which is calculated using a simple clinic sample size calculator with 80% G power by keeping threshold as 0.05 and confidence interval as 95%. This calculation was made using outcomes previously done by the researchers (Mohanraj 2014).

For the purposes of comparison two groups were chosen, namely control group and experimental group. The control group was the coconut samples kept in an iron absorber plate and the experimental group was the coconut samples kept in the stainless steel absorber plate in the solar dryer setup and it was allowed to dry for 48 hours.

The solar dryer experimental setup was constructed using chlorinated polyvinyl chloride (CPVC) pipes of inner diameter 76 mm. Appropriate pipe fittings like tee, elbow and three way joints were used. The framework's dimensions were of length 760 mm, breadth 380 mm and height 915 mm. The dimensions of stainless steel and iron absorber plates are of length 305 mm, breadth 305 mm and thickness 1 mm. The external attachment was fitted in the framework to hold the reflecting mirror. The framework was covered with a transparent polycarbonate sheet of thickness 6 mm. The photographic image of the solar dryer setup is shown in Figure 1. This dryer uses solar radiation as the one and only source for energy and works on greenhouse effect. Greenhouse effect inside the dryer is created with the help of polycarbonate sheets (Udomkun et al. 2020).

High quality coconuts were split open into two, the coconut water was removed, and the coconut samples were kept in the iron and stainless steel absorber plate. The photographic image shows the moisture content of the coconut samples that were determined using a hot air oven as shown in Figure 2. The moisture content of the fresh sample and dried samples was obtained using a hot air oven by the following steps. Firstly the initial weight (Wi) of the samples were noted, then the samples were kept in the hot air oven for 6 hours with the temperature maintained constantly at 130℃, and then the final weight(Wf) of the samples were taken. Finally with the help of the obtained data the moisture content was calculated using the following equation (1) (Mohanraj and Chandrasekar 2009).

$$Wet\ basis\ moisture\ content\ (Mwb) = \frac{(Wi-Wf)}{Wi} \times \mathbf{100} \qquad (1)$$

The moisture content of fresh and dried samples were taken as initial and final moisture content respectively (Deepa et al. 2015). The value of reduction in moisture content is calculated by subtracting the final moisture content from the initial moisture content it was tabulated in Table. 1

Statistical analysis

SPSS v.26 statistical software was used to calculate mean, standard deviation and standard error. In total 20 readings were taken for analysing each group in order to achieve 95% confidence level with P value <0.05. In this work independent variables used are the two types of absorber plates taken for study and the dependent variable is moisture content reduction (%). Independent sample t-test was used to analyse the outcomes of this study.

Results

The calculated reduction in moisture content value of the coconut samples by iron and stainless steel absorber plates are shown in Table 1. Mean, standard deviation and standard error mean values are shown as group statistics in Table 2. From the table it is observed that the mean reduction value of moisture content of the coconut samples for iron is 23.98% and for stainless steel it is 30.77%. The independent samples t-test was performed and it was represented in Table 3 which shows that both the groups are statistically significant with p value (0.046) for the reduction of moisture content.

Figure 1 illustrates the photographic image showing coconut samples placed in iron and stainless steel absorber plate in the solar dryer setup. Figure 2 shows the Photographic image showing the moisture content of the coconut samples that were determined using a hot air oven. A bar chart is used to depict the comparison of the value of reduction in moisture content of coconut samples by iron and stainless steel as the absorber plate in terms of mean and standard deviation as shown in Fig. 3.. Stainless steel absorber plate has better mean value than iron absorber plate whereas iron has better standard deviation.

Discussion

It is observed from the result that the moisture content of coconut was effectively reduced by stainless steel absorber plate in comparison with iron as the absorber plate. The reason for the poor drying efficiency of novel iron absorber plate is its high thermal conductivity due to which iron conducts heat through it rather than absorbing and supplying it to the coconut samples (Carvill 1993). On the other hand, the stainless steel absorber plate has lower thermal conductivity due to which the heat is restored and supplied to the coconut samples, thereby having better drying efficiency than iron absorber plate. This study has a fischer value of 4.275 and a significance value of 0.046 which shows that there is a wide variation between the two groups.

The thermal performance of solar air heaters with galvanised iron and glass as the absorber plate were studied and found that the thermal efficiency of galvanised iron is 9.4% lesser than glass absorber plates (Arunachalam and Edwin 2017). The thermal efficiency of solar air heaters with different solar panel absorbent namely stainless steel, aluminium and iron were studied and evaluated which showed that the stainless steel absorbent plate have higher thermal efficiency than iron and aluminium absorbent plates (Fouda, Darwesh, and ELhosary 2018). The above mentioned two research articles suggest that the iron absorber plate has poor drying efficiency which is in line with our study. The yield obtained from solar still having three different absorber plates made up of Copper, galvanised iron and mild steel were compared which showed that the yield for mild steel absorber plate is very low when compared with the other two absorber plates (Panchal 2010). The addition of iron mesh to the absorber plate has increased the efficiency of the collector by 10% (Güler et al. 2020). The above mentioned research article says that iron absorber plate has increased the drying efficiency which is not in line with our study.

In this study the limitations are unpredictable climatic conditions and the monsoon season during which the experiment is conducted. The scope of this study is to help the researchers to know about the drying efficiency of iron and stainless steel absorber plate and to give insight about it to explore further on their drying efficiency at different climatic conditions.

Conclusion

Coconut drying experiment was performed with a solar dryer setup with two different absorber plates which were made up of iron and stainless steel. The performance of the absorber plate in reducing the moisture content of the coconut samples were evaluated and the mean values of the moisture content reduced were found to be 23.98% for iron and 30.77% for stainless steel. It is concluded that the performance of novel iron absorber plate has lower drying efficiency than stainless steel absorber plate for drying coconut.

DECLARATIONS

Conflict of interest

No conflict of interests in this manuscript.

Author contributions

Author (QHKMA) was involved in the construction of experimental setup,sample collection, data analysis and manuscript writing. Author (TS) was involved in processing the idea, data verification, and critical review of the manuscript.

Acknowledgements

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding: We thank the following organizations for providing financial support that enabled us to complete the study.

1. Solar Nest Agro Products.
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha School of Engineering.

References

1. Ahuja, S. C., Uma Ahuja, and Siddharth Ahuja. 2014. "Coconut-History, Uses, and Folklore." *Asian Agri-History* 18 (3).
2. Alonge, A. F., and O. A. Adeboye. 2012. "Drying Rates of Some Fruits and Vegetables with Passive Solar Dryers." *International Journal of Agricultural and Biological Engineering* 5 (4): 83–90.
3. Anwar, S. I., and G. N. Tiwari. 2001. "Evaluation of Convective Heat Transfer Coefficient in Crop Drying under Open Sun Drying Conditions." *Energy Conversion & Management* 42 (5): 627–37.
4. Arunachalam, U. P., and M. Edwin. 2017. "Experimental Investigations on Thermal Performance of Solar Air Heater with Different Absorber Plates." *International Journal of Heat and Technology* 35 (2): 393-397.
5. Ayyappan, S. 2018. "Performance and CO2 Mitigation Analysis of a Solar Greenhouse Dryer for Coconut Drying." *Energy & Environment* 29 (8): 1482–94.
6. Ayyappan, S., and K. Mayilsamy. 2010. "Experimental Investigation on a Solar Tunnel Drier for Copra Drying," August. http://hdl.handle.net/123456789/9976.
7. Carvill, J. 1993. "Thermodynamics and Heat Transfer." *Mech. Eng. Data Handb*, 102–45.
8. Deepa, J., P. Rajkumar, Thangaraj Arumuganathan, and Others. 2015. "Quality Analysis of Copra Dried at Different Drying Air Temperatures." *International Journal of Agricultural Science and Research (IJASR)* 5 (4): 1–5.
9. Fouda, T., M. Darwesh, and N. ELhosary. 2018. "Evaluate Thermal Performance of Solar Air Collectors." *Misr Journal of Agricultural Engineering* 35 (2): 627–40.
10. Güler, Hande Özge, Adnan Sözen, Azim Doğuş Tuncer, Faraz Afshari, Ataollah Khanlari, Ceylin Şirin, and Afsin Gungor. 2020. "Experimental and CFD Survey of Indirect Solar Dryer Modified with Low-Cost Iron Mesh." *Solar Energy* 197 (February): 371–84.
11. Joshi, Shashank, Vaibhav Kaushik, Vaishali Gode, and Sudhakar Mhaskar. 2020. "Coconut Oil and Immunity: What Do We Really Know about It so Far?" *The Journal of the Association of Physicians of India* 68 (7): 67–72.
12. Kumar, Mahesh, Sunil Kumar Sansaniwal, and Pankaj Khatak. 2016. "Progress in Solar Dryers for Drying Various Commodities." *Renewable and Sustainable Energy Reviews* 55 (March): 346–60.
13. Mohanraj, M. 2014. "Performance of a Solar-Ambient Hybrid Source Heat Pump Drier for Copra Drying under Hot-Humid Weather Conditions." *Energy for Sustainable Development* 23 (December): 165–69.
14. Mohanraj, M., and P. Chandrasekar. 2009. "Performance of a Solar Drier with and without Heat Storage Material for Copra Drying." *International Journal of Global Energy Issues* 31(2): 112-121.
15. Nukulwar, Masnaji R., and Vinod B. Tungikar. 2021. "A Review on Performance Evaluation of Solar Dryer and Its Material for Drying Agricultural Products." *Materials Today: Proceedings* 46 (1): 345-349.
16. Panchal, Hitesh. 2010. "Experimental Analysis of Different Absorber Plates on Performance of Double Slope Solar Still." *International Journal of Engineering Science and Technology* 2 (11): 6626–29.
17. Thanaraj, Thiruchelvam, Nimal D. A. Dharmasena, and Upali Samarajeewa. 2007. "Comparison of Quality and Yield of Copra Processed in CRI Improved Kiln Drying and Sun Drying." *Journal of Food Engineering* 78 (4): 1446–51.
18. Udomkun, Patchimaporn, Sebastian Romuli, Steffen Schock, Busarakorn Mahayothee, Murat Sartas, Tesfamicheal Wossen, Emmanuel Njukwe, Bernard Vanlauwe, and Joachim Müller. 2020. "Review of Solar Dryers for Agricultural Products in Asia and Africa: An Innovation Landscape Approach." *Journal of Environmental Management* 268 (August): 110730.

TABLES AND FIGURES

Table 1. The calculated values of the % reduction in moisture content of coconut samples by using iron and stainless steel as absorber plates has been tabulated and is shown below.

S.No	Reduction in moisture content - Iron (%)	Reduction in moisture content - Stainless steel (%)
1	24.80	30.88
2	23.75	31.54
3	21.95	32.47
4	20.66	29.56
5	24.25	30.98
6	21.23	31.85
7	23.47	32.58
8	22.58	29.74
9	23.42	30.56
10	22.67	31.99
11	22.98	32.71
12	23.44	29.55
13	25.67	30.78
14	23.56	30.54
15	25.79	29.89
16	23.78	30.12
17	26.15	29.91
18	25.81	30.25
19	26.98	29.11
20	26.57	30.37

Table 2. Group statistics **-** Novel iron absorber plate gives lesser % of reduced moisture content than stainless steel absorber plate (Mean - 23.98 and standard deviation - 1.08741) from the collected samples. The standard error mean value for stainless steel absorber plate is 0.24315 and for iron absorber plate is 0.39457.

Group	N	Mean	Std. Deviation	Std. Error Mean

Iron	20	23.98	1.76456	0.39457
Stainless steel	20	30.77	1.08741	0.24315

Table 3. Tabulation for independent sample t - test. The outcome of the independent sample t-test shows a significant difference between the control group and experimental group. The significant value P = 0.046 (P<0.05, t value is -14.658 & -14.658; and the df is 38 & 31.612).

Independent Samples Test										
Levene's Test for Equality of Variances				**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Reduction in moisture content (%)	**Equal variances assumed**	4.275	0.046	-14.658	38	<0.001	-6.7350	0.46347	-7.73175	-5.85525
	Equal variances not assumed			-14.658	31.612	<0.001	-6.7350	0.46347	-7.73801	-5.84899

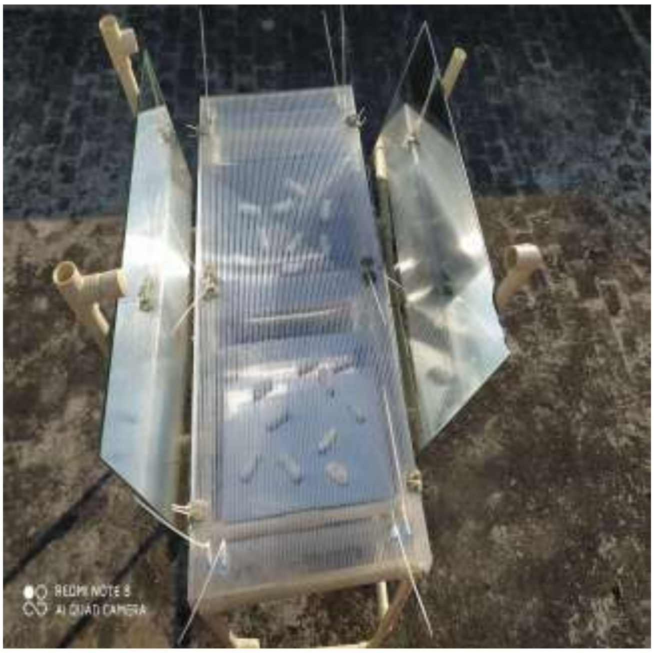

Fig. 1. Photographic image showing coconut samples placed in iron and stainless steel absorber plate in the solar dryer setup.

Fig. 2. Photographic image showing the moisture content of the coconut samples that were determined using a hot air oven.

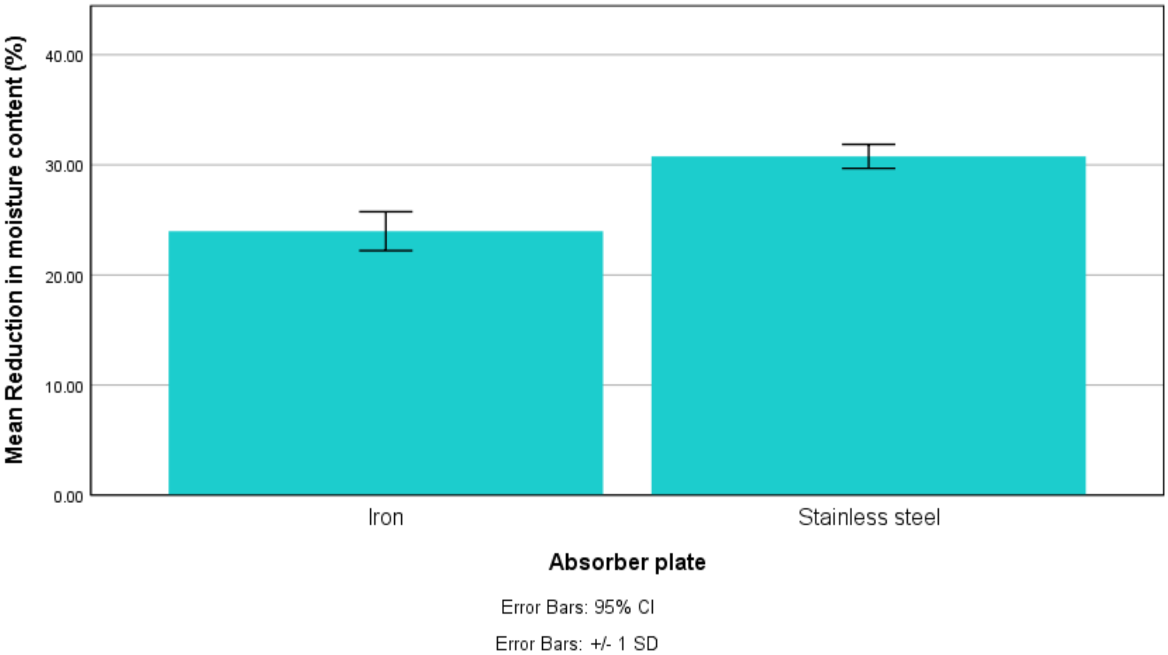

Fig. 3. The bar chart compares the reduction of moisture content in terms of percentage between iron absorber plate and stainless steel absorber plate. The mean value of moisture content reduced is comparatively better in stainless steel absorber plate than iron absorber plate. X axis: Types of absorber plate. Y axis: Mean value of moisture content reduced +/- 1 SD.