Original Article

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

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Abstract

Aim: The aim of this study is to compare the novel black limestone absorber plate with stainless steel absorber plate for its drying efficiency of 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. The control and experimental groups were chosen as comparative groups. A sample size of 20 was allotted to each group. Coconut samples placed on the stainless steel are taken as a control group and the coconut samples placed on black limestone are taken as the experimental group. Moisture content of these coconut samples were determined with the help of a hot air oven and a formula. **Results:** The findings reveal that the mean value for the reduction of moisture content for black limestone is 29.06%, while the mean value for the reduction of moisture content for stainless steel is 36.10% of coconut samples. The independent samples t-test found that both groups are statistically significant for the reduction of moisture content, with a p value of 0.030. **Conclusion:** The drying performance of black limestone and stainless steel absorber plates in terms of moisture content reduction was experimentally tested, and it was discovered that black limestone absorber plate has a lesser drying efficiency than stainless steel absorber plate.

Keywords: Copra, Solar Drying, Novel Black Limestone Absorber Plate, Stainless Steel, Drying Efficiency, Moisture Content.

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INTRODUCTION

This study aims in analyzing and comparing the novel black limestone with stainless steel as an absorber plate in drying coconut. 'The all giving tree' is the word used to glorify the coconut tree in India as all the parts of the tree are useful and used in making various products like coconut milk, coconut butter, coconut water, coconut leaves, coir pith, desiccated coconut, coconut oil etc. (DebMandal and Mandal 2011). Coconut oil is obtained by dry or wet process where dry processing of coconut oil involves drying of coconut followed by cold or hot pressing and refining (Marina, Che Man, and Amin 2009). Cold pressed coconut oil has a higher amount of minerals, vitamins, protein and high antioxidant levels, all of these are retained well as there is no higher heat involved and it is subjected to sunlight (Chan et al. 2017). Drying is most probably the oldest technique, which is used to preserve the food for a longer time (Gupta et al. 2017). Open Sun Drying (OSD) causes deterioration in the product quality as the external environment is in direct contact with the product, on the other hand mechanical drying which uses artificial energy increases the cost of the dried product and solar drying can be adopted to overcome the disadvantages in the above mentioned techniques thereby producing clean and good quality products at a nominal cost (Sharma, Chen, and Lan 2009). Every year, food products which are worth more than million dollars are wasted through spoilage, which can be prevented by drying and this aids in strengthening the economic situation of the nation (Alonge and Adeboye 2012). Solar drying is one of the most cost effective solutions for drying of food products and it has attractive features like free availability of energy, and a controlled drying method also produces high quality dried products (Aravindh and Sreekumar 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, Ravel, and Perumal 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). The following limitations were discovered based on the existing literature study. They were highly energy consuming drying processes, the quality of food products getting altered due to poor drying. Hence, the objective of this study is to compare the novel black limestone absorber plate to the stainless steel absorber plate in terms of coconut drying efficiency, which will aid the farmers and copra producers in selecting the appropriate absorber plate material for solar dryers.

MATERIALS AND METHODS

A solar dryer setup was constructed in order to compare the drying efficiency of the two absorber plates, namely novel black limestone and stainless steel 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. With the help of a simple clinic sample size calculator the sample size was determined as 20 for each group by keeping G power as 80%, threshold as 0.05 and a confidence interval of 95% This calculation was made using outcomes previously done by the researchers (Mohanraj 2014).
Two distinct groups were chosen for comparison purposes. The coconut samples in the control group were placed in a stainless steel absorber plate, while the coconut samples in the experimental group were placed in a black limestone absorber plate in the solar dryer setup and 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 black limestone absorber plates are of length 305 mm, breadth 305 mm and thickness 1 mm & 10 mm respectively. 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). Matured coconuts were split in half, the coconut water was drained, and the coconut samples were kept in a black limestone and stainless steel absorber plate, as shown in Figure 1. 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 following procedures were done to determine the moisture content of the fresh and dried samples using a hot air oven. The initial weight(Wi) of the samples was recorded, then the samples were placed in a hot air oven for 6 hours at 130°C with the temperature held constant, then final weight(Wf) of the samples was recorded. At last 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 initial and final moisture contents were determined using the moisture content of fresh and dried samples, respectively (Deepa et al. 2015). By subtracting the final moisture content from the initial moisture content, the value of reduction in moisture content of the coconut samples was computed and it is shown in Table 1.

Statistical analysis
The mean, standard deviation, and standard error values were calculated using SPSS v.26 statistical software. For each group, a total of 20 readings were taken in order to establish a 95% confidence level with a P value <0.05. The two types of absorber plates employed in this study were used as independent variables, and the dependent variable was moisture content reduction (%). The results of this investigation were analysed using an independent sample t-test.

RESULTS

The values of reduction in moisture content of the coconut samples by the novel black limestone and stainless steel absorber plate is tabulated in Table 1. Standard error mean, standard deviation and mean values are shown as group statistics in Table 2. The mean reduction value of moisture content of the coconut samples for black limestone is 29.06% and for stainless steel it is 36.10%. The independent samples t-test has been used, and the results are shown in Table 3, which reveals that both groups are statistically significant for the reduction of moisture content, with a p value of 0.030.

Figure 1, illustrates the photographic image showing coconut samples placed in stainless steel and black limestone 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. In terms of mean and standard deviation, a bar chart compares the value of reduction in moisture content of coconut samples by novel black limestone and stainless steel as the absorber plate as shown in Fig. 3. The mean and standard deviation value of black limestone absorber plate is lower than that of stainless steel absorber plate.

DISCUSSION

From the result, it is identified that the moisture content of coconut was reduced poorly by black limestone absorber plate in comparison with stainless steel as the absorber plate. The reason for the poor drying efficiency of novel black limestone absorber plate is its low reflecting nature due to which there is less greenhouse effect inside the solar dryer. On the other hand, stainless steel absorber plate has a high reflecting nature due to which the sunlight gets reflected back and forth within the polycarbonate sheet and creates a better greenhouse effect than black limestone, thereby having a better drying efficiency. This study has a fischer value of 5.107 and a significance value of 0.030 which shows that both the groups have a significant difference.
An experiment conducted to compare the thermal efficiency of three different absorber surface of a flat plate collectors which are coated with black paint, black chrome coating and carbon coating, resulted that the carbon coated absorber surface has the highest thermal efficiency and it differs by 13% and 11.3% with black painted plate and black chrome coated absorber plate (Sakhaei and Valipour 2020). Conducted an experiment to study the thermal performance of solar air collectors and found that black limestone to have poor drying efficiency than gravel (Ramadan et al. 2007). The above mentioned two research articles suggest that the black limestone absorber plate has poor drying efficiency which is in line with our study. The thermal efficiency of solar collectors with 0cm, 5cm and 10cm thickness of crushed limestone rock bed was compared and the result is that the solar collector having 5cm thick limestone rock has better overall thermal efficiency than the other two (Abdel-Galil 2007). An experiment performed to compare two sensible heat storage materials namely limestone and beach sand depicted that limestone has higher drying efficiency of 1.55% than beach sand (Cetina-Quiñones et al. 2021). The above mentioned research article says that black limestone absorber plate has increased the drying efficiency which is not in line with our study.
The uncertain meteorological conditions and the monsoon season during which the experiment is conducted are the study's limitations. The scope of this research is to inform researchers about the drying effectiveness of black limestone and stainless steel absorber plates and to provide insight on how to investigate their drying efficiency under various climatic circumstances. Future research in this area could be conducted in different regions to see how it affects the drying efficiency of different absorber plates.

CONCLUSION

The coconut drying experiment was carried out with the help of a solar dryer setup and two absorber plates made of black limestone and stainless steel. The absorber plate's efficacy in lowering the moisture content of coconut samples was analysed, and the mean value of the moisture content reduced was determined to be 29.06% for black limestone and 36.10% for stainless steel. Based on these findings, it can be inferred that the performance of black limestone as an absorber plate for drying coconut is lesser to that of stainless steel.

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.

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TABLES AND FIGURES

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

S.No	Reduction in moisture content - Black limestone (%)	Reduction in moisture content - Stainless steel (%)
1	30.30	35.24
2	29.54	35.90
3	30.35	35.67
4	29.86	35.22
5	28.72	36.47
6	30.95	36.41
7	28.11	36.79
8	31.00	36.22
9	28.99	34.17
10	31.13	34.98
11	28.77	34.61
12	31.47	34.32
13	27.89	37.98
14	31.57	37.51
15	27.54	37.11
16	26.98	37.80
17	27.56	37.54
18	26.67	35.19
19	27.18	36.42

20	26.59	36.59

Table 2. Group statistics - Stainless steel absorber plate gives increased % of reduced moisture content than black limestone absorber plate (Mean - 36.1070 and standard deviation - 1.15863) from the collected samples. The standard error mean value for stainless steel absorber plate is 0.25908 and for black limestone absorber plate is 0.37875.

Group	N	Mean	Std. Deviation	Std. Error Mean
Black limestone	20	29.0585	1.69381	0.37875
Stainless steel	20	36.1070	1.15863	0.25908

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 = 0.030 (P<0.05, t value is -15.360 & -15.360 and the df is 38 & 33.587).

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**	5.107	0.030	-15.360	38	<0.001	-7.04400	0.45793	-7.97104	-6.11696
	Equal variances not assumed			-15.360	33.587	<0.001	-7.04400	0.45793	-7.97518	-6.11282

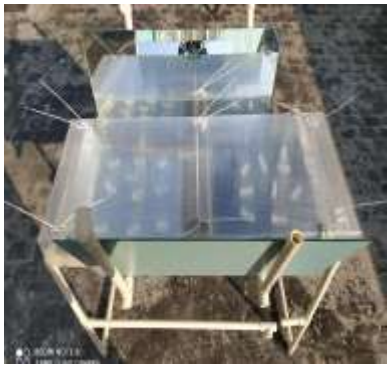

Fig. 1. Photographic image showing coconut samples placed in stainless steel and black limestone absorber plate in the solar dryer setup.

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

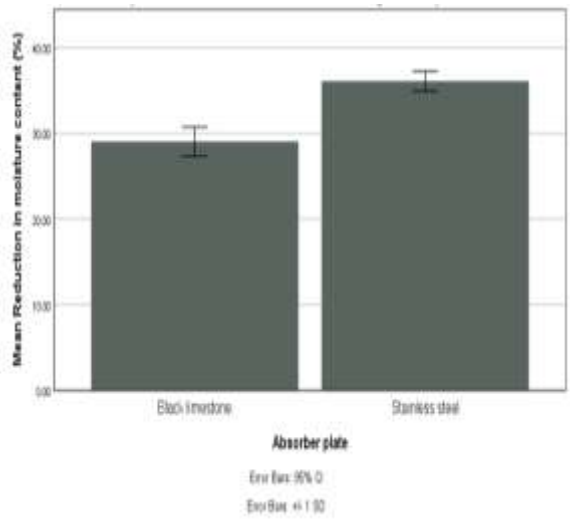

Fig. 3. The bar chart compares the reduction of moisture content in terms of percentage between black limestone absorber plate and stainless steel absorber plate. The mean value of moisture content reduced is comparatively better in stainless steel absorber plate than black limestone absorber plate.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