International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-7, Issue-5S3, February 2019

Feasibility of Introducing Solar Air Dryer for Drying Process in Cashew Industries

V.B. Huddar, M.A. Kamoji

Abstract--- Drying is an energy intensive processes in cashew processing industry. High prizes of electricity and interrupted power supply affecting the production is the motivation for this research. The objective is to develop a solar dryer and check its feasibility to adapt in cashew drying. The end conditions of industrial drying are to bring the moisture content from initial ±13% to ±5% maintaining its color and taste. An electrical heater drying system is developed to find energy required to dry one kg of cashew kernel. A solar air heater developed replaces only electrical heater. Experimental results ensure drying within stipulated time of 6 hours and energy consumption of 255 kJ against 270 kJ and 251 kJ of electrical heater drying and industrial steam drying. Study suggests design is feasible to small and cottage industries. The energy savings up to 25,000 kJ per day for a batch of 100 kg is possible.

Keywords--- Cashew kernels, drying, energy, steam, electricity, solar.

I. INTRODUCTION

Cashew is one of the important tropical crops of India grown mainly in peninsular states particularly along the coastal. It is an important nut crop that provides food, employment and hard currency to the nation [1]. Cashew processing industries are categorized as small, medium and large scale. Dakshina Kannada district has 350 plus industries. All these industries use solar (open sun drying), biomass and electricity for their thermal energy needs. Drying is one of the important and energy intensive processes used to remove high moisture content. Present methods of drying the cashew kernels use conventional fuels like kerosene, diesel, electricity and wood. Use of solar energy proves to be efficient and promising [2]. The annual global solar radiation in India varies from 1600 to 2200 kWh/m^2. Karnataka receives a global solar radiation in the range of 5.1-6.4 kWh/m^2 during summer, 3.5-5.3 kWh/m^2 during monsoon and 3.8-5.9 kWh/m^2 in winter. The global solar radiation in Dakshina Kannada has 6.16, 3.89 and 5.21 kWh/m^2 respectively during summer (February – May), monsoon (June -September) and winter (October – January). The study identifies that coastal parts of Karnataka with higher global radiation is ideally suited for harvesting solar energy [3]. In large and medium scale the processing of cashew is year round as they import the raw cashew nuts from abroad like Vietnam, Ghana in Africa. Small and cottage industries rely on the local supply and the processing is mostly during the summer between February to May. Solar air heating systems have been used for drying several agricultural and food products [4]. Several types of single pass solar air dryers have been designed and tested for their performance evaluation like efficiency; operating temperature and suitability for different applications like drying various agricultural products, space heating etc. [5-9]. Various types of double pass solar collectors with fins, thermal energy storage and reflectors have been introduced to increase the thermal efficiencies ranging from 10 to 30% [10-16]. Multi pass solar collectors show a better performance over single and double solar collectors [17, 18].

Processing industries use drying chamber known as borma using heat of steam. The end conditions of the process are to bring down the moisture content of kernels from initial ±13% to ±5% maintaining its color and taste in the process. Figure 1 presents flow chart of cashew processing along with the dried cashews both in industry and experiment.

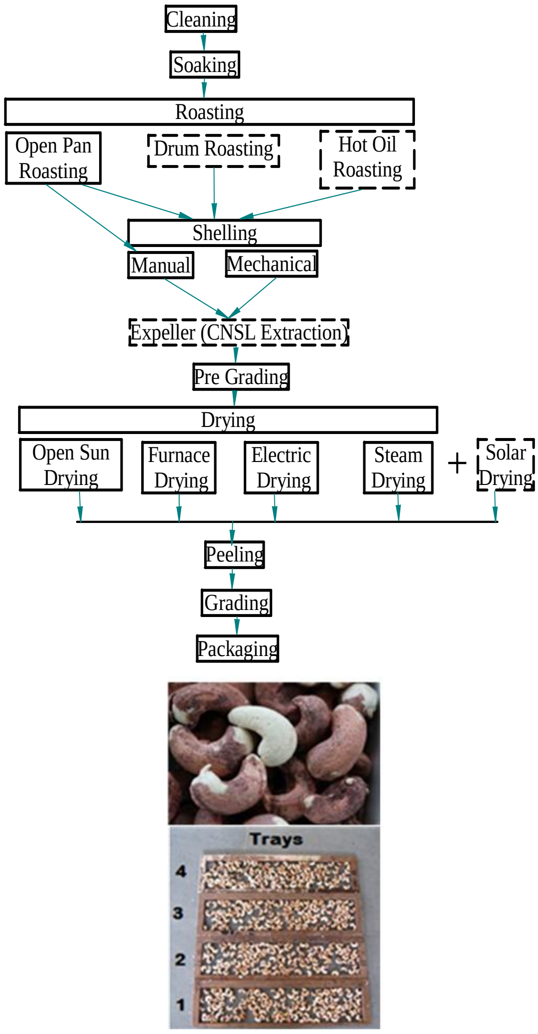


Fig. 1: Flow chart of cashew processing along with the dried cashews both in industry and experiment

Manuscript received February 01, 2019

V.B. Huddar, Professor, Bearys Institute of Technology, Innoli, Karnataka, India. (e-mail: vbhuddar2017@gmail.com)

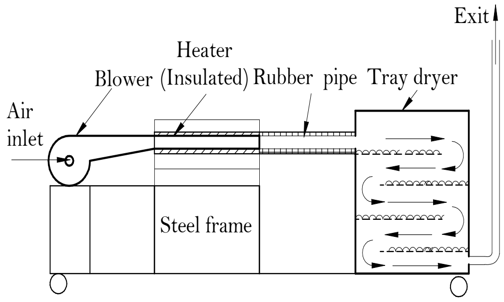
Dr.M.A. Kamoji, Professor, KLE Dr. M.S Sheshgiri CET, Belagavi, Karnataka, India. (e-mail: makamoji729@gmail.com)

The present work focuses on drying of cashew kernels using solar dryers. It aims to check its feasibility to adapt it in cottage and small scale cashew industries. For this a survey of small scale cashew processing industries in the locality is made. The drying process is studied and parameters are recorded. Based on outcome of this study, two experimental setups are designed and developed to dry one kg of cashew kernels maintaining end conditions.

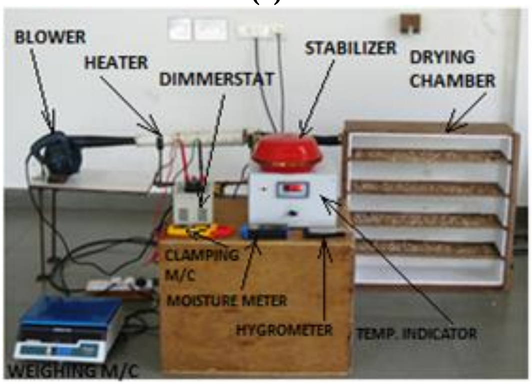
II. PROCEDURE FOR PAPER SUBMISSION

Electric Heater Dryer [EHD] System

Figure 2 shows the sectional details and pictorial view of the EHD system developed that supplies heat using electricity. Electricity is considered for heating the air as it is one of the sources used for drying in cashew processing industries. Experimental set up consists of a blower that supply air at 1.5 m/s, a coil type heater of 1 kW capacity wound around copper tube and a drying chamber with four GI wire mesh trays of each 0.25 kg capacity each with all required the test rig. Adiabatic conditions are maintained across the system. Three experiments are conducted with variations in drying chamber, i) single tray, ii) four trays with baffle plates and iii) four trays without baffle plates.



(a)

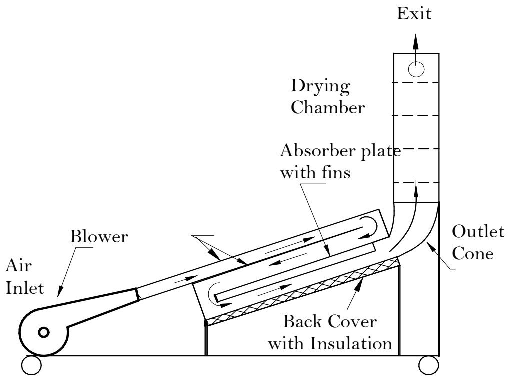


(b)

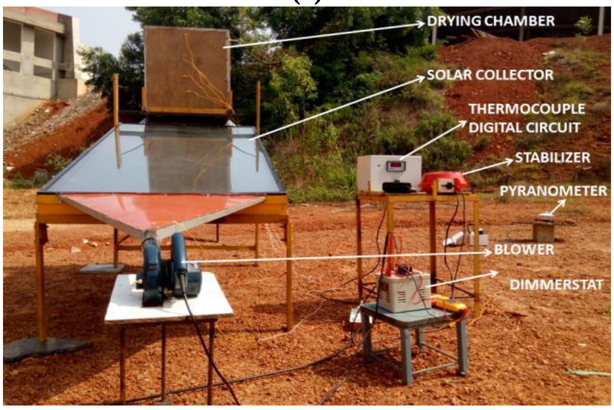
Fig. 2: Sectional and pictorial views showing experimental setup of EHD system

Drying Chamber-Four Tray without Baffle Plates

Drying chamber was made up of 12 mm thick plywood. The interior of the chamber was covered completely with 21 mm thermacol (Expanded Polystyrene – EPS). The corners are properly glued to avoid possible leakages. Inlet is connected through a cone and outlet is provided at top of the chamber to allow convective air flow. It has insertion type of door with provision to seal the leakages. The trays are sliding type and are made of GI wire mesh with wooden frame that allows hot air through them for drying the products. Cashew kernels are distributed equally with space in between for air movement. The randomly selected sample cashew kernels from all trays were tested for initial and final weight using precision weighing scale for percentage of moisture removed. The initial and final moisture content is measured using moisture content meter.



(a)



(b)

Fig. 3: Sectional & pictorial views showing experimental set up of ASAD system

Active Solar Air Dryer [ASAD] System

Figure 3 shows the sectional details and pictorial view of the ASAD system developed that consists of a multi pass solar flat plate collector with V groove mild steel absorber plate with fins on alternate groves to increase the heat transfer area. It has an area of 2 m2 with dimensions of 1m × 2m. All the components of the earlier setup are maintained same except the inlet to dryer. Inlet and outlet cones are provided to connect the dryer to blower and drying chamber respectively. The cones are facilitated with ribs to provide uniform distribution of air throughout the width of dryer. All the joints were made leak proof and are wrapped with asbestos to make it adiabatic. In this mode of experiment, only heater was replaced with multi pass solar flat plate collector to maintain the similarity in end conditions. The complete setup was mounted on a steel frame and was kept facing due south on a selected plain area during experimentation. Table 1 provides the specifications of the instrumentation used.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

TABLE I: SPECIFICATIONS OF INSTRUMENTATION

Instrument	Specifications
Blower	Power input : 220V, 60W, 50-60Hz, 16000rpm
Coil heater	Power input : 2000 W, 230V,50Hz
Anemometer	Resolution: 0.1m/s, Accuracy:+/-0.2m/s
Temperature indicator	Resolution: 0.1^{o}C, Accuracy:+/-0.5^{o}C
Thermocouples	K type, Range 0-180^{o}C
Pyranometer	Model: LPPYRA03AC, Sensitivity: 10µV(W/m^2),
Moisture meter	Range: 2-70%, Resolution : 0.5%
Weighing scale	Model : SA1torius, Range : 0.1mg-22g
Hygrometer	Resolution: 0.1%RH, Accuracy : +/-3%RH
Clamping meter	Resolution : 0.1 A and 0.1V, Accuracy : 1% +/- 5 digits,

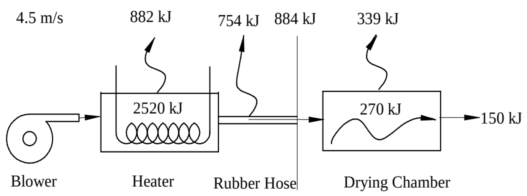
III. RESULTS AND DISCUSSIONS

Test Performance Analysis

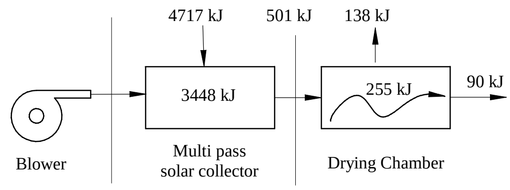
The performance of the tests carried out on both EHD and ASAD systems is discussed as below.

The final experiment on EHD system is conducted on 29 April 2015. The baffle plates in the drying chamber are removed and only four trays are retained at equidistance between them. Fresh one kg of cashew is loaded for testing. The velocity of the air at the inlet of the drying chamber is maintained at 1.05 m/s. The estimated energy consumption for drying one kg of cashew kernels is 270 kJ with a drying rate of 2.83 kg/h. Experimental results of three hours duration show a final weight as 932g which is 6.5% weight reduction. The moisture content is found to be 5.5%.

The final experiment on ASAD is performed on 19 May 2015 with set of instrumentation between 10.00 am to 4.00 pm. The experimental site is a coastal area near the city of Udupi, Dakshina Kannada district, in the state of Karnataka, India with coordinates; Latitude (φ) 13^{o}15'10"N and Longitude 74^{o}47'39"E. An average solar radiation of 615.15 W/m^2 is measured with pyranometer with shade at the site on the day. The measured value is compared with the predicted solar insolation on the day as 588.2 W/m^2. The predicted value lies well within the acceptable difference of 10%. Different readings like air temperatures at inlet and outlet of cone, inlet and outlet of drying chamber and at all four trays are recorded on half hourly basis. Air velocity is measured with digital anemometer and maintained at 1.05 m/s at the inlet of the drying chamber. The relative humidity is measured with digital hygrometer and is recorded as 59.6% average. Test analysis shows exit temperatures of the collector in the range of 42-52 ^{o}C.



(a)



(b)

Fig. 4: Block diagrams showing energy analysis of EHD and ASAD systems

The heat transfer to the working fluid air by the heater of EHD system and flat plate collector of ASAD system is found to be 2016 kJ and 3448 kJ respectively. The drying process with ASAD for a period of 6 hours ensures average moisture removal of 6.5% with expected final moisture content ranging between of ±5%. The study shows useful energy extracted as 541 kJ and estimated efficiency of the collector is found to be 71.8%. Fig. 4 shows the block diagrams of the energy analysis of both EHD and ASAD systems. The drying chamber efficiency of 30.54% and 50.9% is found with EHD and ASAD systems respectively. For ASAD system the solar flat plate collector shows a useful energy extraction of 541kJ and an efficiency of 71.8%. Table 2 provides the important results important results of the experiments.

TABLE II: IMPORTANT RESULTS OF EHD AND ASAD SYSTEMS

SN	Description	Symbol	Value
EHD system			
1	Electrical energy supplied to heater	Q_{elect}	2520 kJ
2	Energy loss in transit	Q_{loss}	1468 kJ
3	Efficiency	η_{dc}	30.54 %
4	Drying rate	DR	2.68 kg/h
ASAD system			
1	Solar Flat Plate Collector-Input energy	QI	4717 kJ
2	Energy received	Q_{gain}	3448 kJ
3	Efficiency	η_{FPC}	71.8 %
4	Drying Chamber-Energy entering	q_{in}	501 kJ
5	Energy utilized	$q_{utilized}$	255 kJ
6	Efficiency	η_{dc}	50.9 %
7	System ASAD-Instantaneous efficiency	η_i	26.25%
8	Drying Rate	DR	1.66 kg/h

The results obtained were used to compare the performance of both the systems. The estimated energy consumption and drying rate for drying one kg of cashew kernels with EHD system is 270 kJ and 2.68 kg/h respectively against 255 kJ and 1.66 kg/h of ASAD system with an unaccounted energy of only 18 kJ. Figure 5 shows the energy balance of the drying chamber used for both the systems and Table 3 provides the analysis results.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

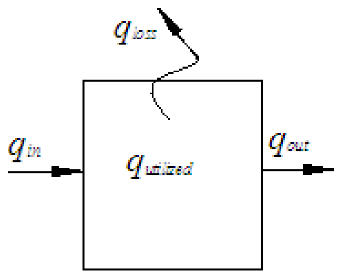
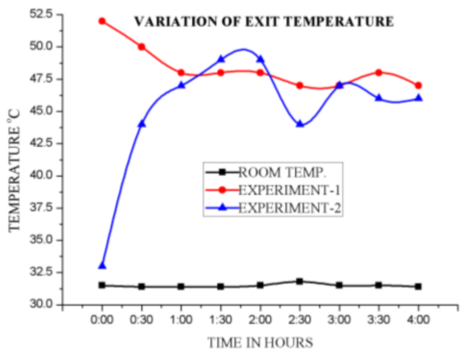


Fig. 5: Energy analysis in drying chamber

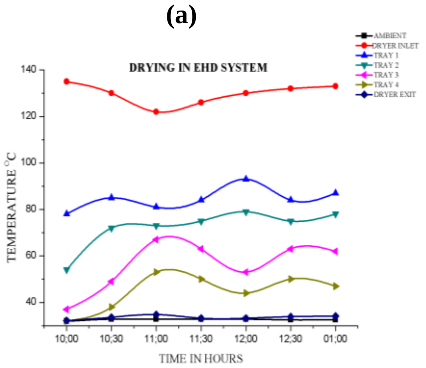
Experimental Results

TABLE III: ANALYSIS OF DRYING CHAMBER – ENERGY BALANCE

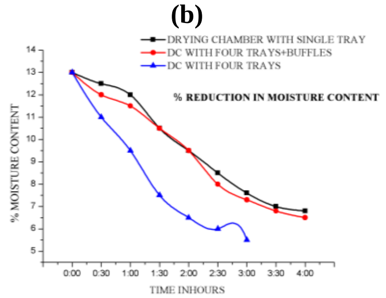
S N	Description	Symbol	Value kJ EHD	ASAD
1	Energy entering	q_{in}	1052	501
2	Energy utilized	$q_{utilized}$	270	255
3	Energy lost	q_{lost}	339	138
4	Energy exited	q_{out}	150	90
5	Energy unaccounted	$q_{un\ ac}$	293	18



(a)



(b)



(c)

Fig. 6: Variation of temperatures and moisture content in EHD system

Electrical Heater Drying System:

Fig. 6 shows the variation of temperatures and moisture content. Fig. 6(a) shows the graph of variation of ambient temperature & temperatures in drying chamber with single tray and four trays with baffle plates. The average temperatures in the drying chamber is found to be around 50°C. Fig. 6(b) shows the variation of temperature at the inlet and outlet of the drying chamber and in all four trays with respect to time. The temperature difference between dryer inlet to exit is found to be in the range of 85 to 95 °C. The system has supplied a consistent heat to the drying process. In drying chamber, on trays from 1 to 4, a temperature ranging from 33 to 72 is recorded. Fig. 6(c) shows the reduction in moisture content of cashew kernels of all the three experiments. Drying chamber with four trays and no baffle plates has shown a better results than the other two with final moisture content of 5.5% as against the 6.8% and 6.5% of the single tray and four tray with baffle plates. The difference is because of the heat distribution pattern in the drying chamber. The final experiment takes three hours to achieve the required moisture content. After drying to check the end conditions cashew kernels are tested for peeling and quality. All of the cashew kernels have been peeled and are found good in appearance and taste.

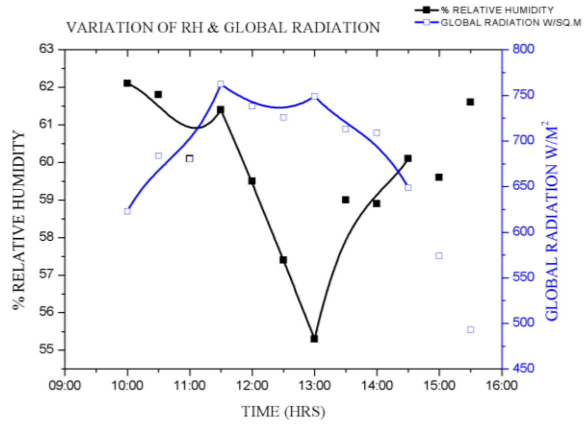


Fig. 7: Variation of relative humidity and solar global radiation against time of the day

Active Solar Air Drying system

Fig. 7 shows typical day results of variation of relative humidity, and global radiation with respect to time on half hourly basis. The final experiment is conducted on a clear sunny day. The global radiation obtained on the day varies from 419 to 764 W/m^2.The duration of experiment is six hours conducted between 10.00 am to 4.00 pm. The relative humidity show a quite minimum value during the mid of the day whereas global radiation was found maximum. The root mean square value of same was found to be 59.65 %. The reasonable temperatures achieved in all the four trays ranging from 35°C to 58°C dried the cashew kernels to the required moisture content. Thus the half hourly variation of hot air temperature on four trays is much higher than the ambient temperature during most of the hours of the experimentation on the day and indicates a better performance of the system.

The dried cashew kernels are tested for peeling process and quality. All of the cashews

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

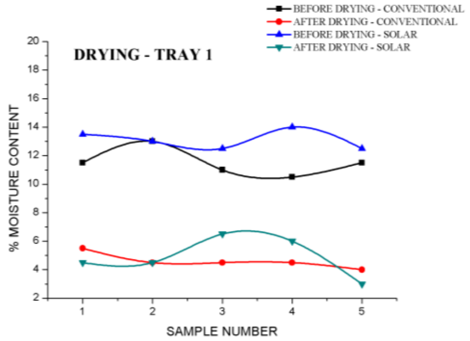
are peeled off and their taste and appearance found good.

Chamber Trays

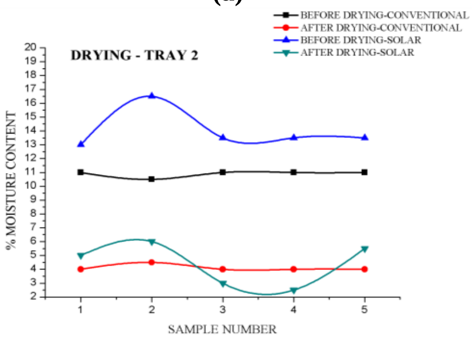
Fig. 8 shows the comparison of drying curves of cashew kernels before and after drying in trays 1 to 4 respectively for the selected samples in both conventional (EHD) and solar (ASAD) mode of drying. A variation in curves for before drying can be observed in all the four graphs as the samples for the two experiments conducted are on different dates and are collected from different sources.

Tray 1 shows a close agreement between the moisture content profiles of before and after drying process of conventional and solar drying methods. The percentage of moisture content in the tray of the solar setup varies from 3 to 6%. In tray 2, the variations of the before and after drying curve profiles of conventional and solar are linear based on the initial and final moisture contents of the cashew kernels. Even though a large variation was found with curve of after drying profile of solar setup the variation is within the range except for selected sample 4. This variation was because of the hot pockets in the convection current within the dryer. In tray 3 even though there is greater variation in initial moisture contents, final moisture contents in both the cases show a close approximation. However, the range of moisture content lies well within the limits 3 to 6 %. Similar conditions were found in tray 4. Unlike conventional the final results of the solar setup are found well within the acceptable range of 3 to 6% final moisture content.

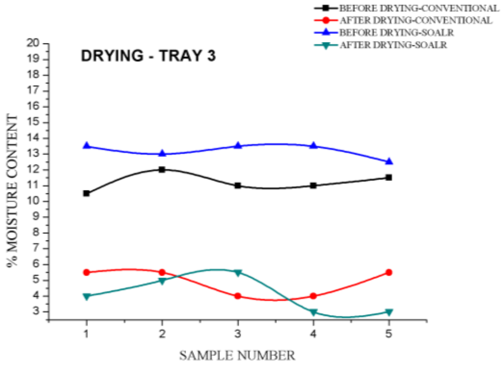
In all the four trays the hourly variation of the drying chamber temperature is much higher than the ambient temperature during the most part of the experimental period. A uniform temperature of 40-45^{o}C is achieved in all the four trays throughout the experimentation providing constant heat to the product as well retain its nutritional values and appearance.



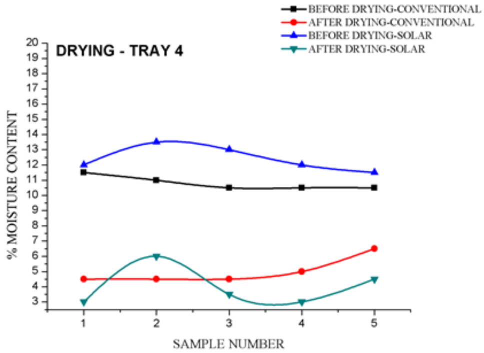
(a)



(b)



(c)



(d)

Fig. 8: Profile of moisture content in trays 1 to 4

IV. CONCLUSIONS

The following conclusions are drawn from the experimental study of EHD and ASAD systems

1. The energy consumption to dry one kg of cashew kernel is 255 kJ/kg against 270 kJ/kg for electrical heater set up, which indicates that the developed ASAD setup has consumed lesser energy compared to EHD.
2. The difference in variation of energy consumption with two systems is because of the temperatures during sensible heat addition to raise the temperature of working fluid-air.
3. The system exhibited sufficient ability to dry cashew kernels at a reasonable time of 6 hours with good appearance and quality ensuring its feasibility to introduce.
4. It is observed from the experiment that suitable environment is available for drying cashew kernels to achieve a safe moisture content of ±5% of the product.
5. The systems exhibited an instantaneous efficiency of 30.54% and 26.25 % with a drying rate of 2.68 kg/h and 1.66 kg/h respectively.
6. Study reveals that 6 to 7 kg of cashew kernels can be dried per square meter of flat plate collector.
7. The system provides an energy savings up to 25,000 kJ per day for a batch of 100 kg.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

ACKNOWLEDGEMENT

The author would like to thank Karnataka State Council for Science and Technology for its financial assistance under SPP program No. 38S1629. Also thank Karnataka Council for Technology Up-gradation for its financial support for instrumentation and in developing the set up.

REFERENCES

1. Atul Mohod , Sudhir Jain, Ashok Powar, Naren Rathore, Anilkumar Kurchania, Elucidation of unit operations and energy consumption pattern in small scale cashew nut processing mills, Elseveer, Journal of Food Engineering, 2010, 99 184–189
2. Dr. T V Ramachandra, CES technical report 88, Energy Alternatives: Renewable energy and energy conservation technologies, 2000, page # 25
3. T V Ramachandra, Solar energy potential assessment using GIS, Energy Education Science and Technology, 2007, Volume (issue) 18(2): 101-114
4. C.L. Hii, S.V. Jangam, S.P. Ong and A.S. Mujumdar, Solar Drying: Fundamentals, Applications and Innovations,2012, ISBN: 978-981-07-3336-0, page # 25 – 30
5. Ali Zomorodian and Maryam Zamanian, Designing and Evaluating an Innovative Solar Air Collector with Transpired Absorber and Cover, Renewable Energy, 2010, Volume 2012, Article ID 282538, 5 pages
6. A.Anuradha & Dr (Mrs) Rachel Oommen, Fabrication and Performance evaluation of a v-groove solar air heater, International Journal of Scientific & Engineering Research, 2013, Volume 4, Issue 6, 2072 ISSN 2229-5518
7. Abhishek Saxena & Harish Yadav, **(**Jan. 2013**),** Thermal Performance of a Hybrid Solar Air Heater, MIT International Journal of Mechanical Engineering, Vol. 3, No. 1, pp. 57–62, ISSN No. 2230–7680 © MIT Publications
8. M. Joseph Stalin & P. Barath, Effective Utilization of Solar Energy in Air Dryer, International Journal of Mechanical and Production, Engineering Research and Development (IJMPERD), 2013, ISSN 2249-6890, Vol. 3, Issue 1, 133-142
9. Salwa Bouadila, Sami Kooli, Mariem Lazaar, Safa Skouri, Abdelhamid Farhat, Performance of a new solar air heater with packed bed latent storage energy for nocturnal use, Applied Energy, 2013, 110, 267-275
10. Bashria Abdrub alrasoul Abdallah Yousef and Nor Mariha Adam, Performance Analysis for V-Groove Absorber, Sci. Technol. 14(1):39-52
11. Ahmad Fudholi, Mohd Hafidz Ruslan, Lim Chin Haw, Sohif Mat, Mohd Yusof Othman, Azami Zaharim & Kamaruzzaman Sopian, Performance of Finned Double-Pass Solar Air Collector, Recent Advances in Fluid Mechanics, Heat & Mass Transfer and Biology, ISBN: 978-1-61804-065-7
12. Jose E. Quiñonez, Alejandro L. Hernandez, Silvana Flores Larsen, Development and Experimental Evaluation of a Vertical Solar Air Collector for Heating of Buildings, PLEA 2012 - 28th Conference, Opportunities, Limits & Needs Towards an environmentally responsible architecture Lima, Perú, 2012, 7-9
13. K. Sopian, M.A. Alghoul, Ebrahim M. Alfegi, M.Y. Sulaiman, E.A. Musa, Evaluation of thermal efficiency of double-pass solar collector with porous–nonporous media, Renewable Energy, 2009, 34, 640–645
14. S.S.Kashinath & K. Kalidasa M, Experimental Study of The Double-Pass Solar Air Heater with Thermal Energy Storage, Journal of King Saud University-Engineering Sciences, 2013, 25, 135-140
15. Hiroshi Tanaka, Theoretical analysis of solar thermal collector with a flat plate bottom booster reflector, Energy Science & Technology, 2011, Vol 2, No. 2, pp26-34
16. S.P. Sukhatme, Solar energy, “Principles of thermal collection and storage” 2^{nd} edition, Tata McGrow Hills, 173-200.
17. P. Velmurgan & R Kalaivanan, “Thermal performance studies on multi pass flat plate solar air heater with longitudinal fins: An analytical approach”, Springer, 2015, 40, 1141-1150
18. G.O.I. Ezeike, Development and performance of a triple-pass solar collector and dryer system, ELESEVIER, Energy in agriculture, 1986, Vol.5, Issue 1, 1-20.
19. Vivekanand B. Huddar and Dr. Mahesh A Kamoji, Experimental investigations on electrical heat-assisted drying of cashew kernels, IOP conference series (In Press).

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication