FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 12, N° 3, 2014, pp. 277 - 288

Original scientific paper

DESIGN AND THERMAL PERFORMANCE OF THE SOLAR BIOMASS HYBRID DRYER FOR CASHEW DRYING

UDC 662.6

Dhanushkodi Saravanan[1], Vincent H. Wilson[2], Sudhakar Kumarasamy[3]

[1]PRIST University, Thanjavur, India
[2]Toc H Institute of Science and Technology, Arakkunnam, Kerala, India
[3]Energy Centre, National Institute of Technology, Bhopal, M.P, India

Abstract. *Drying of Cashew nut to remove testa is one of the most energy-intensive processes of cashew nut process industry. For this reason a hybrid dryer consisting of a solar flat plate collector, a biomass heater and a drying chamber is designed and fabricated. 40 kg of Cashew nut with initial moisture of 9 % is used in the experiment. The performance test of the dryer is carried out in two modes of operation: hybrid-forced convection and hybrid-natural convection. Drying time and drying efficiency during these two modes of operation are estimated and compared with the sun drying. The system is capable of attaining drying temperature between 50º and 70ºC. In the hybrid forced drying, the required moisture content of 3% is achieved within 7 hours and the average system efficiency is estimated as 5.08%. In the hybrid natural drying, the required moisture content is obtained in 9 hours and the average system efficiency is 3.17%. The fuel consumption during the drying process is 0.5 kg/hr and 0.75 kg/hr for forced mode and natural mode, respectively. The drying process in the hybrid forced mode of operation is twice faster than the sun drying. The dryer can be operated in any climatic conditions: as a solar dryer on normal sunny days, as a biomass dryer at night time and as a hybrid dryer on cloudy days. Based on the experimental study, it is concluded that the developed hybrid dryer is suitable for small scale cashew nut farmers in rural areas of developing countries.*

Key Words: *Biomass heater, Collector efficiency, Hybrid dryer, Cashew nut, Drying rate*

1. INTRODUCTION

Within the whole of the world cultivation of cashew nut plants, India occupies the top position with about 8.93lakhs ha while its total annual production is estimated as 6.95lakhs M.T [1]. In addition, India has an enormous experience in processing the plants as indicated by its high export of cashew kernels in comparison with other countries.

Received October 19, 2014 / Accepted November 21, 2014
Corresponding author: Dhanushkodi Saravanan
PRIST University, Thanjavur 613403, Tamilnadu, India
E-mail: dhanushkodi.vs@gmail.com

Besides, it imported raw nuts (about 7.52 lakh MT) during 2009-10 to meet out the requirements of its cashew nut processing industries [2].

The main objective of the cashew processing is to remove a valuable cashew kernel from the shell with as little damage as possible. Whole kernels command a higher price than the broken pieces. Pale, ivory colored (or) white kernels are preferable. Therefore, the processor must finely tune the process in order to achieve the best quality kernels.

The cashew nut processing consists of the following five steps:

1. Removal of the outer shell called a shelling process,
2. Removal of the testa (the thin skin covering the kernel) called a peeling process,
3. Grading into different sizes and color in accordance with different grade standards,
4. Humidifying or drying to attain a final moisture content of 3-5 percent, and,
5. Depending upon the quantity, finally pack into air tight bags or cans.

Of the above five processes, peeling is a very important and difficult one.

It needs temperature around 65°C - 70°C with time duration of 5-6 hours. The moisture content of the raw kernel is reduced from 9% to 3% to prevent natural decay [3]. Majority of the processing industries carry out this process by using steam drying and electrical drying. The total energy consumption for processing (cashew nut drying, cashew nut steaming and drying of cashew kernels altogether) of 1000 kg of raw cashew nuts is around 5000-6000 MJ [4]. In the sun drying, the kernels are uniformly spread out on the floor and the process is heavily reliant on a constant supply of sunshine. Although the sun drying does not pose any risk of scorching the kernels, it may be prolonged in the case of bad weather, which can lead to an extended drying process time. Other drying methods represent very expensive processes. Therefore, the cashew nut farmers are searching for alternative methods for drying cashew kernel.

2. Referential Literature Review

Mohamad Hanif et al [5] have used a dish type solar dryer for drying grapes. Debbarma et al [6] have designed and tested a low-cost solar bamboo dryer for drying chillies at MANIT, Bhopal. Amer et al [7] have designed and evaluated the performance of a new hybrid solar dryer for banana drying. Hossain et al [8] have developed a prototype hybrid solar dryer for tomato drying. Chandra Kumar and Bhagoria [9] have carried out performance evaluation of the mixed mode solar dryer with forced convection. Andrew et al [10] have designed and developed an indirect solar dryer with a biomass backup heater for drying pepper berries. Azimi et al [11] have carried out an experimental study on eggplant drying by an indirect solar dryer and open sun drying. A mixed mode dryer with a natural convection mode and a biomass backup heater is designed by E Tarigan et al [12].

Many of them use solar energy in the natural and the forced convection mode (or) a solar biomass heater in the hybrid mode for drying agricultural products with the temperature ranging from 45°C-65°C.

This brief review of referential literature clearly indicates that very little information is available about a small scale hybrid dryer for drying cash crops like cashew. Cashew drying is a highly energy intensive and expensive process. In order to reduce the energy cost associated with cashew drying, alternate renewable energy based sources of drying need to be explored. Hence, the present investigation is carried out with the following objectives in mind:

1. To fill the void left by the researchers in this area,
2. To design and develop a solar biomass hybrid dryer for drying cashew, and,
3. To ensure continuous day and night operation of the hybrid dryer.

3. EXPERIMENTS

The dryer consists of a biomass heater, a solar air heating collector, a centrifugal blower and a drying chamber with chimney. The schematic view and a photograph of the experimental setup are shown in Figs. 1 and 2, respectively.

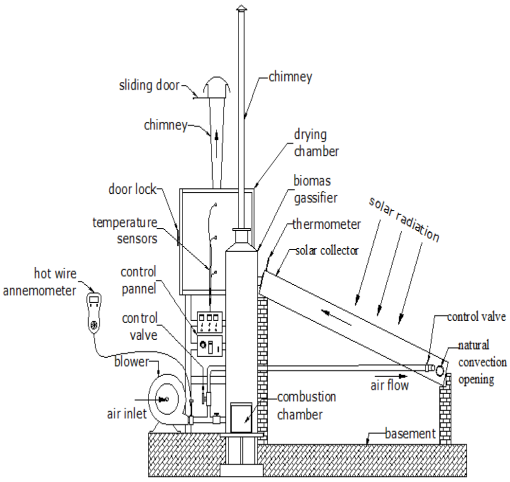

Fig. 1 Solar biomass hybrid dryer

Fig. 2 Perspective view of the hybrid solar dryer

3.1. Solar collector

The solar air heating collector system consists of an absorber, a double glass cover, a back plate and insulation. The solar air collector has dimension of (2m×1.1m×0.2m). The whole system is enclosed in a rectangular box made of galvanized iron sheet of 0.99 mm thick. The absorber is made of 2mm thick aluminum plate coated with black paint to absorb incident solar radiation. Two toughened glass plates are fixed on the top of the collector at a distance of 0.04m above the absorber plate in order to reduce heat losses from the top side of the collector. During the operation the air flows through the space between the absorber plate and the back plate. The spaces inside the collector are baffled to change the direction of the airflow while two inlet connections are provided at the front end of the collector. One is connected to the blower for running the system in the forced convection mode and another one is opened to the atmosphere for running the system in a free convection mode.

3.2. Biomass heater

The biomass heater consists of four main parts: inner and outer shells, a cross pipe, a chimney and openings. The base of the biomass heater acts as a combustion chamber.

The cylindrical MS cross pipe is located in the middle of the inner shell to divert the flame towards the periphery of the inner cylindrical shell. Glass wool insulation of 0.08 m thickness with aluminum cladding is provided on the outer shell of the biomass heater.

3.3. Drying unit

The drying unit consists of four main parts: a base frame, a drying chamber, drying trays and a loading door. This chamber is made up of a mild steel frame and covered with galvanized iron sheet of 1mm in thickness. The drying chamber consists of ten perforated aluminum trays which are arranged from the bottom to the top of the drying chamber. They are evenly placed at a distance of 0.015m. A door is provided with locking arrangement for loading and unloading of the product

3.4. Blower

The blower is attached to the solar air heating collector to induce and control the airflow rate inside the collector. The blower is connected to the solar air collector and the biomass heater by a pipe line. The maximum operating speed of the blower is 2800rpm.

3.5. Chimney

A chimney with varying cross-sections (bottom 0.16 m, top 0.2 m, height 0.6 m) is provided at the top of the drying chamber to remove moist air. A sliding door is provided at the top of the chimney to control the exhaust air flow. The design parameters of the hybrid solar dryer are given in Table 1.

Table 1 Design parameters of the hybrid Solar Dryer

Component	Specifications
Solar collector	
Type	Flat plate
Area	$2.2m^2$
Glass cover	4mm
Number of Glazing	2
Absorber plate	Aluminum sheet, 2 mm thick
Tilt angle	15^o
Insulation	Glass wool
Drying chamber	
Size/No of Trays	0.64×0.6×0.73 m / 10
Tray area	0.54×0.51 m
Chimney	Bottom 0.16 × 0.16 ,Top 0.2×0.2 & Height 0.6 m
Tray thickness	0.003 m
Blower	
Capacity, Speed & Voltage	0.37 KW,0-2800 Rpm & 440 V(A.C)
Biomass heater	
Inner shell diameter	0.34 m
Outer shell diameter	0.42 m
Height	0.94 m
Shell thickness	0.003
Drying capacity	40kg

3.6. Operating system

Two different modes of operation are carried out in order to study the thermal performance and drying characteristics of the system. The drying system is operated in the hybrid forced mode by running the blower at 1400 rpm. An optimum air flow rate of 0.0402 kg/s is maintained continuously during the trail. The air is uniformly distributed to the solar collector and the biomass heater. Additional heat input is provided by burning 0.5 kg of fuel wood in the biomass heater. A hybrid forced mode operation. The experiment is repeated in a hybrid natural mode without the use of blower. Sun drying operation is also carried out simultaneously in order to get the drying time.

3.7. Drying product

Boiled cashew nut shell weighing 80 kg is procured from a local farmer in Cuddalore district, Tamilnadu, India. A hand operated shell cutter is used to remove shell. The cashew nut kernel obtained after cutting operation and has a brown skin called testa. To remove the testa from the kernel, a drying operation is performed. The uniformly controlled heating of 60-70°C for a period of 6-8 hours is required to remove the moisture from 9% to 3%.

3.8. Experimental procedure

The given experiments are conducted in the forced convection solar biomass hybrid dryer under no load condition. At each hour of drying the temperature is measured of the drying chamber at bottom, middle and top trays by using a thermocouple inserted inside the drying chamber. Ambient temperatures, collector outlet temperature, drying chamber outlet temperature are all measured by means of RTDs. Other results observed are solar intensity by solar power meter, relative humidity in ambience and drying chamber by thermo hygrometer. The initial and final weights of the product are measured by using digital weight balance. The air flow rate is calculated by using a hotwire anemometer connected between the blower and collector and the gasifier inlet; energy consumption of the blower is also calculated by energy meter. The experiment is repeated in different solar days by varying the speed of the blower in the range of 100 rpm with minimum speed of 300rpm and maximum speed of 2500 rpm in a total number of 23 days. Three optimum flow rates are identified (0.0289 Kg/s, 0.035 Kg/s, 0.042 Kg/s) as suitable for this product. The three optimum flow rates are used to dry 40kg of cashew per batch and the results are notified. Similar experiments are repeated in a natural convection solar dryer and a biomass dryer with a forced convection mode and compared with the open sun drying. The comparison is done with the open sun drying on same day and at same time (from 8.00 am to 5.00pm).

3.9. Instrumentation

Solar radiation is measured by means of a solar power meter. Three calibrated thermocouples with ± 0.5°C accuracy are fixed at top, bottom and middle of the solar drying chamber to measure the drying air temperature. Energy consumption of the blower is measured with an energy meter having ±0.5 accuracy. Air velocity at the collector inlet as well as the biomass heater are measured by means of a hot wire anemometer (accuracy of ±0.01m/s). The relative humidity of the ambient air and the drying chamber are measured by using a thermo hygrometer. The cashew nut kernel mass and the biomass fuel are measured with an electronic balance of accuracy 0.01g. The list of instrument used in the experiment is shown in Table 2 for ready reference.

Table 2 Instrumentations used in the experiment

S.No	Parameter	Instruments	Accuracy
1	Temperature	Thermocouple and RTDs	0.05°C
2	Mass	Electronic Balance	0.01g
3	Solar radiation	Solar Power Meter	± 1w/m²
4	Air velocity	Hot Wire Anemometer	±2.5%
5	Power consumption of blower	Energy Meter	±0.1Kwh
6	Relative humidity	Thermo Hygrometer	±2.5%

3.10. Efficiency calculation

The performance of the system and of the drying characteristics is calculated using the following expression. The moisture content (M_c) is expressed as a percentage of moisture present in the product. The instantaneous moisture content at any given time on wet basis and dry basis is calculated using the following expression.

$$M_c(Wet\ Basis) = \frac{M_i - M_d}{M_i} \times 100 \tag{1}$$

$$M_c(Dry\ Basis) = \frac{M_i - M_d}{M_d} \times 100 \tag{2}$$

Where M_i is the initial mass of the sample in kg M_d is the final mass of the sample in kg Drying rate (R_d) is formed by a decrease of the water concentration during the time interval between two subsequent measurements divided by this time interval:

$$R_d = \frac{M_i - M_d}{t} \tag{3}$$

Where 't' is the time of drying in sec. **C**ollector efficiency (η_c) is defined as the ratio of useful heat gain (Q_u) over any time period to the incident solar radiation over the same period, with I denoting the solar intensity in W/m^2 and A the collector area in m^2:

$$\eta_c = \frac{Q_u}{I.A} \tag{4}$$

$$\eta_c = \frac{mC_p\ (T_o - T_i)}{I.A} \tag{5}$$

Where 'm' is the mass flow rate of air in kg/sec, C_p is the specific heat of air in kJ/kg K, T_o is the collector outlet temperature in ^{o}C and T_i is the collector inlet temperature in ^{o}C. Dryer efficiency (η_d) of a system is defined as the ratio of energy used to evaporate the moisture from the product to the energy supplied to the dryer. In the case of forced convection dryer the energy consumption of blower is taken into account. The efficiency of forced convection and natural convection solar biomass hybrid dryer is calculated by the following expression:

$$\eta_d = \frac{m_w h_{fg}}{IAt + E + m_f C_v} \times 100 \tag{6}$$

$$\eta_d = \frac{m_w h_{fg}}{IAt + m_f C_v} \times 100 \tag{7}$$

Where 'm_w' is the mass of moisture evaporated at a time in kg, h_{fg} is the latent heat of vaporization of water for the drying chamber in kJ/kg, E is the energy consumption of blower in kWh, m_f is the mass of fuel used in kg/hr, Cv is the calorific value of wood chips in kJ/kg.

The effectiveness factor can be defined as the ratio of the drying rate in the indirect solar dryer to that in the open sun drying:

$$\text{Effectiveness factor} = \frac{\text{Drying rate in hybrid mode}}{\text{Drying rate in sun drying}} \tag{8}$$

4. Results and Discussion

4.1. Analysis of temperature profile inside the dryer

The results obtained by running the dryer from 8am to 5pm in hybrid natural convection mode are shown in Fig. 3. The ambient air temperature at the dryer inlet varies from 28 to 32ºC and solar intensity varies from 600W/m² to 880W/m² on the test day.

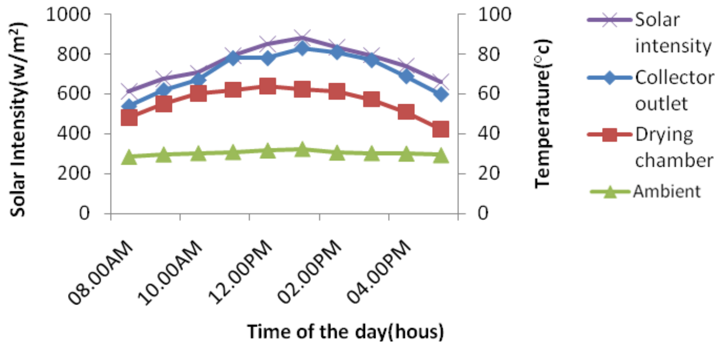

Fig. 3 Temperature profile inside the dryer in Hybrid natural mode

The collector outlet temperature varies from 50 to 80°C and drying chamber temperature varies from 50 to 65°C. Average temperature gain in the collector is around 41ºC in the hybrid natural mode. During this period the bottom, middle and top tray temperatures are almost the same.

The results obtained for running dryer from 8am to 5pm in the hybrid forced convection mode are shown in Fig. 4. The ambient air temperature at the dryer inlet varies from 28 to 33ºC and solar intensity varies from 600W/m² to 960W/m². An optimum air flow rate of 0.042 kg s^{-1} is maintained during the forced mode operation. The collector outlet temperature varies between 60 and 90°C. The drying chamber temperature remains between 55-70°C which is ideally suitable for drying of cashew. Average temperature gain in the collector is around 45ºC in the hybrid forced mode, respectively.

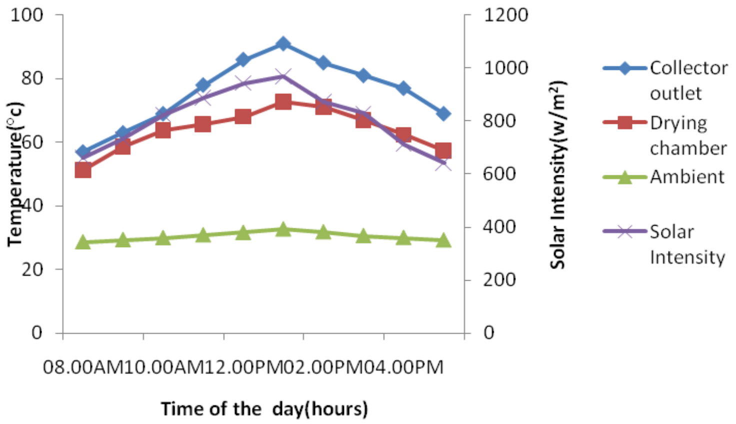

Fig. 4 Temperature profile inside the dryer in Hybrid forced mode

Maximum average temperature of 62.5 C is measured at the top tray and temperatures of 63.7°C and 62.5ºC are observed in the middle and bottom tray, respectively (Table 3). The temperature recorded inside the drying chamber in the hybrid forced mode is moderately higher than that in the hybrid natural mode. A slight decreasing temperature profile is observed from the bottom to the top tray of the dryer. There are no significant variations in different tray temperature. This ensures uniformity in drying to maintain the commercial value of the product. Uniform temperature inside the drying chamber is also essential for avoidance of searing and under-drying.

Table 3 Collector and drier efficiency at different drying modes (%)

Drying mode	Average collector outlet temperature	Drying Chamber Bottom	Drying Chamber Middle	Drying Chamber Top
Hybrid natural mode	71.4	57.5	56.4	55.1
Hybrid forced mode	75.6	65	63.7	62.5

4.2. Moisture loss and drying rate

The initial moisture content of the Cashew nut shell is 9.29%.The desired final moisture content is in the range of 3.5 to 4.6 %. Fig. 5 shows the variation of drying rate in the sun drying, the hybrid natural mode and the hybrid forced convection mode with time. The average drying rate by the hybrid forced and the hybrid natural drying are 0.0012 and 0.00088 kg/hr, respectively. Variation of moisture content with drying time is shown in Fig.6. Final moisture content of 3.5 % is obtained within 7 hours of drying in the forced convection mode, whereas it takes 9 hours of drying in the natural convection mode. However, it takes more than 14 hrs in the open sun drying. The sun drying performance is purely influenced by the climatologically conditions like ambient temperature, relative humidity and solar intensity. The ambient temperature is fluctuating and not sufficient enough to dry the cashew within permissible time. This prolonged drying time leads to poor product quality which is not acceptable for cash crops like cashew. In all the three cases, the drying rate decreases with the decrease in moisture content.

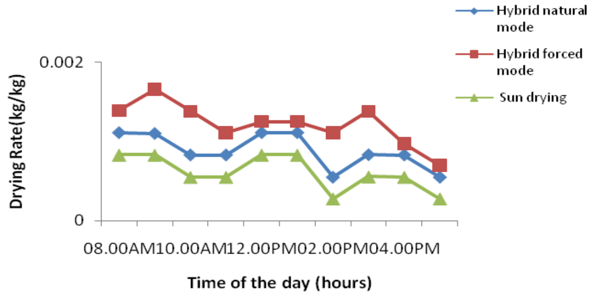

Fig. 5 Variation of drying rate with time

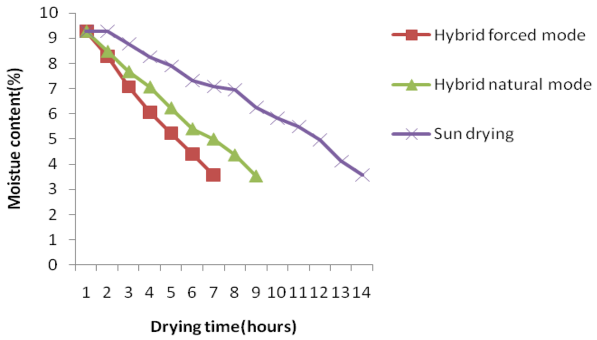

Fig. 6 Variation of moisture content with drying time

4.3. Thermal efficiency of the solar collector and dryer

The efficiency of the solar collector depends on the inlet air flow rate and outlet temperature of collector and solar intensity. Fig. 7 shows the variation of collector efficiency with time in the hybrid natural and the forced mode. Maximum efficiency of 40 - 55% is obtained in the hybrid natural mode. Collector efficiency ranging from 58% and 90% is obtained in the hybrid forced mode.

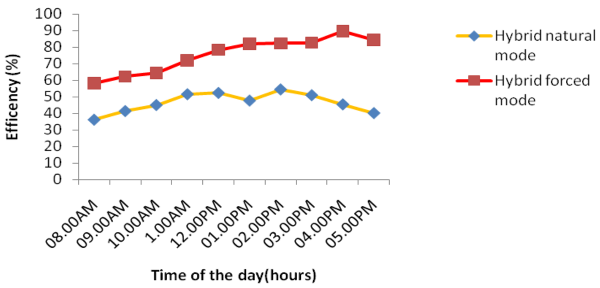

Fig. 7 Variation of collector efficiency with time

The solar air heating collector efficiency follows a similar pattern of the solar intensity**.** Overall drying efficiency has been evaluated for the system based on the energy used to evaporate the moisture from the product to the total input energy (solar intensity + biomass fuel) supplied to the drier. The latent heat of vaporization is calculated by means of the average drying chamber temperature from standard steam tables. Fuel wood of 0.5 kg/hr is burned during the natural mode operation .The hourly efficiency of the dryer run by in natural convection mode varies from 2% to 4%. Fuel wood of 0.75 kg/hr is burned during the forced mode operation. The hourly efficiency of the dryer in forced convection mode varies from 3 to 8 % as shown in Fig. 8. Also the average dryer efficiency and collector efficiency in both modes of operation is depicted in Table 4.

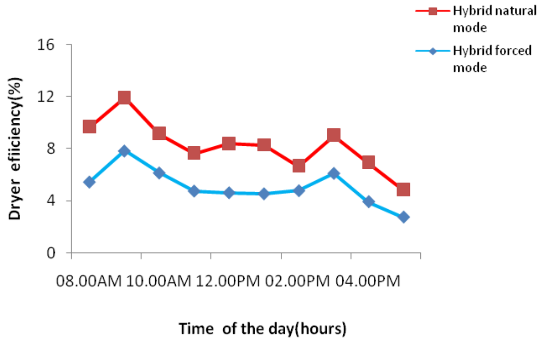

Fig. 8 Variation of dryer efficiency with time

Table 4 Collector and drier efficiency at different drying modes (%)

Drying mode	Collector efficiency (%)	Overall dryer System efficiency (%)
Hybrid natural mode	46.6	3.17
Hybrid forced mode	75.64	5.08

4.4. Effectiveness of the drying

The variation of drying time versus effectiveness factor is shown in Fig. 9. It is observed that the effectiveness factor is always higher than one except during the last phase of the drying time. A high effectiveness factor of 13.25 indicates the usefulness of the hybrid dryer as compared to the sun drying.

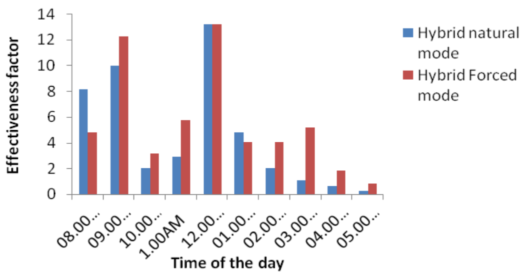

Fig. 9 Variation of effectiveness factor with time

4.5. Quality evaluation and energy conservation benefits

The dried cashew nut kernels from both the test conditions are analyzed for their quality. The kernels are graded manually by using a hand/ sieve. The grading is carried out in accordance with the Export criteria set by the Indian government. Kernel dried in both the mode is having size conforming to W 240 (between 485-530 kernels per kg) superior quality grade. There is no significant scorched and splits kernel among the dried samples in the hybrid forced and the natural mode. The conventional drying of cashew nut using steam drying to reduce the moisture content from 10 % to below 3.5% is one of the energy intensive operations in cashew nut processing industry. The hybrid solar biomass drying technology reduces the drying time and cost of energy associated with the conventional drying operation. The system could be one of the most viable options for the cashew nut farmers.

5. CONCLUSIONS

The solar biomass hybrid dryer has been fabricated for the purpose of drying 40kg of cashew nut per batch. The average collector efficiency of the system in the hybrid forced mode is 75.6%. Temperature between 5575ºC and 75ºC can be obtained depending on the weather conditions and fuel used. This is a practical technology which can be used for dying of cashew as well as of other agricultural products. This system could reduce drying time by half when compared to the open sun drying and it produces a high quality cashew nut (W240). Improvements in the performances of dryer could be achieved through further modification which include (1) providing the parabolic reflector on both sides of the collector, (2) increasing the absorptivity of the absorber plate by replacing copper plate with aluminum one, (4) increasing air flow rates, and (5) providing PVT operated electrical heating coil. It can be concluded that the developed dryer is more suitable for cashew nut farmers in rural areas of developing countries.

REFERENCES

1. Senthil A., Mahesh, M.P., 2013, *Analysis of Cashew Nut Production In India*, Asia Pacific Journal of Marketing and Management Review 2(3), pp. 106-110.
2. Babaganna G.,Silas K., Ahmed M., 2012, *Solar dryer an effective tool for agricultural products preservation*, Journal of Applied Technology in Environmental sanitation 2(1), pp.31-38.
3. Atul M., Sudhir J., Powar, A.G., 2010, *Energy Option for Small Scale Cashew nut processing in India*, Energy Research Journal 1(1), pp. 47-50.
4. Atul Mohod, Sudhir Jain , Ashok Powar, 2011, *Quantification of energy consumption for cashew nut (Anacardium occidentale L.) processing operations*, International Journal of Sustainable Energy 30, S11-S23.
5. Muhammad, H., Muhammad, R., Muhammad, A., 2012, *Drying of Grapes using Dish Type Solar Air Heater*, Journal of Agricultural Research 50(3), pp.423-431
6. Debbarma M., Rawat P., Sudhakar K., 2013, *Thermal performance of Low cost solar bamboo dryer*, International Journal of Chem Tech Research. 5**,** pp. 1041-1045.
7. Amer B.M.A., Hossain M.A., Gottschalk, K., 2010, *Design and Performance Evaluation of a New Hybrid Solar Dryer for Banana*, Energy Conversion and Management 51, pp. 813-820
8. Hossain M.A., Amer B.M.A., Gottschalk K., 2008, *Hybrid solar dryer for quality dried tomato*, Drying Technology 26, pp. 1591-1601
9. Pardhi B.P., Bhagoria, J.L., 2013, *Development and performance evaluation of mixed mode solar dryer with forced convection*, International Journal of Energy and Environmental Engineering, 4(23)

10. Andrew Ragai Henry Rigit, Abdul Qauoom Jakhrani, Shakeel Ahmed Kamboh, Patrick Low Tiong Kie, 2013, *Development of an Indirect Solar Dryer with Biomass Backup Heater for Drying Pepper Berries*, World Applied Sciences Journal 22 (9), pp. 1241-1251.
11. Azimi A., Tavakoli T., Beheshti H.K., Rahimi A., 2012, *Experimental study on eggplant drying by an Indirect Solar Dryer and Open Sun drying*, Iranica Journal of Energy and Environment 3(4), pp. 347-353.
12. Tarigan, E., Tekasakul, P., 2005, *A mixed-mode natural convection solar dryer with biomass burner and heat storage back-up heater*, Proceedings of the Australia and New Zealand Solar Energy Society Annual Conference, pp. 1–9.

DIZAJN I TERMIČKA PERFORMANSA HIBRIDNE SOLARNE SUŠILICE SA BIOMASOM ZA SUŠENJE INDIJSKOG ORAHA

Sušenje indijskog oraha radi uklanjanja ljuske jeste jedan od energijski najzahtevnijih procesa u agro-industriji. Iz tog razloga je projektovana i proizvedena hibridna sušilica koja se sastoji od solarnog kolektora sa ravnom pločom, grejača sa biomasom i komorom za sušenje. U eksperimentu se koristi 40kg indijskog oraha sa početnom vlažnošću od 9%. Testiranje performanse sušilice se obavilo u dva radna režima: sa hibridno-indukovanom cirkulacijom i sa hibridno-prirodnom cirkulacijom. Procenjeni su vreme sušenja i efikasnost sušenja tokom ova dva radna režima i upoređeni sa sušenjem na suncu. Sistem je sposoban da postigne temperaturu sušenja između 50 º i 70 º. Kod hibridno-indukovanog sušenja, traženi sadržaj vlažnosti od 3% postiže se za 7 sati a prosečna efikasnost sistema je procenjena na 5,08%. Kod hibridno-prirodnog sušenja, traženi sadržaj vlažnosti postiže se za 9 sati a prosečna efikasnost sistema je procenjena na 3.17%. Potrošnja goriva tokom procesa sušenja je 0,5 kg na sat i 0,75 kg na sat za indukovani i za prirodni režim, respektivno. Proces sušenja kod hibridno-indukovanog režima rada je dva puta brži nego kod sušenja na suncu. Sušilica se može koristiti pod bilo kojim klimatskim uslovima: kao solarna u normalne sunčane dane, kao sušilica sa biomasom noću i kao hibridna sušilica kada je oblačno. Na osnovu ovog eksperimentalnog istraživanja, zaključuje se da je razvijena hibridna sušilica pogodna za male odgajivače indijskog oraha u seoskim oblastima zemalja u razvoju.

Ključne reči: *solarna sušilica sa biomasom, efikasnost kolektora, hibridna sušilica, indijski orah, stopa sušenja*