Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

Advances in Applied Science Research, 2015, 6(8):101-111

ISSN: 0976-8610
CODEN (USA): AASRFC

Design and performance evaluation of biomass dryer for cashewnut processing

S. Dhanushkodi[1], Vincent H. Wilson[2] and K. Sudhakar[3]

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

---

ABSTRACT

Design and construction of biomass dryer for small scale cashew kernel drying is presented in this work. It uses the biomass heater for producing hot air, blower for supplying hot air and drying chamber for accommodating the products to be dried. Performance characteristics of the biomass dryer including system efficiency has been evaluated experimentally based on drying of 40 kg of cashew kernel. The dryer is capable of producing hot air continuously with temperature ranging between 70 to 75°C. Performance analysis showed that the moisture reduction from 9% to 4% was achieved within 7 hours in biomass drying and it had taken almost 15 hours in open sun drying. The system efficiency of the dryer was found to be 9.5%. The main features of the dryer is to maintain uniform temperature across the tray by using chimney effect and an acceptable system efficiency. The dryer has been designed as an substitute to the electrical and conventional dryers. It is simple in construction and it is suitable for small scale cashew industries present in both rural and urban areas of India.

Key words: Biomass gasifier stove, System efficiency, Drying rate, Moisture content, Cashew kernel

---

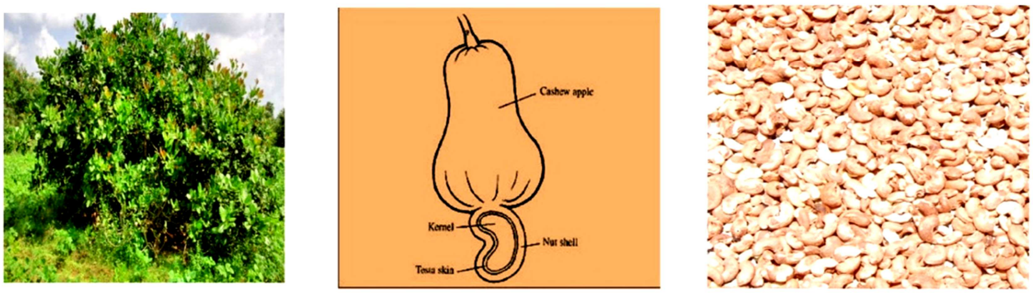
INTRODUCTION

Anacardium occidentale L(Cashew) in India.

Anacardium occidentale L(Cashew) is an important commercial plantation crop that provides employment,food and foreign exchange to many farmers in India. Portuguese travellers introduced cashew tree in 16th century along Malabar coast of India. Later it spread as a popular crop in coastal states like Tamilnadu,Kerala,Karnataka,Andhra Pradesh,Maharashtra,Goa,West Bengal and Orissa.

Cashew tree is evergreen and grows upto 12 meters high and has a spread of 25 meters (Figure 1). Cashew fruit is edible false fruit with the nut outside the fruit.Cashew nut shell is leathery in raw state and contains thick vesicant oil.

A thin pink color skin surrounds the cashew kernel and keeps it separated from the inside of the shell.



Cashew tree Cashew Fruit Cashew Kernels

Figure 1: Schematic diagram of Cashew tree,cashew fruit and cashew kernel

India is the third largest producer of cashew nut in the world (17.3%) and it produces 7.0 Lakh MT of raw cashew nut from an area of around 9.45 lakh hectares with an average productivity of 720kg/ha [1].

Indian cashews are consumed in as many as 60 countries around the world and is well acclaimed for its good quality,taste and appearance. India has around 3650 cashew processing Industries scattered across various states of the country [2].

The most energy intensive operation in cashew processing are drying of cashew nut,steaming of raw nut and drying of cashew kernel. During the cashew kernel drying process the initial moisture content of the raw cashew kernel 9% will be reduced to the optimum final moisture content of 3%. This drying process needs 65-70^{o}C for 6-8 hours [3] .

Literature review

Sachinananda et al. [4] developed biomass fired dryer for copra in sub-tropical climate. It took 22 hours to reduce initial moisture content from 54.7% to 6.8 % which saved 40% and 47% of total drying time compared to traditional methods.

Jevgenijs et al. [5] carried out research on wood products such as wood chips and sawdust drying in rotary dryer. The dryer was tested experimentally and calculations were carried out based on the industrial conditions. On the basis of empirical models datas were collected and the relationship between the parameters were found. On conclusion it is found that moisture content of the raw sawdust has high level of moisture reduction.

Mohapatra et al. [6] developed a natural convection grain dryer for drying paddy and other cereals by use of thermal energy effectively. Average drying temperature of paddy is between 50°C to 58°C. For drying 100 kg of paddy the drying efficiency of the system is estimated as 50.4%. A 20kg of paraffin wax grade-II was used as a phase change material for constant rate of drying. The moisture content of the product is reduced from 30.1% to 14.6%.

Bukola and Ayoola [7] evaluated the performance of a mixed-mode solar dryer. The experiment was conducted in ogun state, Nigeria. The yam chips were used for the experiment and the temperature rises inside the drying cabinet was upto 74% within 3hours immediately after 12:00 noon. The drying rate was upto 0.62 kgh^{-1}, the moisture removed from yam chips were 85.4% and collector efficiency was upto 57.5%. This dryer is suitable for drying a superior quality of products.

Reyes et al. [8] developed hybrid solar dryer for dehydration of tomato. In this dryer, the air temperature is increased to 18°C above the ambient temperature. The various drying curves are obtained at different operation conditions and this curves exibhit good adjustment with empirical models of page such as modified page, Henderson and pabis model. Resulting in the value of R^2 is higher than 0.99 for this three models. The sorption isotherms of rehydration were determined by Guggenheim-Anderson-Boer and peleg models. This two models exibhit good adjustment with RMSE and RMSE is lower than 0.24. the result obtained by this paper is water is rehydrated into to ± 2% for all runs, in less than 20 minutes and the energy is saved upto 6.6 – 12.5%

Amer et al. [9] developed a new hybrid solar dryer for drying banana. In this dryer, the total capacity of the dryer is 30 kg of banana slice. At the end of the drying the moisture content reduced from 82% to 18%. This dryer can be used with some auxillary heat source during the day time, about 15°C of heat can be stored in water and it transfers the stored heat to the solar dryer at night time.

Jaishree Prasad et al. [10] studied the performance evaluation of hybrid drier for turmeric drying and temperature ranging between 55 and 60°C. The efficiency obtained from the quantitative analysis shows that 28.57%.

Mursalim et al. [11] developed natural convection solar dryer for drying Cashew Nut in Shells (CNS). The dryer could heat dry air upto 78°C temperature and also high quality standard product was obtained through this process.

Debbarma et al. [12] designed and developed a low cost bamboo solar dryer at MANIT Bhopal ,India to test its performance for crop drying. The dryer is a greenhouse-type designed for multi-crop solar drying. The solar bamboo dryer reduces the moisture content of green chillies from 90% to 10% in 20 hours with an average efficiency of 17%.

Problem identification

Many small scale cashew nut industries in India have adopted open sun drying,electrical drying, and steam drying for cashew kernel processing. In open sun drying cashew kernels are spread uniformly on mats, cement floor, roof top and exposed to direct sun light. The cashew kernel are dried up consequently and internal temperature raise without uniformity that destroys vitamins, flavor and color of the cashew kernels. Moreover sun drying affects high products loss due to inadequate solar radiation during rainy or cloudy days and its unavailability at night time. It is also affected by encroachment of insects, fungal growth, birds and rodents etc. Other drying methods such as electrical drying, steam drying are energy intensive and cost expensive.Curently small scale processing industries are facing severe problems like high energy cost and environmental issues associated with steam and electrical drying. Therefore there is need of sustainable solution to overcome the present energy crisis .While there are several options of renewable energy, biomass technology is the right and suitable option for drying of cashew kernel because it is locally available, environvmental friendly and sustainable .

Reports available in the above literature survey suggest that most of the dryers developed was operated in either in solar mode (or) solar biomass in hybrid mode with the temperature range from 45°C to 60°C. Literature survey clearly shows that so far no research work has been carried out on biomass energy alone for drying cashew nut and other agricultural products. The reports available in the literature fails to find out a solution for cashewnut processing industries.

Hence the present work is carried out to fill the gap left by the researchers/

Objective of the study

The purpose of this work is to study the possibility of using biomass based system for cashew kernel drying. The following are the objective of the study were.

1.To construct and design a biomass dryer for small scale farmers.

2. To evaluates the performance of biomass dryer that employs lowcost biomass as fuel.

3.To test it continuously (day and night) under different conditions and comparing it to traditional open sun drying.

MATERIALS AND METHODS

Design of the biomass dryer

The biomass dryer is developed as an alternative to steam dryer, solar dryer and electrical dryers. The biomass dryer design was based on the following considerations :

1.Area selected for the study has a considerable production of cashew.

2.Local availability of biomass resources .

3.Indirect heating method ie drying air and flue-gas from biomass burner would not be mixed.

4.Inlet drying air temperature would be in the range 70-75°C.

5.Temperature control of drying air is obtained by controlling the feed of biomass and speed of the blower.

6.Biomass heater is designed to operate continuously for an hour with one time loading of wood or briquettes.

The biomass dryer consist of biomass heater, drying chamber and chimney. The detailed schematic diagram of the system are shown in Figure.2. The biomass dryer consumes about 0.75 kg per hour of wood or 1.5 kg per hour of briquettes. The system can provide a drying air temperature of upto 75°C.

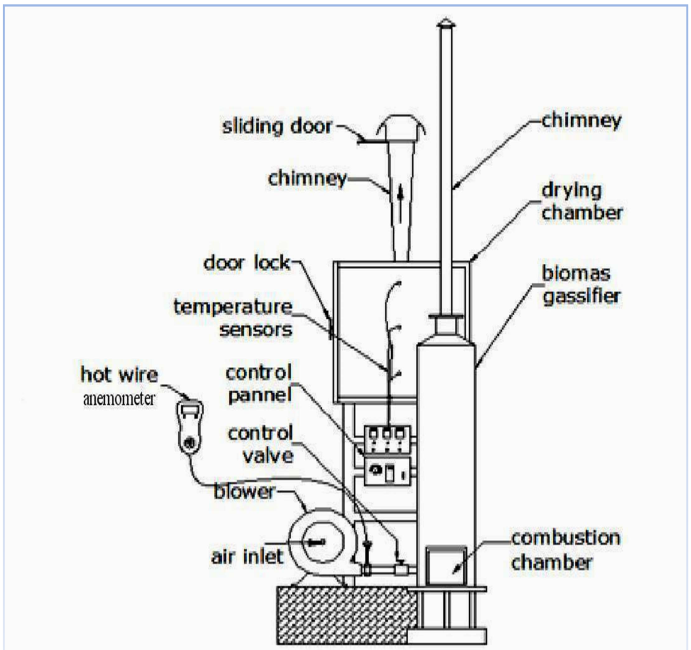


Figure 2: Schematic diagram of biomass dryer

Table 1: Technical Specification of Indirect Forced Biomass Dryer

Component	Specifications
Drying chamber	
Size of aluminium trays	0.64×0.6×0.73m
Tray area	0.54×0.51m
Chimney with increasing cross section	Bottom 0.16×0.16, Top 0.2×0.2 & Height 0.16 m
Number of Trays	10
Tray thickness	0.003m
Height of Stand	1.2m
Chimney pipe diameter	0.076m
Length of the chimney	1.30m
Blower	
Capacity, Speed & Voltage	0.37KW, 0-2800 Rpm & 440 V (A.C)
Biomass Heater	
Diameter of inner shell	0.34m
Diameter of outer shell	0.42m
Height	0.94m
Shell thickness	0.003m
Drying capacity	40 Kg

Biomass heater

The biomass heater is made up of 3 mm thick mild steel plate and it has four main parts namely, inner and outer shell, cross pipe, chimney, inlet and outlet openings for air circulation. The inner shell is in cylindrical shape and located above the base. The base of the gasifier act as combustion chamber. A gate with locking arrangement is provided in the combustion chamber for loading of fuel and disposal of ash. The outer cylindrical shaped shell surmounts the inner shell. It has two manifolds, one act as inlet for ambient air and the other acts as outlet for hot air. The top part of the outer shell is conical shaped, above which chimney is attached. At the middle of the inner shell a cylindrical MS cross pipe is located and connected by welded joint. The main purpose of the cross pipe is to direct the flame towards the outer periphery of inner cylindrical shell. A aluminium duct with 8 mm thick glass wool insulation is provided at the outside of the shell to prevent heat loss. The technical specification of the biomass dryer is shown in Table 1.

Drying chamber

The drying cabinet consists of four important parts namely the basic frame, drying trays, drying chamber and loading doors. The chamber is designed by Galvanized iron sheet of 1mm thickness with length, breadth and height of 0.64m x 0.6m x 0.73m and with mild steel frame. Perforated aluminium drying trays are placed inside a drying chamber at a distance of 0.05m apart from bottom to top. A door with locking facility is provided for loading and unloading of cashew kernel at the front side of the drying chamber. To regulate the air flow a sliding door is provided at the top of the chimney. The biomass dryer with drying chamber is shown in figure.3.

Figure 3. Pictorial view of biomass dryer and drying chamber

EXPERIMENTAL PROCEDURES

Biomass drying : Drying experiments were carried out at Department of Mechanical Engineering, PRIST University, Puducherry (11.93° N, 79.83° E) to study the performance of the biomass dryer. 40 kg of fresh cashew kernel was procured from local cashewnut processing industry with initial moisture content of 10% . These were weighed and spread uniformly in all trays. Drying was started after burning of biomass fuel in the heater. Initially 0.5 kg of wood pieces were used for biomass combustion. Weight loss of the samples were measured every one hour till the sample reaches the required moisture content.

Sun drying : Similar experiments were also conducted in open sun drying. The experimental results obtined from biomass drying are compared with open sun drying.

Instrumentation

Ambient temperature, drying chamber and gasifier outlet temperature were measured using RTDs. The ambient relative humidity and humidity inside the drying chamber are measured using thermo hygrometer. Flow rate of air supplied to the drying chamber was measured with a hotwire anemometer. Energy meter measures energy consumption of the blower. Bottom, middle and top tray temperature of drying chamber are measured using thermocouple. The specification of the instruments used in the experiment are listed in Table 2.

Table 2 Instrumentation

S.No	Parameters	Instruments	Accuracy
1	Temperature (drying chamber)	Thermocouple	0.05
2	Mass	Electronic balance	0.01g
3	Air Velocity	Hot wire anemometer	±2.5%
4	Power consumption of blower	Energy meter	±0.1Kwh
5	Relative Humidity	Thermo hygrometer	±2.5%
6	Ambient temperature and Gasifier outlet	RTDs	0.01°C

Thermal Analysis of dryer performance

The following parameters are calculated to assess the dryer performance.

1. Moisture content:

The moisture content 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.

$$M_c = \frac{M_i - M_d}{M_i} \times 100 \qquad (1)$$

2. Drying rate:

The drying rate was found by decrease of the water concentration during the time interval between two subsequent measurements divided by this time interval.

$$R_d = \frac{M_i - M_d}{t} \qquad (2)$$

3. Biomass heater combustion efficiency:

Biomass heater combustion efficiency (η_g) can be defined as the ratio of useful heat gain over the product of fuel consumption and calorific value.It can be expressed as

$$\eta_g = \frac{m_f.c_p(T_o - T_i)}{FC.CV} \qquad (3)$$

Biomass heater efficiency for forced convection mode is

$$\eta_g = \frac{m_f.c_p(T_o - T_i)}{FC.CV + E} \qquad (4)$$

4. Drying chamber efficiency:

It can be defined as the ratio of difference between the drying chamber inlet and drying chamber outlet temperature to the difference between the drying chamber inlet and ambient temperature.

$$\eta_d = \frac{(T_1 - T_2)}{(T_1 - T_a)} \qquad (5)$$

5. Biomass system /overall efficiency:

System efficiency is defined as the ratio of the energy required to evaporate the moisture to the heat supplied to the drier . It is a measure of the overall effectiveness of a drying system, including biomass heater and dryer chamber. It can be expressed as

$$\eta_s = \frac{\text{Ø}xL(Mi - Md)}{FCXCV(100 - Mi)} \qquad (6)$$

6. Effectiveness factor:

It can be defined as ratio of drying rate in the biomass dryer to the drying rate in the open sun drying.

$$= \frac{\text{drying rate in Indirect biomass dryer}}{\text{drying rate in open sun drying}} \qquad (7)$$

7. Saving in drying time:
Using the following equation saving in drying time is calculated and compared to the open sun drying

$$= \frac{t_{os} - t_{bd}}{t_{os}} \times 100 \qquad (8)$$

RESULTS AND DISCUSSION

Drying load test
The drying tests were carried out using the biomass dryer due to unfavourable weather conditions and when solar radiation was not available at the said area. The biomass gasifier heater was used for drying of 40 kg/batch of cashew kernel. By burning waste biomass (wood pieces) of 1kg, 75°C can be achieved within 40 minutes in the system. The ambient air temperature and air temperature inside the drying chamber throughout the experimental duration is presented in Table.3. From the Table, it is seen that the ambient air temperature varied from 28.8±0.5°C to 31.5±0.5°C. The biomass heater outlet air temperature varied from 70.0±0.5°C to 75.0±0.5°C. The average air temperature raised inside drying chamber over ambient temperature was 30°C -35°C during the full load condition. The maximum temperature obtained inside the drying chamber was 74°C. The temperature of the top tray measures 65°C and temperature of bottom & middle tray were 70°C and 69°C respectively. The dryer is able to maintain this temperature, regardless of outdoor ambient conditions. The difference between the gasifier outlet and drying chamber inlet air temperature is considered as negligible because of the adequate insulation provided for the duct connecting the biomass gasifier and dryer chamber.

Table 3. A typical day results of biomass drying

Time	Ti (°C)	To (°C)	Drying chamber temperature (°C)				Humidity (°C)		Mass of product (kg)	
			Outlet	**Bottom**	**Middle**	**Top**	**Ambient**	**Drying Chamber**	**Initial**	**Final**
09.00	29.2	70	57	69	65	58	62	40	500	494
10.00	30	73	58	70	64	59	61	38	494	489
11.00	31	75	63	74	69	65	60	39	489	484.5
12.00	31.2	74	60	71	68	63	48	40	484.5	480.5
01.00	31.5	75	63	72	69	64	40	41	480.5	477
02.00	31.3	75	64	73	70	65	41	38	477	474
03.00	30	74	62	73	69	63	44	37	474	471.5
04.00	29.8	75	60	71	66	62	50	38	471.5	469.5
05.00	29.2	73	60	70	64	61	55	39	469.5	468
06.00	28.8	73	57	72	63	58	60	40	468	468

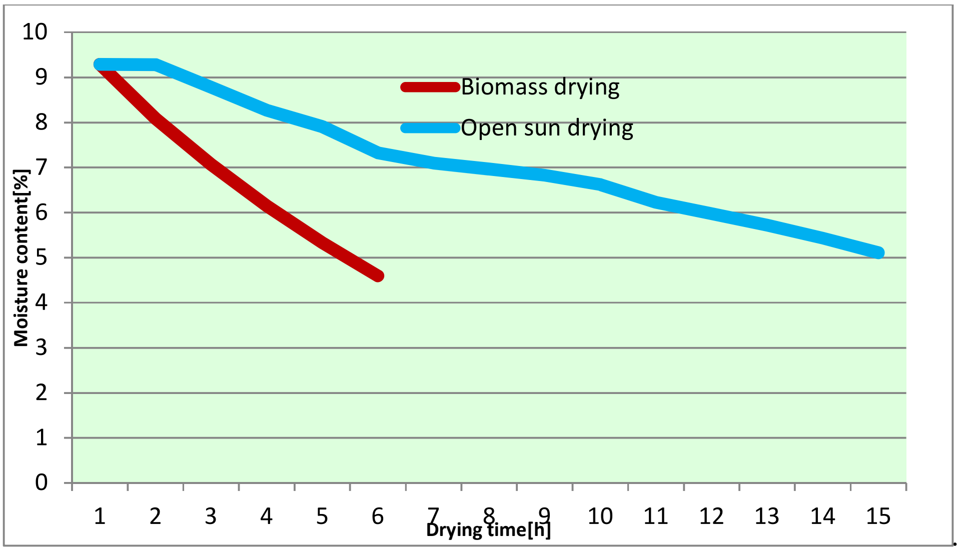


Figure 4.Variation of moisture content with drying time

Drying rate and Moisture loss

Using biomass drying the variation of moisture content in cashew is compared with the conventional sun drying. The initial moisture content of cashewnut kernel is 9% wet basis and it is reduced to the range of 3.5 to 4 % (wb) at the final. This was attained by 15 hours in sun drying and whereas 7 hours in biomass drying. Fig 4 shows the variation of moisture content with drying time.

The drying rate varies with drying time for biomass drying and Fig 5. Represents the sun drying In all these cases, the moisture content decreases with the decrease in drying rate. It is seen that the drying rate is not constant throughout the drying period. The drying curves show a short period of slow drying rate followed by long period of steep drying rate change. Further, it might be commented that a large drying rate is observed corresponding to higher initial moisture content of the product. The drying quality of the product is predominantly affected by the drying rate and drying air temperature.

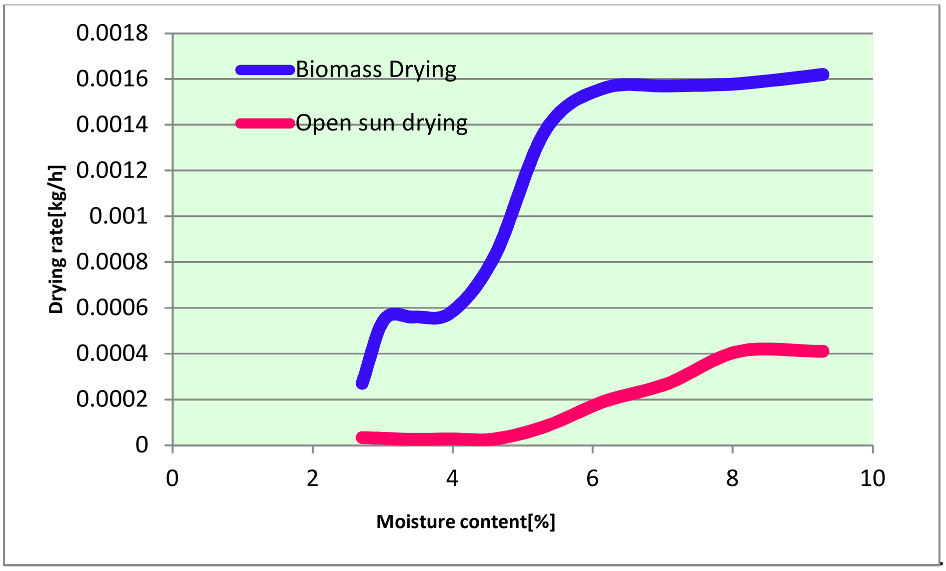


Fig 5 Variation of drying time with drying rate

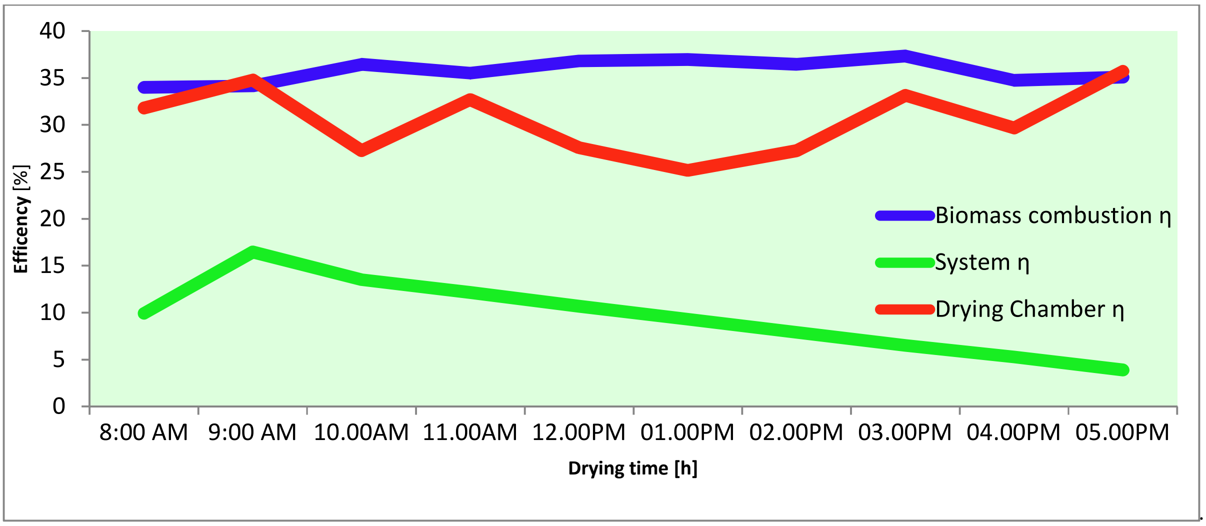


Figure 6. Variation of biomass combustion efficiency with drying time

Thermal efficiency

Fig.6 describes variation in the biomass heater efficiency, drying chamber and system efficiency with time. Biomass heater and drying chamber efficiency follow similar trend. It was observed that maximum efficiency of 36.98% and lowest efficiency of 34.01% was obtained. The average thermal efficiency of biomass heater was calculated as 35%. On the other hand,the drying chamber efficiency varies from 25% to 35%. The average efficiency of drying chamber was found to be 30.5% which indicates a rather effective use of bio energy in drying the product. Biomass heater efficiency and drying chamber efficiency were greater than the system efficiency, as it has always been in most cases.

The overall efficiency of the drier is also represented by the performance evaluation of the drying system. The drier was calculated to be 9.5% in overall system efficiency. It may be noted that the system overall efficiency varies between 4% and 16%. The moisture content of the product decreases with decrease in overall efficiency. At the initial state the overall efficiency will be low and in later state high efficiency is obtained due to decrease in the moisture content. The result indicated shows that the efficiency was low because of nature of the product. Drying efficiency os related to the factors such as chemical and physical properties of dried materials, drying time, local environmental conditions and design of the drying system. System efficiency is also influenced by biomass heater and radiation from the drying chamber. efficiency of the overall dryer could be improved by re circulating some of the exit air. High input air may result in a higher drying rate and a higher temperature.

Effectiveness and saving in drying time.

The variation of effectiveness factor with drying time is shown in Fig.7 The maximum effectiveness factor obtained was 16.32 which is very much higher. Effectiveness factor was found to be higher than one during the drying period. This indicates the usefulness of biomass drying over sun drying. Biomass drying leads to 53.33% of time saving when compared to sun drying. 0.5 kg of fuel wood/hour was used during the experiment. The fuel wood input energy is low as 50 MJ. 3.5 kg of water content was removed from 40 kg of fresh cashew kernel and the moisture content was reduced to 4% . Energy consumed in biomass drying is very less compared to electric drying (504.28 MJ for 60 kg) [1].

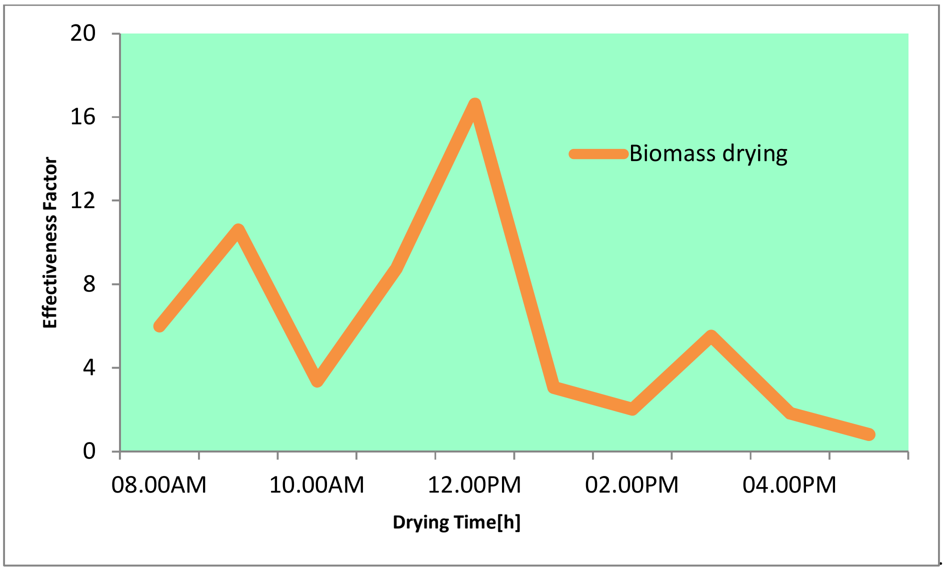


Figure 7.Variation of biomass drying efficency with drying time

Performance variation eith other dryers

Conventional drying of cashew nut kernel using electrical energy as input is highly energy intensive operation. Biomass drying could be one of the viable option for reducing the energy cost associated with cashew kernel drying. Table 4 shows the moisture reduction and drying time of different types of dryers used for cashew kernel drying. The drying efficiency is better in solar-biomass dryer and followed by biomass dryer and solar dryer. Based on the results , hybrid dryer is the better option when compared to solar and biomass dryer.

Table 4. Comparison of drying time of different dryers (drying basis: 40 kg cashew)

Type of Dryer	Moisture reduction	Drying time(hrs)	Reference
Hybrid dryer	9 % to 3%	7	[13]
Solar dryer	10 % to 5%	6	[14]
Biomass dryer	9 % to 4 %	7	In this study
Open sun drying	9 % to 3 %	15	[13-14]

However ,biomass dryer is also one of the profitable option for the area where biomass fuel is abundantly available. The advantageous quality of the biomass dryer is that it can be effectively used during nights and even on rainy days without additional energy from other sources**.** Subsitution of these renewable energy based dryer in small scale cashew processing industries could provide better performance, promote energy security and sustainable development.

Quality evaluation

Dried cashew kernel were peeled and are graded based on size and condition.Physical appearance,size and color of the kernel were observed visually. The surface color was recorded in relation to standard one. Figure 8 shows a photograph of grading operation of the cashewnuts . Sun dried cashew were little bit dark color and their quality got deteriorated. Furthermore, color and texture were also lost in the sun dried cashew. Whereas the color ,texture and appearance were preserved in the biomass dried cashew as determined by visual inspection. Biomass dried cashew were good and bright white in color and having less orange yellow surfaces. Produce dried in biomass drying was having more whole piece without butts and splits than sun dried product. Biomass dried cashew were of superior quality (grade W240) based on CNS standard in India.

Figure 8. Visual quality appearance of the dried cashew

CONCLUSION

A biomass dryer was designed, constructed and tested at PRIST University,Puduchery Campus,India for drying cashew kernel. On the basis of the experimental results the following conclusions are drawn.

- The developed system is suitable for drying maximum of 40 kilograms of cashew in one batch.
- The required air temperature of 65-75°C was obtained with minimum fuel consumption of 0.5-0.75 kg/hr.
- The biomass dryer can dry cashew kernel from a moisture content of 9% w.b. reduced to 3% w.b.within 7 hours.
- Maximum biomass system/overall efficiency of 9.5 % was observed .
- The dryer does not depends on weather condition and can be operated maximum 3 batches per day.
- Experiential results revealed that biomass drying was more efficient than sun drying in significantly increasing drying rate and time.
- And also the dryer performance is improved by incorporating solar unit; the system can be operated as a solar biomass hybrid dryer.
- This dryer produces good quality cashew nut (W240).
- The technology can improve the life style of small scale cashewut farmers in India.

It can be concluded that the new developed biomass dryer is suitable for drying cashew nut and other agricultural products.

REFERENCES

[1]Atul Mohod, Sudhir Jain,Ashok Powar,Naren Rathore,Anil Kumar Kurchania, *Journal of food engineering* . **2010**, 99, 184-189

[2]Atul Mohod, Sudhir Jain,Ashok Powar, *Journal of Sustainable Energy*. **2011**, iFirst: 1-13

[3]Anonymous, 2009. Statistical information. Annual Report, Directorate of Cashew and Cocoa Development Kochi, India, **2006-2007**, 23-28.

[4]Sachidananda Swain, Din M, Chandrika R, Sahoo GP, S Dam Roy, *J Food Process Technol* **2014,**5(1), 294.

[5]Jevgenijs Selivanovs, Dagnija Blumberga, Jelena Ziemele, Andra Blumberga4, Aiga Barisa , *Environmental and climate technologies* , **2012**, 10 :46-50

[6]Mohapatra S. S., D. V. N. Lakshmi,P.Mahanta, *International Journal of Agriculture and Food science technology*, **2013**,4(6), 523-530.

[7]Bukola O Bolaji, Ayoola P.Olalusi, *AU Journal of Technology*. **2008**,11(4), 225-231

[8]Reyes A, Mahn A, Huenulaf P and González T, *J Chem Eng Process Technol*, **2014**, 5:4

[9]Amer B. M. A., M. A Hossain ,K. Gottschalk, *Energy conversion and management*, **2010**, 51: 813-820.

[10] Prasad J, Vijay VK, Tiwari GN, Sorayan VPS. *J Food Eng* , **2006,** 75(4), 497–502

[11] Mursalim, Supratomo, Yuliani Shinta Dewi, *Science & Technology* ,**2002,** 3(2):25–33.

[12] Debbarma M., Rawat P., Sudhakar K., *International Journal of Chem Tech Research*. **2013**,5**,** 1041-1045

[13] Dhanushkodi Saravanan,Vincent H.Wilson, Sudhakar Kumarasamy, *Facta Universitatis Series : Mechanical Engineering* **2014**,12(3). 277-288.

[14] Dhanushkodi S,Vincent H.Wilson, K. Sudhakar, *American-Eurasian Journal of Agricutural and Environmental Science*. **2014**, 14(11): 1248-1254.

NOMENCLATURE

Cp - Specific heat of air (kJ / kg-K)
CV-Calorific value of wood (14,200 kJ/kg)
DR – Drying rate
E- Energy consumption of the blower (kWh)
FC-Fuel consumption(kg/hr)
L- Latent heat of vaporization (2.26 x10^3 kJ/ kg)
mf- mass of flue gas (kg/h)
M_i *– Initial mass of sample before drying (kg)*
M_d *- Final mass of sample after drying (kg)*
t - Time of drying (sec)
t_{OS}*- time taken for drying the product in open sun (h)*
t_{bd}*- time taken for drying in biomass heating(h)*
T_o *- Outlet air temperature of biomass heater (°C)*
T_i *- Ambient air temperature (or) Inlet air temperature (°C)*
T_1 *– Drying chamber inlet temperature (°C)*
T_2 *– Drying chamber outlet temperature (°C)*
T_a *– Ambient temperature (°C)*
Ø- Quantity of final dried product at final moisture content (kg)
η_g *– Biomass gasifier efficiency(%)*
η_d *– Drying chamber efficiency(%)*
η_s *– Overall system efficiency (%)*