International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Indirect Natural Convection Air Flow through Valvular Conduit Duct Type Solar Dryer for Agricultural and Marine Products

Sarjeet Kumar[1], Adit Rana[2], Ravinder Kumar[3], Raminder Preet Pal Singh[4]

[1]M. tech Scholar Department of Mechanical Engineering Sri Sai University Palampur dist Kangra Himachal Pradesh
[2]Assistant Professor Department of Mechanical Engineering, Sri Sai University Palampur dist Kangra Himachal Pradesh India
[3] Head of Department Mechanicalical Engineering, Sri Sai University Palampur dist Kangra Himachal Pradesh India
[4]Dean Engineering Department of Mechanical Engineering, Sri Sai University Palampur dist Kangra

ABSTRACT

This paper presents the valvular conduit unidirectional air flow solar dryer design and fabricated to harness the maximum available solar energy with restricted back flow and minimum thermal losses around the collector section. In this proposed solar dryer natural convection air draft is used for drying and the drying chamber is equipped with an array of sensors temperature and humidity sensors to control required temperature and humidity range. A thin acrylic polycarbonate transparent glazing is placed over the collector section to trap and harness the thermal energy from incoming solar irradiation. Due to the greenhouse effect caused by glazing in collector section will raise the temperature and decrease the relative humidity of ambient air. This heated and dehumidified air is used for drying operation along with the advantage of eliminating moisture content by avoiding any possible contamination like in open sun drying operation. Thus the quality of dried product can be achieved to the highest level with a thermal efficiency and pick up efficiency at 62% which is can be consider as significant and the payback period of proposed solar dryer also have very significant number which can also considered as satisfactory.

Keywords: Solar Dryer, Valvular Conduit , Glazing, Unidirectional Air Flow, Global irradiance, Drying Chamber

1. INTRODUCTION

Solar drying is the oldest technique to maintain agricultural and marine products and medicinal herbs. It's used for to reduce the moisture content to its saturation level. The natural utilized heated air is means and moisture concentration gradient thus created causes the movement of moisture from inside to outer surface of the product. Temperature more than the acceptable limit causes both physical and chemical changes and ultimately deteriorates the quality of the dried product. Air supplied at controlled temperature enhances their storage life, minimizes loss and saves transportation cost as most of the water contents are dehydrated. Dehydration of such products is necessary to avoid bacterial and fungal growth.

This energy can reach the earth's surface either in direct form as a beam or extra-terrestrial radiations, or as diffuse solar radiation which has been scattered or reflected off the surface. Approximately 50% of short-wave radiations is reflected back into space, while the remaining is absorbed by the surface and re-radiated as thermal infrared (or long wave) radiation. The atmospheric further reduces direct beam radiation by 10% on clear days, and 99% during periods of thick clouds. The sum of the diffuse and direct solar radiations is called global or solar radiation, while reflected radiation that is either diffuse or direct radiation reflected from the earth's surface completes. A schematic diagram of indirect solar dryer is shown in figure 1.

Solar dryer is essential for dehydrating agricultural products, marine /sea products, medicinal plants and chemicals. Active dryer makes use of an absorber plate to obtain energy from the sun and transport it to the drying chamber where the product is dried, while passive dryer used the natural convection of air to heat the drying chamber. A systematic classification of solar dryers for agricultural and marine products has been developed to address the disadvantages associated with solar drying [1-4]. These new designs have proven very useful for the fruits, vegetables [5-6] with long hours of sunshine. Overall, different types of solar dryers have been developed in recent years for efficient and effective drying of various products [7].

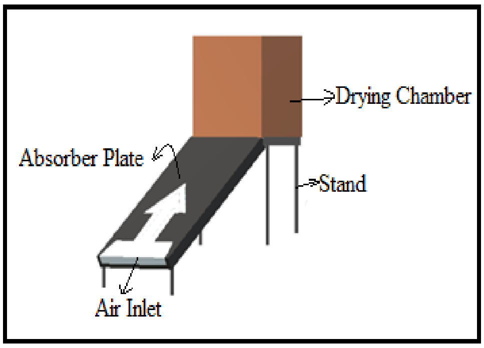

Figure 1: Schematic diagram of valvular conduits connected with drying chamber.

The sustained process is required while drying of agricultural and marine products moisture content is not removing after the sunshine hours. In continuously, global radiation drying the products through the hot air coming in the drying chamber [8]. The temperature of drying chamber is increased in the peak of sunshine hours and also, decreased the temperature after removing the sunshine hours for provide flow the hot air to the dryer [9]. Even the theoretical concept of natural indirect type of solar dryer with the black reversed absorber collector and hot air flow drying chamber was evolved by Jain [10]. After, the solar panel to connect for night time and rainy days to dry the products.

From up to times, different types of fagrant herbs to use in different products to better the taste [11]. Agricultural products and herbs are mainly used in its fresh or dried nature. The controlled temperature needs for the drying of products and herbs because the color and taste of products and herbs can be preserved. So, alternative dryers convert into mechanical dryers. A natural indirect solar dryer with controlled temperature drying procedure can be use [12].

1.2 Natural convection solar drying without thermal storage

The incoming solar radiation is generally harnessed using the thermal solar collector of solar dryer which is utilized the production of dried products efficiently. In India we have very high potential of solar energy that can be efficiently utilized for various applications and it can successfully fulfill overall need and requirements of energy at various distinguish sector [13].

Thus, harnessing this type of free energy will lead to a very cost effective and sustainable system which will easily reduce the base of energy and capital cost. The two best known methods for air flow circulation are: natural convection system and forced convectional system. As natural conventional type system do not required any external source of energy and power unit. Therefore, they required very less depends on different electro mechanical devices and basic work for natural convection type solar dryer with an aim to harness the solar energy and used it for efficient drying application can be successfully achieved.

Therefore, this research paper endeavors to present very new and innovated design for drying application with an enhanced thermal pick up efficiency [14].

The objectives of this proposed solar dryer study are:

1) Valvular unidirectional conduit helped in maintaining the optimum drying temperature and air flow range to achieved thus quality product output.
2) The maximum available solar energy with restricted back flow and thermal losses around the collector section.
3) Significant thermal efficiency of the solar thermal collector.
4) Eliminating various problem like contamination of moisture pollutants and other micros as well macro.

2. Methodology

2.1 The detail description of proposed solar dryer

An indirect type solar dryer equipped with a flat plate absorber unit without thermal storage and natural convection type air flow unit was design and fabricated. The proposed solar dryer is divided into the following major parts as: Newly design flat plate collector equipped with valvular conduit and a drying chamber with natural convection air flow as shown figure 2.

Figure 2**:** Actual setup of Valvular Conduits for air flow in unidirectional solar dryer.

2.1.1 Flat plate collector and new duct system

The solar collector section is an important part of the experimental setup are shown in figure 3 (a), is fabricated from ply-wood flumps of various cross sections. It has a radiation collecting area of 1.25 m ×17.5 m × 0.84 m and is placed at an inclination angle of (320). The design and fabricated collector section equipped with a 0.009 m film which was placed on the flat plate at distance of 0.75m.

The special designed conduit is placed in between the glazing and absorber plate will allow heated air to circulate through the drying chamber for drying application. Valvular conduit collector section of solar dryer is subjected to incoming solar irradiance will pass through the place glazing to the absorber plate. Valvular conduit collector section which will create air circulation as the heated and air will rise towards the drying chamber and remove the moisture content remove from chosen product as shown in figure 3 (b).

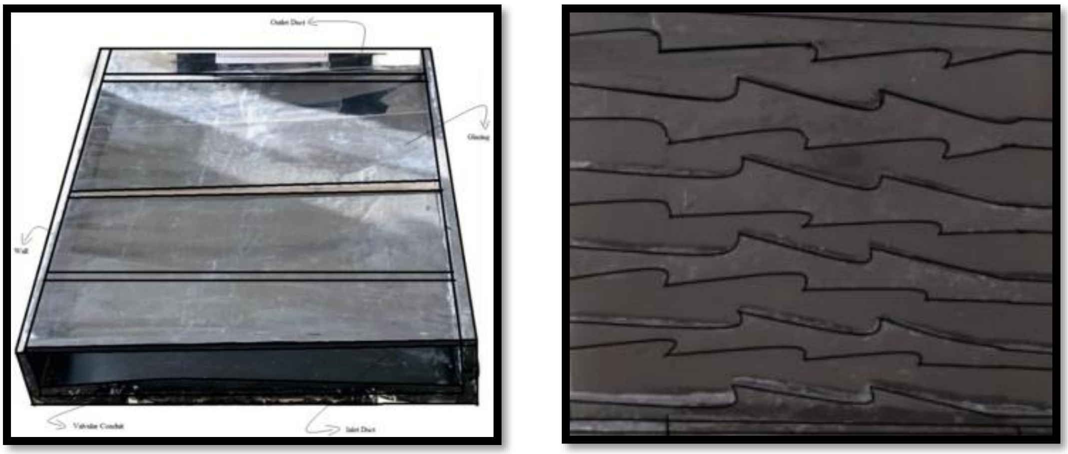

Figure 3 (a), (b): Sectional views of the solar collector and a valvular conduit duct.

2.1.2 Valvular Conduit

Valvular conduits play very important role to achieve unidirectional air flow in the solar dryer. The conduit is made up of made up of wood and painted with black color. The intentional irregular shape of conduit helps in creating significant restricted air flow rate as the various drying process only require the drying air flow rate in a range of 0.5-.9 m/s. The spacing between every section of valvular conduits to each other is 0.85m and the height of each valvular conduit is 1.09 m. The pointy and irregular sharp edges have an approach angle of 2^0-4^o and it will help us to restrict the back flow of heated air to minimize the various thermal losses as shown in figure 4.

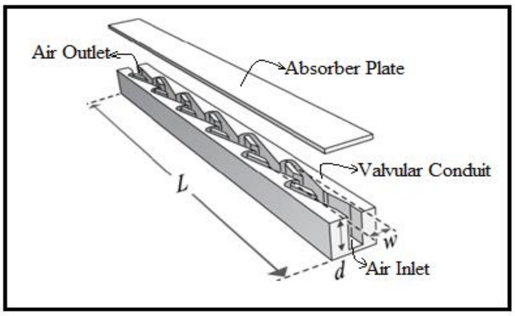

Figure 4: Schematic diagram of valvular conduits with absorber plate.

(A) Air flow restricted in unidirectional

Its major role to circulation the heated air from collector section to drying chamber and also used to harness the maximum available solar energy with restricted back flow and thermal losses around the collector section is shown in figure 5.

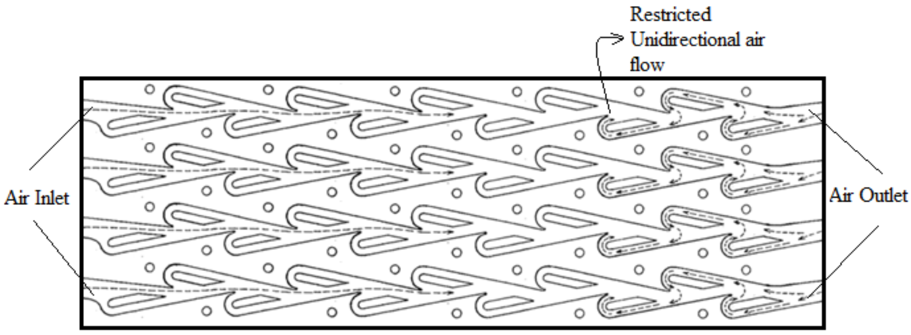

Figure 5: Schematic diagram of restricted unidirectional air flow of valvular conduits.

2.1.3 Drying chamber

A sectional view of the drying chamber is shown in figure 6 and fabricated from plywood flumps of different cross sections. It measures 0.6 m × 0.53 m × 0.375 m, with trays of dimensions 0.42 m × 0.44 m, where the product is dried with hot air from a solar collector. The frame work of the drying chamber is a .003 m thickness of glass sheet and there is a door at the back for product loading and unloading.

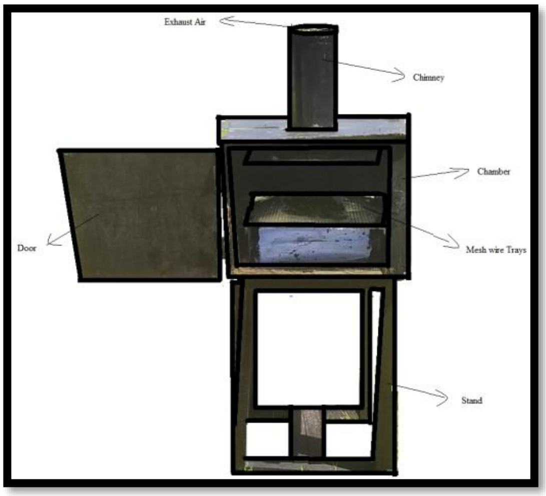

Figure 6: Sectional view of the drying chamber/cabinet.

2.1.4 Natural draft or natural convection air flow system

Natural convection air flow system is design for heat exchanger. The working of natural convection air flow system is warm and moist air is less dense. The cold air enters from the inlet duct of the system.

2.2 Working principal of solar dryer

The solar dryer is placed on a sunny area at Sri Sai University, Palampur (H.P). The collector section of solar dryer is subjected to incoming solar irradiance and the useful solar irradiance will pass through the place glazing to the absorber plate. The glazing will prevent solar radiation from reflecting back and it will create a greenhouse effect resulting the rise in temperature inside the collector section solar dryer which will create air circulation as the heated and air will rise towards the drying chamber which can be used for drying application effectively. The new type of duct used in this solar dryer will help to achieved unidirectional flow. Resulting least thermal losses around the collector section.

2.3 Thermal Performance of proposed solar dryer

Overall the solar dryer observed for selected products reflects the thermal efficiency of collector section and the overall drying efficient solar dryer [15-18]. The overall drying efficiency is defined as the ratio of energy which is essential and necessary to absorber the moisture from the products to the net heated air supplied to the drying chamber. Similarly the heat Energy supplied collector section can be identified by the net solar incident radiance supplied to the collector and data or rise in temperature during the operation till we achieved the study rate condition [19-24]. Therefore the system drying efficiency a major of the overall effectiveness of a proposed solar drying system. And the efficiency a used for the effective utilization of input energy for drying can be explained by the following equation natural convection solar dryer.

Where, (η_{o1}) is the efficiency of drying system being explain the solar collector heated air to supplied the drying chamber for the remove the moisture content through the natural convection are written as [25-28].

$$\eta\,\dot{}_o = \frac{L^*{}_c \sum_{t=1}^{t=24} M^*{}_{ec}}{3600(A_{c^{\cdot}} + A_{p^{\cdot\cdot}}) \sum_{t=1}^{t=24} I_r} \times 100 \qquad (1)$$

So, $L^*{}_c$ is latent heat evaporate the water in JKg^{-1}, $M^*{}_{ec}$ is remove the moisture from product in hourly Kgh^{-1}, $A_{c^{\cdot}} + A_{p^{\cdot\cdot}}$ are the collector area and absorber plate area of natural circulation m^2, I_r is the global radiation for dryer in Wm^{-2} ,

(P_d) Total capital cost per batch of drying can be expressed as:

$$P_d = C_{r^{\cdot}} + C_{o^*} + C_c + L_a + P_e + I_d \qquad (2)$$

Where, $C_{r^{\cdot}}$ Cost of raw material of product, C_{o^*} solar dryer operational cost, C_c maintains cost, L_a annual labor cost, P_e Net per day feasibility for drying, I_d insurance cost of dryer.

Studied the performance of investment in the production can be expressed as:

($P^*{}_r$) is Profits and P_z is total sale price of product

$$P^*{}_r = P_z - P_d \qquad (3)$$

Where, $P^*{}_r$ is Profits and P_z is total sale price of product.

C_s Capital cost of proposed solar dryer can be written as:

$$R^{\cdot\cdot}{}_c = \frac{P^*{}_r}{C_s} \qquad (4)$$

Thus, $R^{\cdot\cdot}{}_c$ is the return of capital also known as profit from the investment and influence by time.

Simple Payback period P_c calculated by expression:

$$P_c = \frac{C_s}{P^*{}_r} \qquad (5)$$

P_c is the investment cost per annual net income.

$$P_v = \sum P_v(1+i)^n - C_s \qquad (6)$$

Where, $P_v = S_n(1+)^{-n}$ is currently discount value and S_n is n year investment.

2.4 Optimization of data and major parameters for solar dryer

The optimization of data and the optimization of observe data and the correlation of various parameters like; incident irradiance, ambient air temperature and relative humidity, temperature of cabinet Tc, temperature of ambient air Ta, temperature of solar irradiance I. For the process of optimization, the design expert software is used for the identification of various parameters those are associated with the thermal performance of proposed solar dryer from the optimization significant results of optimized data has been identified as shown in figure 7.

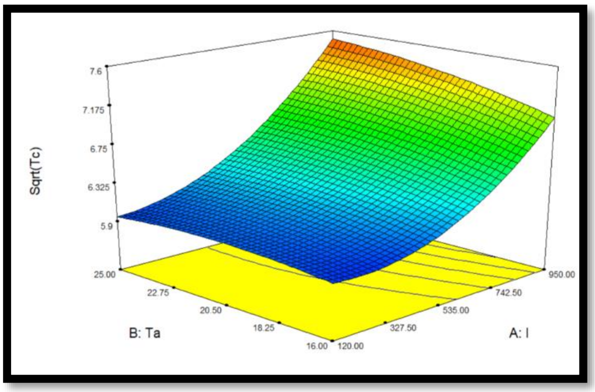

Figure 7: A 3D plot of the correlation between Tc, Ta, and I.

2.5 Wind Velocity Direction

The wind rose analysis of parameters wind velocity and wind direction are analysed and optimized using R studio software and the data recording for the required parameters are done by using a hot wire anemometer and the data is recorded for six days. The figure 8 shows that the creamy color is maximum at 2 to 4 in the North-South direction. So the prevailing wind gust can we observed from the NES direction with a maximum speed of 2-4 ms^{-1}. Therefor, solar dryer is placed at NE direction in a sunny field area at Sri Sai University, Palampur (H.P).

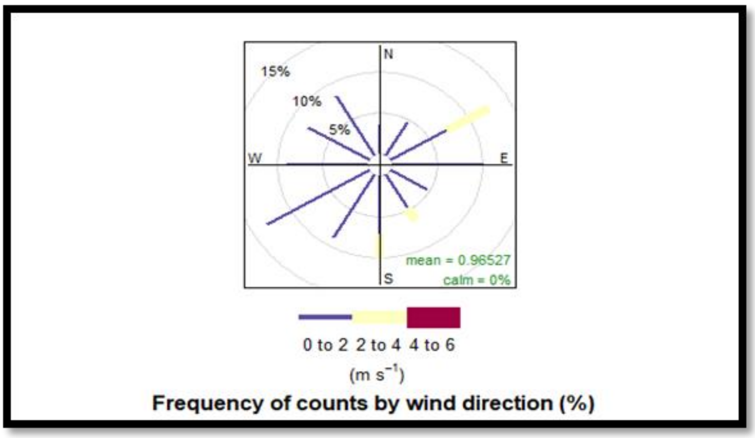

Figure 8: Wind rose plot of frequency of count by wind direction and wind velocity.

3. Results and discussion

The standard performance of collector section and new design and fabricated valvular conduit that is installed just below the absorber plate in flat bed type of collector and this collector is installed at the proposed solar dryer. This is installed in abundant solar field of Sri Sai University Palampur facing the south east direction at 320. As the main aim and objective to receive maximum falling radiations for maximum efficiency from solar dryer and the effect of radiation on ambient air temperature and relative humidity is represented by the figure 9. The rise in temperature is recorded for 6 days at and interval of one hour.

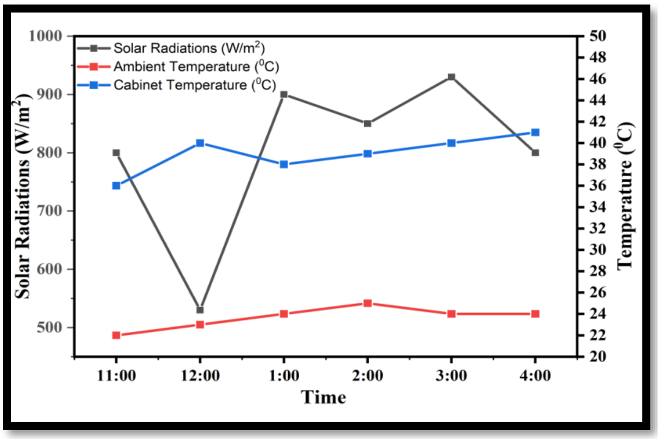

Figure 9: The correlation between temperature rise & incident solar radiation.

The selected product was only water washed from for one minute under the shower of running water to remove any devilries and dirt from the leaves and buds. And then there are placed directly for drying in proposed solar dryer.

Considering the packed that the effect of incident irradiance will rise the ambient air temperature and also decrease ambient relative humidity simultaneously. More the heated the dehumidified air i.e. (least RH % and maximum temperature) will have higher the capacity to absorber moisture from the products that is subjected for drying application as shown figure 9.

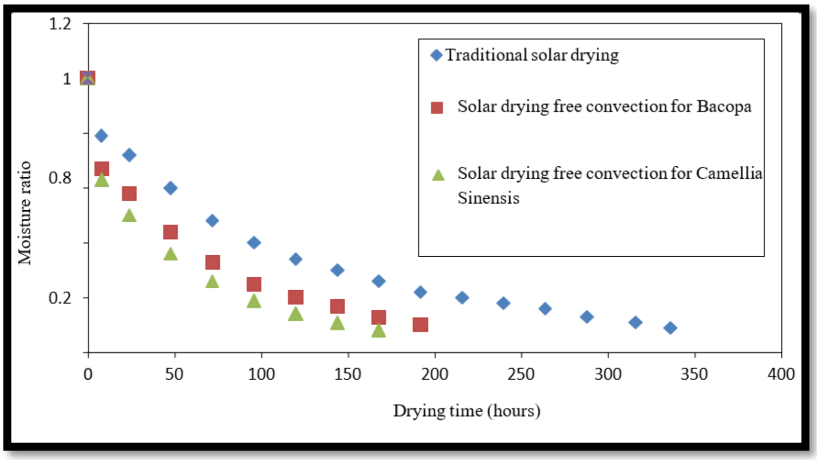

Figure 9: Moisture content variation with the drying time.

The effect of relative humidity also placed crucial role that generally influence the pickup efficiency and overall drying process rate it as observed that the recorded relative humidity in the drying chamber was observed significantly very low that the drying process for product 1 took only 3.5 hours. The final observed moisture content after 3.5 hours was quite low enough to consider it fully dried and efficiency was found near about 62% i.e. slightly better than previous studies and pick up efficiency is represent in figure 9.

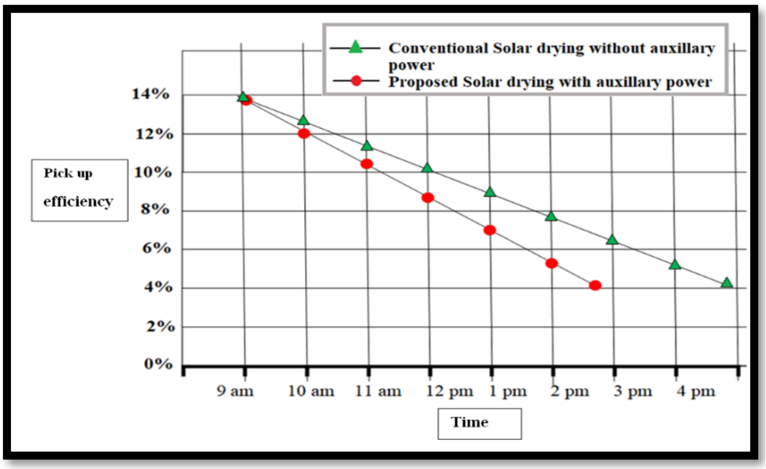

Figure 9: Shows that the pick-up efficiency with time.

4. The economic analysis of proposed solar dryer

Table 1: The detailed description of components of dryer	
Description	Value in ₹
Capital cost of proposed solar dryer (C_s),	8,000
Life time of proposed dryer (n), y	5
Capacity of dryer (S_n), Kg d^{-1}	6 to 9
Discount rate (i), %	5
Cost of raw material of the product ($C_{r'}$), ₹ kg^{-1}	130
Net per day feasibility for drying (P_e),	1560
Total capital cost per batch of drying (P_d), kg^{-1}	780
Days of operation in year ($d^*{}_n$), d	240
Drying time of one batch (t'_d), h	3
Net drying for a month ($S_{v'}$), ₹ kg^{-1}	46800

The frame work represented for the design calculation in this generalized form will also help in the evaluation financial fusibility of solar drying in any agricultural products using the solar thermal technology. The various following economic indicators can be considered as the annual return pay back capital and net present value for the feasibility analysis of solar drying Capital cost the fabrication of solar dryer was approximate 8000. Similarly the products used for trial generally find its market price about 130 rupees per kg-1. And overall capacity for drying the product per batch is 6-9 kg. Therefore the total capital cost per batch of drying is rupees 780. Total batch per day is 2 also the net per day feasibility for drying per day is about 1560. Similarly for a month are 46800. Therefore, the payback period for the fabrication of solar dryer is only less than 10 days for the selected crop or products. The various parameters for the analysis of the performance of proposed solar dryer is given table 1.

5. Conclusions

The proposed solar dryer can be successfully used for drying operation along with the advantage of eliminating various problem like contamination of moisture pollutants and other micros as well macro devilries like the traditional open sun drying methods and it is also found that the use of valvular conduit widely help to achieved significant thermal efficiency of the solar thermal collector. This can be used to harness the maximum available solar energy with restricted back flow and thermal losses around the collector section. This special type conduit unidirectional conduit helped in maintaining the optimum drying temperature and air flow range to achieved thus quality product output and various experiments have already confirm the satisfactory the performance of solar dryer and thermal efficiency of solar dryer thermal dryer pick up efficiency of proposed solar dryer at 62% which is can be consider as significant and the payback period of proposed solar dryer also have very significant number which can also considered as satisfactory.

REFERENCES

1. Ekechukwu OV, Norton B. Review of solar-energy drying systems II: "An overview solar drying technology", Energy Conversion and Management 1999; 40: 615-55.

2. Ministry of New and Renewable Energy, Government of India, www.mnre.nic.in accessed on 24/1/2015.

3. BP energy outlook 2035, BP statistical review of world energy Feb 2015. London, United Kingdom, Feb 2015.

4. Murthy. "A review of new technologies, models and experimental investigations of solar dryers", Department of Mechanical Engineering, Osmania University College of Engineering, Osmania University, Hyderabad 500007, India2009.

5. Biswas DR. Thermal Energy Storage using Sodium Sulphate – deca -hydrate and water solar Energy 1977; 1999-100.

6. Energy outlook, MNRE, Government of India ministry of new and renewable energy, 2015.

7. Ministry of New and Renewable Energy, Government of India, www.mnre.nic.in accessed on 24/1/2015.

8. Duffle, J.A and Beckman, W.A, Solar Engineering of Thermal processes, John Wiley and Sons, Inc. Publication, New York, Fourth edition, Chapter 6, 6.1-236, 2013.

9. Aboul-Enein S, El-Sebaii AA, Ramadan MRI, El-Gohary HG. Parametric study of a solar air heater with and without thermal storage for solar drying applica- tions. Renew Energy 2000; 21:505e22.

10. Tyagi VV, Panwar NL, Rahim NA, Kothari R. Review on solar air heating system with and without thermal energy storage system. Renew Sustain Energy Rev 2012; 16(4):2289e303.

11. Augustus leon M, Kumar. "A comprehensive procedure for performance evaluation of solar food dryers", Vol-6: 367-93, 2002.

12. Sanchez AC, Szumunv A. Figiel A Jatoszynski K. Adamskl M. Angel A, etr al. Effects of vacuum level and microwave power on rosemary volatile compo- sition during vacuumemicrowave drying. J Food Eng 2011; 103(2):219e27.

13. Viuda-Martos, Ruiz-Navajas, Sanchez-Zapata, Fernandez-Lopez J, Alvarez Perez. Antioxidant activity of essential oils of five spice plants widely used in a Mediterranean diet. Flavor Fragr J 2010; 25:3e19.

14. Sharma A, Chen CR, LAN NV. Solar energy drying systems: a review. Renew Sustain Energy Rev 2009; 13(6e7):1185e210.

15. Farid MM, Khudhair AM, Razack SA, Hallaj SA. A review on phase change energy storage: materials and applications. Energy Conserv Manag 2004; 45: 1597e615.

16. Jain D. Modeling the performance of greenhouse with packed bed thermal storage on crop drying application. J Food Eng 2005; 71(2):170e8.

17. Seveda MS, Rathore NS, Singh P. Techno economics of solar tunnel dryer- a case study. J Agric Eng 2004; 41(3):13e7.

18. Sukhatme SP. Solar energy. New Delhi: Tata McGraw-Hill Limited; 1998.

19. Mastekbayea GA, Leon MA, Kumar S. Performance evaluation of a solar tunnel dryer for chilli drying paper presented at the Asean Seminar and Workshop on Solar Drying technology, 3-5 June, Phitsanulok, Thailand, 15-26, 1998.

20. Moyls AL. Evaluation of a solar fruit dryer. Canadian Ag. 28 (2(summer): 137-44, 1986.

21. Ekechukwu OV, Norton B. Review of solar-energy drying systems II: "An overview of solar drying technology", Energy Conversion and Management 1999; 40:615–55.

22. Tsamparlis M, "Solar drying for real applications". Drying Technol, Vol-8, 261-85, 1990.

23. Kliein, S. A., "Calculation of flat plate collector loss coefficients", Solar energy, Vol-17, 79-80, 1975.

24. Augustus leon M, Kumar. "A comprehensive procedure for performance evaluation of solar food dryers", Vol-6: 367-93, 2002.

25. Malhotra, A., "Heat loss calculation of flat plate soar collectors", Journal of Thermal Engineering, Vol-2, 59-62, 1981.

[26]. Duffie, J.A. and Beckman, W.A., Solar Engineering of Thermal processes, John Wiley and Sons, Inc. Publication, New York,. Fourth edition, 4-240, 2013.

[27]. Winkler AJ, Cook JA, Kliewer WM, Lider LA. General viticulture, Berkeley, CA: "University of California Press", 1974.

[28]. A. Fudholi, K.Sopian. "Review of solar dryers for agricultural and marine products", University of Kebangsaam Malaysia,14: 1-30, 2010.