Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 63 (2013) 18107-18109

Elixir ISSN: 2229-712X

Performance analysis of solar assisted drying system

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ARTICLE INFO

Article history:
Received: 26 August 2013;
Received in revised form:
20 September 2013;
Accepted: 1 October 2013;

Keywords
Solar energy,
Tea leaves,
Performance,
Moisture content,
Weight loss.

ABSTRACT

Solar energy is an economical alternative for today's energy demand in comparison with other energies. Solar air heater is used for heating the air which in turn is used for drying the agricultural products. The objective of this paper is to design, develop and perform a detailed experiment and analyze the solar assisted drying system (SADS) for drying tealeaves. Green tealeaves plucked directly from the plantations are soaked in warm water for few minutes. Water is drained out; wet leaves are dried using the SADS consists of drying chamber maintained at a temperature of 55°C and pressure of 3Kg/cm^2 through solar collectors. The initial weight of the green tea leaves is of 100 gms, which is reduced to 38gms in an hour.

Introduction

Drying of the agricultural products is the most energy consuming process among the various processes in the farm. The purpose of drying is to remove moisture from the agricultural products. Normally green tealeaves are harvested at a moisture level of between 80% and 50% depending on the climatic condition. Among the various approaches of drying the crops, solar drying produces a wide implementation, significant savings to farmers which strengthens the economic situation. SADS is an alternative method for solving the problems of drying tealeaves at moderate operating temperature in short duration of drying time. Due to the adverse climatic condition such as rain, wind, moist, dust, and storm etc, loss of material by birds and animals, deterioration of the material through decomposition, insects and fungus growth occurs in open drying or natural drying which is a major disadvantage in open atmosphere drying. The usage of solar energy is a viable alternative compared to other conventional drying techniques for green tea, at 55°C chamber temperature easy to remove the moisture content of 33% from the initial moisture content of 87% of green tea after 12 hours drying period [1]. The solar drying method is very safe for food grains, vegetables from damage, birds, insects and unexpected rainfall also getting better quality dried product with in a minimum period of drying time compare to conventional sun drying system [2]. It was concluded that 86.05% of moisture has been removed from okra after 23 hours of effective drying time with chamber temperature of 55°C inside the drying tent [3]. By maintaining optimum temperature of 50.50°C inside the dryer with corresponding ambient temperature of 34.50°C can remove 43.2% and 40.6% of moisture against using sun drying method with minimum construction cost compare to other dryers [4]. The use of glass and polycarbonate sheet as glazing cover, can improve dryer efficiency from 9% to 12% with a short drying period [5]. The quality of the product (fish) has been improved by taking the parameters such as temperature, relative humidity with high drying rate [6].The forced convection solar dryer is more suitable for producing high quality dried chilli[7], 63.3% of moisture content has been removed from the initial moisture of 72.8% with rate of 0.87kg/kWh. Tealeaves are heat sensitive products if the drying process conducted at high temperature and long drying time and the traditional sun drying method is commonly used for drying tealeaves which is highly labor intensive, time consuming, requires large areas and slow drying time [8-13]. Once a tealeaf is harvested, it may have to be stored for a period of time before it can be used as feed. It contains high moisture content and it's highly perishable. Therefore after harvesting it must be dried as earlier as possible to reduce the moisture content and make it ready for the process. In this paper the author discusses about drying tealeaves using the solar assisted drying system and the effects of moisture content is investigated.

Design of SADS

The various factors considered in selection of the materials for the fabrication of the equipments are (i) cost of the fabrication (ii) mechanical properties of material (iii) corrosion resistance (iv) ease of fabrication and service requirement. The materials used for the solar dryer system are inexpensive and easily available in the market. Solar assisted drying system consists of various components like solar collector, drying chamber with trays and compressors. Solar collector system consists of absorber, glass cover, back plate and insulator. The single layer of typical glass covers the top surface of the collector, the backside and edges of the collector are insulated to minimize heat losses. The distance between absorber and glass cover is maintained in such a way the heat is produced in an efficient manner, the solar collector system is faced towards south direction and tilted 45° from the ground level.

Drying chamber was manufactured with the size 635x635x127 mm with the exterior made up of plywood and it as a tray made up of galvanized iron sheet to hold the tea leaves. The distance between tray and surface of the chamber is 317.5mm. Drying chamber is linked with the solar collector by duct of 10x8 mm, the hot air is passed to the chamber from the

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collector through outlet of solar collector. The chamber air is circulated and exhausted to the atmosphere. Digital thermometer is used for measuring chamber temperature ranging from -50°C to 300°C. Pressure gauge is used to measure the inlet pressure of collector which ranges from 0 to 8kg/cm^2, pressurized air is produced from the compressor with the capacity of 0 to 10kg/cm^2. Assumptions taken for this solar drying system is initial moisture content of the tealeaves is (at harvest) 80% wet bulb and final temperature moisture content while storage is 10%wet bulb. Ambient temperature is 28 °C , maximum allowable temperature of drying chamber is 70 °C.

Components

1)Drying Chamber: The drying chamber is of highly polished plywood because of poor conductivity of heat and its smooth surface finish thereby minimizing the radiation heat losses.

*2)*Cover plate: Transparent sheet is used to cover the absorber to prevent dust and rain, it also retards heat from escaping, and glass is used as a common material for cover plate.

*3)*Absorber plate: This is a metal painted black and placed below the cover to absorb the incident solar radiation transmitted by cover.

*4)*Insulation: This is used to minimize heat losses from the system located under the absorber plate, the insulation must be able to withstand stagnation temperature, fine resistance and should not be damageable by moisture and insect.

Design Calculation

The amount of moisture to be removed of 1kg tealeaves is calculated using the equation 1

$$M_w = \frac{m_p[m_i - m_f]}{[100 - m_f]} = 0.77\text{kg} \qquad \text{---- 1}$$

The quantity of heat required to evaporate 0.77kg of H_2O is calculated using the equation 2

$$Q = M_w h_{fg} = 167.36KJ \qquad \text{------- 2}$$

The determination of drying rate is calculated using the following equation

$$Drying\ rate = \frac{mass\ of\ moisture\ removed}{usage\ of\ solar\ energy\ per\ day\ in\ hours} = 0.077kg/hr$$

Experimental Procedure

The amount of moisture to be removed from the tealeaves per kg, quantity of heat needed to evaporate the H_2O is calculated by theoretical calculations and determination of drying rate to design and fabricate the solar collector, drying chamber and helpful to choose the range of compressor, thermometer and pressure gauge. From the analytical calculation 167.36 kJ of heat is necessary to evaporate 0.77 kg of moisture from 1kg of tealeaves with the drying rate is 0.077kg/hr. Based on the above analytical results the procure of the needed equipments and fabrication of the SADS was carried out..

Fig 1 explain the working of drying system, in this AC input power supply has been used to operate the compersesor to avoid the usage of solar panel that increase the operating cost. While increasing the capacity of solar drying system, solar panel can be used instead of AC power supply to operate compressor to generate air. Fig 2 shows the assembled view of experimental setup, solar system has been placed towards south with 45° angle by horizontal level reference assemble all the components like compressor, pressure gauges and drying chamber

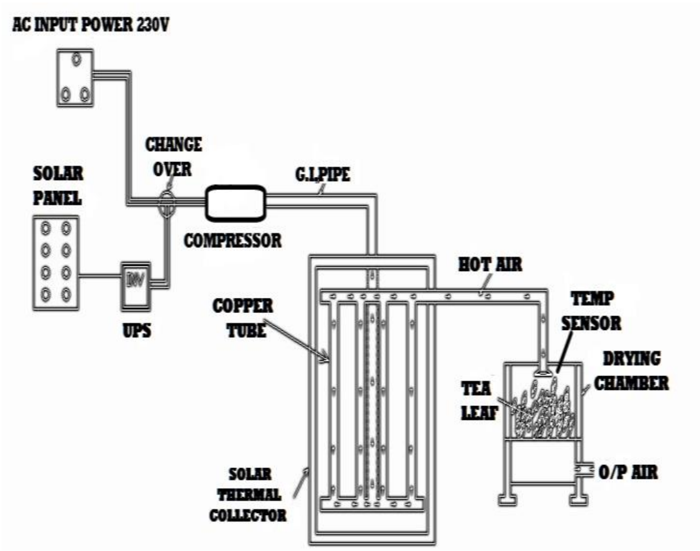

Fig. 1 Schematics of Solar Assisted Drying System

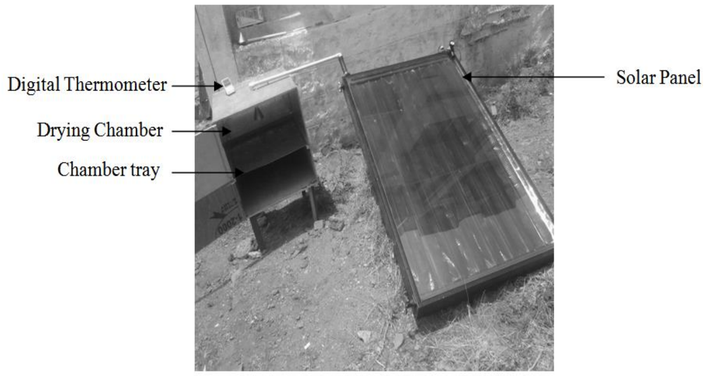

Fig. 2 Assembled View of Solar Assisted Drying System

Result And Discussion

Ambient temperature, ambient relative humidity, temperature inside the chamber, pressure of the compressed air are measured on hourly basis while drying green tealeaves in the designed SADS. The initial weight of the tealeaves was 100 gms measured by electronics weighing machine and placed on a tray in the drying chamber. Hot air from the solar collector is discharged into the drying chamber from outlet duct of the solar collector by using compressor with constant supply of 2.5 to 3.5kg/cm^2.

Table: 1 Analysis Report of Drying Process

Time	Duration (secs)	Pressure (Kg/cm^2)	Net Weight (gms)	Weight loss (%)	Remaining Weight (gms)	Chamber Temperature (°C)
12-12.30pm	1800	3.0	100	36	64	61.2
1- 1.45 pm	2700	3.0	100	52	48	60.8
3-4 pm	3600	3.0	100	62	38	60

The above tabulation clearly explains the experimental analysis of various samples for different conditions of the humidity of the solar radiation, the drying chamber temperature of the SADS. The first sample is kept inside the chamber for 1800 seconds (12 to 12.30pm) with chamber temperature of 61.2°C and measured the weight of sample after drying which was around 64gms, thereby moisture removed from the sample is 36% by weight which is also validated in the reference [1,4] . In similar fashion the samples were kept inside the chamber at different time of the day with same constant pressure and chamber temperatures of 60.8°C and 60°C respectively. After conducting each experiment the weight loss of the moisture content is measured. While comparing the ambient temperature and the temperature inside the chamber it is evident that the efficiency of the designed drier is more than the natural sun drying.

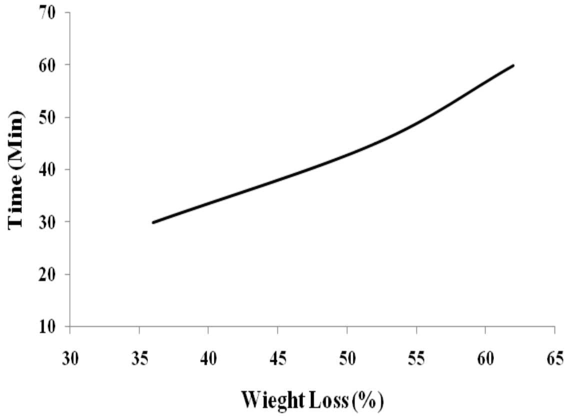

Fig.3 Variation of weight loss against time

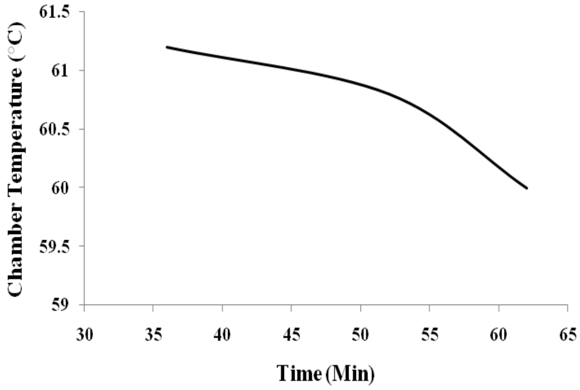

Fig. 4 Variation of chamber temperature

But in natural sun drying, the time taken by tealeaves to reach equilibrium moisture content varies from 13hours to 15hours. It is observed that drying time gets reduced as air velocity flow rate increases. The variation of the weight loss versus time is illustrated in the Figure 3. Figure 4 explains the characteristic curve of the drying process between time and chamber temperature with reference to weight loss of tealeaves. Weight loss of the tealeaves is increases as time increases, if the time period is minimum, increase the chamber temperature to remove the moisture content from the tealeaves likewise if the chamber temperature is increases, minimum time consumption is required to remove the moisture content. From the figure clearly explained removal of moisture content by increasing time with minimum temperature or increasing temperature with minimum time period.

Conclusion:

An experimental study on the drying of tealeaves has been conducted using solar assisted drying system. The green tea must be dried for storage before extraction of the active component. The use of solar energy is a viable alternative compared to other conventional drying techniques. An initial weight of 100gms and final weight of 38gms of green tea are obtained using the drying system 62gms of moisture content has been removed per 100gms of tea leaves. Experimental studies using the solar drying system under clear sky and ambient temperature of 30-34°C and drying temperature of 60°C.

Acknowledgement:

Authors would like to thank Mr. V.Manikandan, Mr.V.Sreenivasan, Mr.R.Naveenkumar and Mr.S.Shanmugavel for their valuable contribution in completion of this experimental work.

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