A SOLAR ASSITED DRYING SYSTEM FOR GREEN TEA

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Abstract

Indonesia being situated near the equator receives abundant solar radiation and having characterized by an average daily solar radiation of about 600-700W/m^2. This could be contributed as energy sources for drying green tea. This paper present the experimental studies conducted on the herbal tea or green tea using a solar assisted drying system. The drying system has an array of collector with the size 13.8 m^2. The fresh tealeaves form the plantations are first soaked I warm water for five minutes. Next, Water from the tealeaves will be drained out and dried in the chamber. The collector is of the V-Groove type. The system has two fans to circulate air. A 10 kW auxiliary heater is also included and will be on if the temperature of the drying chamber is less than the specified preset temperature of 50^{o}C. A drying chamber of 55^{o}C can be reached at solar radiation levels of 600-700 Wm2 and ambient temperature of 27-34^{o}C. The flow rate is fixed at 15.1 m^3/min. The initial moisture content is 87% (wet basis) and the final moisture content is 54% (wet basis). A total of 12 hours of drying time is required where solar energy contribute about 56% the total energy requirement.

***Keywords**: - Solar assisted drying, green tea, V-groove solar collector, energy requirement.*

INTRODUCTION

The use of herbal medicines has been increasing rapidly in the last decade's world wide (Saras, 2003). It's as alternatives to modern medications are safe and have virtually no side effects. Green tea as medicinal herb its made from the dried leaves of *Camellia sinensis*, is one of the most popular beverages consumed around the world which is of great interest due to its beneficial medicinal properties (Nakachi et al, 2000; Fujiki et al, 2001; Yang et al, 2002; Jian et al, 2004; Sinija & Mishra, 2009). Green tea contains appreciable amounts of catechins: primarily epicatechin (EC), gallocatechin (GC), epigallocatechin (EGC), epigallocatechin gallate (EGCG), gallocatechin gallate (GCG), epicatechin gallate (ECG), and catechin gallate (CG) (Hyong Seok Park et al, 2007). It is has been used for antioxidative (Liu et al, 2000; Cai et al, 2002; Joshi et al, 2004), anticancer (Moyers & Kumar, 2004), anti-inflammatory (Tedeschi et al, 2002; Trompezinski et al, 2003), antiaging (Cooper, 2005), antibiotic, and antiviral effects (Fassina et al, 2002; Yanagawa et al, 2003; Stapleton et al, 2004), antiallergic (Kakegawa et al., 1985) and enhancing energy consumption (Dulloo et al, 2000; Osaki et al, 2001).

After harvesting tealeaves L contain high moisture content and it's highly perishable. Therefore, after harvesting its must be dried as soon as possible to reduce the moisture content to such a level where spoilage due to the various reactions is minimized and to prevent the expected contamination by rodents, birds, insects, dust and dirt (Garg & Kumar, 2001; Janjai et al., 2005).

In the drying process, beside removal of water the drying time, the quality of dried product and energy requirement must be taken into consideration (Szentmarjay et al., 1996).

Tealeaves are heat sensitive products and discoloration of the products will occur if the drying process conducted at high drying temperature and long drying time (Saijo et al, 1973; Kirsi et at, 1989).

Traditional sun drying methods is commonly used for drying medicinal herbs, although this method is very cheap and practice, however the dry products are of poor quality due to contamination by insects, birds and dusts, discoloration by the UV radiation and also slow drying time. Indonesia being situated near the equator receives abundant solar radiation and having characterized by an average daily solar radiation of about 600-700W/m^2 (Manan, 2011). This could be used as energy sources for drying medicinal herbs by using solar collector devices.

Solar assisted drying system is an alternative method for solving the problem of drying of tealeaves. Because of this system operated with low drying temperature and short drying time. The aim of this study was to evaluate the energy requirement of solar assisted drying system for drying Green tea (tealeaves).

Description of Solar Assisted Drying System

The system consists of solar air collector, blower, auxiliary heater and drying chamber. The photograph of the solar drying system is shown in Fig.1 and the schematics of diagram of the solar drying system are shown in Fig.2. The solar collector is of the back-pass V-groove as show in Fig.3. The size of each collector put in 3 series is 4.6 m x 1.0 m x 0.15 m. The total area of the collector is 13.8 m^2. A 10 kW electric auxiliary heater is equipped with an on/off controller. The air temperature in the chamber can set according to required temperature. The size of the chamber is 1.0m x 2.5 m x 2.9 m. There are 3 layer of trays made of wire-mesh stainless inside the drying chamber as show in Fig.4. The specification of the drying system is described in Table 1.

Fig.1: Photograph the solar assisted drying system.

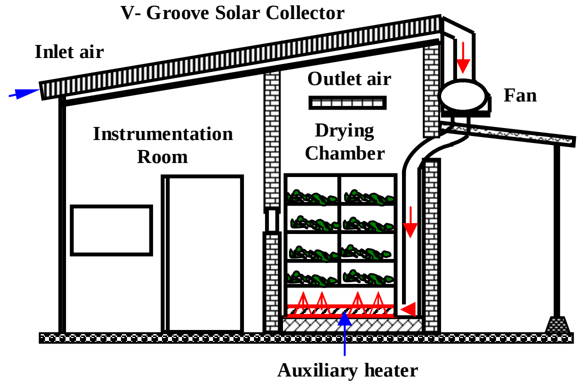

Fig.2: Schematics of the solar assisted drying system.

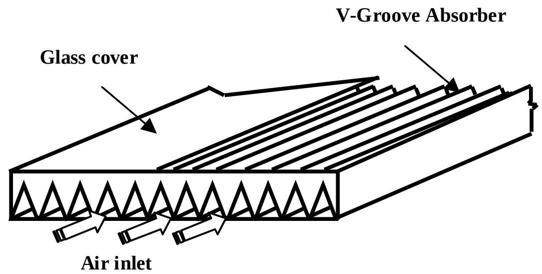

Fig.3: Schematic diagram of V-Groove Back-pass Solar Collector.

Fig.4: The drying chamber with the tealeaves

Table 1: Specification of the V-Groove Solar Drying System.

System Components	Specifications
Collector:	
Type of absorber	V-Groove back-pass
Material of absorber	Folded aluminum sheet SWG22 standard size: 244 cm x 122 cm
Angle of groove	49°C and height 7.8 cm
Collector area	100 cm x 460 cm per unit collector
Total collector area	13.8 m^2
Top cover	Glass: thickness 2.5 cm, one side tempered
Insulator	Fiberglass wool: 2.5 cm thickness, density 46.0 kgm^{-3}
Air Circulation:	
Two unit axial fan	2700 rpm, 85 W, 230 V (AC), single phase motor, 18 cm outlet diameter.
Ducting	PVC pipe
Air flow rate	6.0-16.5 m^3 min^{-1}
Drying Chamber:	
Type	Adjustable set of shelved frame
Size	1.0 m x 3.0 m x 3.0 m.

Instrumentation

In order to evaluate the energy requirement for drying tealeaves, measurements of temperatures, humidities, moisture contents, air velocities, solar radiation on collector surface, mass of tealeaves were made during tests conducted. Dry bulb temperatures were measured with type-K thermocouples. Solid-state hygrometers were used to measure humidities at different locations. A hygrometer with type-K thermocouples was also used to measure dry-bulb and wet-bulb temperatures at selected locations in the dryer. These temperatures were used to obtain air humidities from psychometric charts. A turbine flow meter is used to measure the flow rate and velocity of the air. The flow rate of water is measured with the help of a water flow meter. The instantaneous solar radiation has been measured by using the Eppley Pyranometer and mounted near the collector on the plane of the collector. The moisture measurement in the product has been done with the help of a weighing machine. The power consumption of the system is measured by a wattmeter.

PROCEDURES

Fresh tealeaves were purchased from a local medicinal herbs supplier. The initial moisture content of the tealeaves was 87% (wet basis). This sample was placed on a tray in the drying chamber. Hot air from solar collector is discharged into the drying chamber from outlet duct. The drying air temperature maintained at 50°C using an auxiliary heater. Weight loss of the sample was recorded every 15 minutes by a weighing machine.

The total energy required for drying tealeaves can be determined using equation follow as:

$$\dot{Q}_{required} = \dot{Q}_U + \dot{Q}_{HE} \qquad (1)$$

Where $\dot{Q}_U$ and $\dot{Q}_{HE}$ are useful energy of collector and energy electric auxiliary heater, respectively. The useful energy of collector can be determined using equation follow as (Duffie & Beckman, 1991):

$$\dot{Q}_U = F_R A_C \left(I_T(\tau\alpha) - U_L\left(T_{C,in} - T_a\right)\right) \qquad (2)$$

Or

$$\dot{Q}_U = \dot{G}_a C_{pa}\left(T_{C,out} - T_{C,in}\right) \qquad (3)$$

Where:

F_R = heat-removal factor for the solar air heater
A_C = Surface area of the absorbing plate (m^2)
I_T = solar radiation incident (W/m^2)
U_L = Overall coefficient
$T_{C,in}$ = collector inlet air temperature (^{o}C)
$T_{C,out}$ = collector outlet air temperature (^{o}C)
T_a = ambient temperature (^{o}C)
$\dot{G}_a$ = Mass-flow rate of air (kg/s)

C_{pa} = Specific heat of air at constant pressure (J/kg/K)

τ = Transmittance of glass cover

α = absorptivity of the absorbing plate

The energy electric auxiliary heater can be determined using equation follow as:

$$\dot{Q}_{HT} = \dot{G}_a C_{Pa} \left(T_{HT,out} - T_{HT,in}\right) \qquad (4)$$

Where $T_{HT,in}$ and $T_{H,out}$ are auxiliary heater inlet air temperature and auxiliary heater out air temperature, respectively.

RESULT AND DISCUSSION

The fresh tealeaves has an initial moisture content of 87% (wet basis). Drying is required to lower the a final moisture content of 54 % (wet basis). This will allow the green color of the tea to be maintained. The auxiliary heater is on if the drying chamber is below 50°C. The flow rate is fixed at 15.1 m3/min. The initial weight of the fresh tealeaves is 10.03 kg and the final weight is 2.86 kg.

Figure 5 shows the variations of solar radiation, ambient temperature, drying chamber inlet air temperature and drying air temperature with time. As seen from figure the drying chamber inlet air temperature achieve 50°C under clear sky with an average solar radiation level of 567.4 Wm^{-2} and ambient temperature of 27-34°C.

Figure 6 shows the energy requirement for the drying process of herbal tea. The drying process started at 8:00 and ended at 18:00. The total energy required to maintain a drying temperature of 50°C is 60.2 kWh. The auxiliary energy contribution is 17.6 kWh. Hence, solar energy contibutes 42.6 kWh during the process and contibutes approximately 70.2% of the overall energy requirement. To further decrease the weight to 2.86 kg. Further drying is required. The drying process is continued until 20:00 and the contribution of solar energy in the total energy requirement dropped to 56.3%.

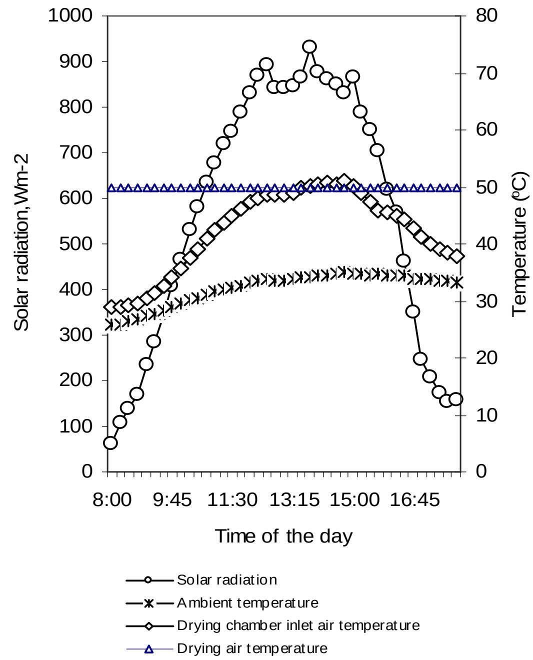

Fig.5. Variations of solar radiation, ambient temperature, drying chamber inlet air temperature and drying air temperature with time.

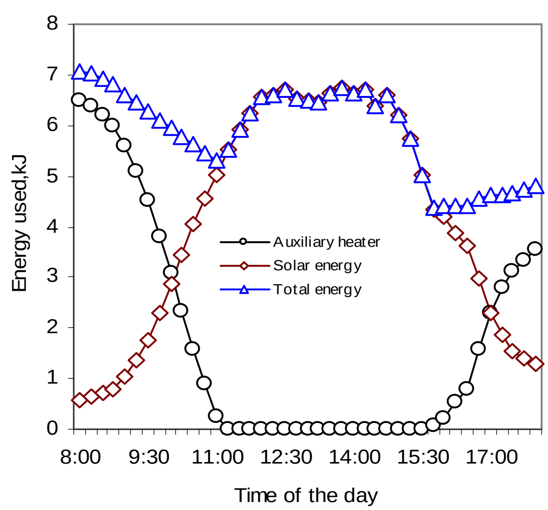

Fig.6. Variations of energy contribution for drying process with time

CONCLUSIONS

An experimental study on the drying of herbal tea or green has been conducted using the 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 weigh of 10.03 kg and a final weight of 2.86 kg of green tea are obtained using the drying system. For best results, the moisture content of 54 % (wet basis) must be obtained for maintaining the green colour of the herbal tea. With this condition, optimum extraction of tea can be performed later. Experimental studies using the solar drying system under clear sky with an average solar radiation level of 567.4 Wm-2 for the day and ambient temperature of 27-34^{o}C and drying temperature of 50^{o}C concluded that the drying process requires a period of 12 hours and 56.3% of the total energy requirement is supplied by solar energy.

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