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Design, Development and Performance of Indirect Type Solar Dryer for Banana Drying

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Abstract

Due to higher prices and shortages of fossil fuels and to reduce the fuel consumption used in the drying process, more importance is given to solar energy sources as it is freely available. For these purposes, an indirect type solar dryer was designed and developed to dry agricultural products. Solar dryer consists of solar flat plate air collector with V-corrugated absorption plates, insulated drying chamber, and chimney for exhaust air. The total area of the collectors is 2 m^2. The size of the drying cabinet is 1 m × 0.4 m × 1 m (width, depth, and height). An experiment was conducted to study drying characteristics of banana. The qualitative analysis for drying of banana showed that moisture content of banana was reduced from initial value of 356% (db) to final moisture content of 16.3292%, 19.4736%, 21.1592%, 31.1582%, and 42.3748% (db) for Tray1, Tray2, Tray3, Tray4, and open sun drying respectively. The average thermal efficiency of the collector was found to be 31.50% and that of drying chamber was 22.38%. The temperature of drying air is the most important and effective factor during drying. The humidity of air as well as air velocity is also an important factor for improving the drying rate.

Keywords: Solar drying; Indirect type solar dryer; Moisture content; Banana.

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1. Introduction

The energy, for drying, supplied from various sources (fossil fuel, natural gas, solar etc.). Rapid depletion of natural fuel resources and rising fossil fuel cost, environmental damages caused due to fossil fuel, the use of solar energy for drying is expected to become popular source [1]. People, from rural India, are using open sun drying method to dry their agricultural products, but it has a number of disadvantages such as contamination of dust, pollution, damage by birds, animals, insect, etc. Indirect type solar dryer is one of the options to overcome the above issues [2].

The energy from the sunlight can be utilized for drying of food products. Solar drying of fruits and vegetable is an ancient food preservation technology. Drying is very important and essential process for preservation of agricultural products. Also, it is important for other industries, such as textile, cement, tea industry, tiles, wood processing, paper industry, etc. [3-5]. Although the solar radiation is used for drying of food materials, it has not yet been widely commercialized because of high investment cost, time-consuming operation etc.

Solar drying has a number of advantages as solar energy is non-polluting, free, abundant renewable energy source. But several practical difficulties arise and it should be overcome. The intensity of incident radiation is not constant throughout the day, therefore, heat storage is needed to store the solar energy at its peak value. The auxiliary energy source is required after sunset and at the time of bad weather. Also, solar radiation has a very low energy density, which requires the large surface area to collect solar radiation (collectors). Because of these things, investment costs are notably larger [6, 7].

An alternative solution for traditional drying method and to overcome the problem of open sun drying, indirect type solar dryer is used. The main reasons are as follows,

- Indirect type solar drying maintains good product quality compared to open sun drying.
- Time for drying process can be significantly reduced as compared to open sun drying.
- Dried foods can be preserved for a long time period and the product becomes extremely lightweight hence easy for transportation.

Therefore the main objectives of this present experimental work are, (i) to design and develop an experimental setup for indirect type solar dryer, (ii) to conduct the drying experiments with the sample product of banana, (iii) to find the initial moisture content of banana using hot air oven, (iv) to estimate the transient moisture content distribution of banana placed at different trays of drying chamber (v) to estimate the collector efficiency and dryer efficiency and (vi) to develop drying correlations.

Nomenclature

A_c	area of collector (m^2)	T_c	temperature of collector outlet air (°C)
C_{pa}	specific heat of air (J kg^{-1} k^{-1})	T_d	temperature above tray (°C)
h_l	latent heat of vaporization of water (kJ/kg)	T_{atm}	atmospheric air temperature (°C)
I	solar radiation (W/m^2)	t	time (h)
L_c	characteristic length (m)	t^*	Dimensionless time
W_{wet}	initial mass	W_{dry}	final mass
$\dot{m}_a$	air flow rate (kg/s)	**Greek**	
m_w	amount of water (kg)	η_c	efficiency of collector (%)
M	moisture content (%)	η_d	efficiency of dryer (%)
M_i	moisture content (%)	**Subscripts**	
M_e	equilibrium moisture content (%)	db	dry basis
T_i, T_{in}	temperature of collector inlet air (°C)	wb	wet basis