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Development and recent trends in greenhouse dryer: A review

Sumit Tiwari [a,*], G.N. Tiwari [a], I.M. Al-Helal [b]

[a] Centre for Energy Studies, Indian Institute of Technology Delhi, Hauzkhas, New Delhi 110016, India
[b] Department of Agricultural Engineering, College of Food & Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

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A B S T R A C T

Food is necessity for human being. As the world population is increasing, it is very difficult to fulfil everyone's need of food. One of the alternatives of this problem is the preservation of crops, vegetable and fruits when it is available in abundant amount. Drying is one of the best methods to preserve agricultural products for long time but it requires lot of energy. As availability of electricity per capita in developing and under developed countries is very less, thus the electricity uses for heating purpose cannot be economically and environmentally justified option. So entrapment of thermal energy from solar radiation may be the best option for drying. Solar energy can be utilized for drying in different ways namely open sun drying and closed drying (direct and indirect). Open sun drying have various disadvantages like contamination of dust particles, bacteria in crop, decolouration of the product after drying etc. To overcome these problems greenhouse drying or closed drying has been developed. This review is an attempt to explore different types of drying systems was developed across the world. Further different thermal modelling, mathematical modelling and performance evaluation on the basis of characteristic curve have been discussed. One of the thermal modelling has been discussed in detail to evaluate heat transfer coefficient, heat absorbed and moisture evaporate with experimental validation to give practical exposure to the researchers.

Contents

* Corresponding author.
E-mail address: tiwsumit@hotmail.com (S. Tiwari).

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Nomenclature

Q_c	useful energy collected
α	absorptivity of the absorber plate
U	overall heat loss coefficient
T_a	ambient temperature
$\dot{M}_a$	air flow rate
C_p	specific heat
T_o	temperature in mixing chamber
$IA_{c,eff}$	effective total radiation
A_c	surface area of collector
F_n	fraction of solar radiation on north wall
α_j	absorptivity of jaggery
A_i	area of greenhouse wall
M_j	mass of jaggery
T_j	jaggery temperature
T_r	room temperature
$P(T_j)$	vapour pressure at jaggery temperature
γ_r	relative humidity in greenhouse
α_g	ground absorptivity
T_∞	ground temperature
A_g	ground area
A_v	area of vent
g	gravity
ΔP	difference in vapour pressure
L_c	characteristic length
$P(T_p)$	partial vapour pressure of moist air at crop surface temperature
γ_e	relative humidity of moist air above crop surface
A_t	area of tray
MR	moisture ratio
a, b, c	constant
μ_v	dynmic viscosity
V_v	wind velocity
I	available solar energy falling on the collector,
τ	transitivity of the glazing
$\overline{T}_f$	average fluid temperature in the collector
η	collector efficiency
TR	temperature rise
h_i	convective heat transfer coefficient on the inner layer
T_i	initial temperature
T_{m1}	mean temperature in bottom compartment
h_0	outer convective heat transfer coefficient
F_j	fraction of solar radiation on jaggery
I_i	intensity on greenhouse wall
τ_i	transitivity of greenhouse wall
C_j	specific heat of jaggery
h_c	convective heat transfer coefficient of crop
A_j	area of jaggery
$P(T_r)$	vapour pressure at greenhouse air temperature
$h_{g\infty}$	convective heat transfer coefficient greenhouse floor to ground,
$T_{y=0}$	temperature of surface of floor of greenhouse,
h_{gr}	convective heat transfer coefficient greenhouse floor to room
C_d	coefficient of discharge
ΔH	difference in pressure head
U_i	overall heat loss from greenhouse wall
h_c	convective mass transfer coefficient due to moisture evaporation in crop drying
K_v	thermal conductivity of humid air
$P(T_e)$	partial vapour pressure of moist air above crop surface
λ	latent heat of vaporization
t	time interval
k, n	drying coefficient or empirical coefficient
β'	coefficient of thermal expansion $=(1/(T+273))$
ρ_v	density
T_{fi}	initial fluid temperature

1. Introduction

Food is one of the basic needs of human being after air and water. The imbalance between food production and immediate consumption is the biggest hurdle in mitigating this problem. The problem of this imbalance can be solved by two methods;.

i) Increasing food supply and
ii) Controlling population growth.

But both of the solutions require a considerable amount of capital and time to fulfil the objective. Esper and Muhlbauer have given a third and most viable solution to the world's food problem and this is to reduce the food loss. They found many advantages of closed solar drying over open sun drying like improvement in product quality on the basis of colour, texture and taste, no contamination by insects, microorganism and mycotoxin, decrement in drying time up to 50%, reduction of the drying and storage losses, considerable increase in life of the products [1]. Yaldiz et al. concluded that solar dryers can reduce crop losses and improve the product quality significantly when compared to the traditional methods of drying such as sun/shade drying. The food loss occurs due to various reasons in developing countries such as improper cultivation and fertilization, lack of suitable technology, improper transportation, lack of marketing channels, high post-harvest losses, etc. The food loss occurs from 10% to 40% of total production due to above stated reasons. The food preservation is the only technique to reduce the post-harvest food losses [2]. Drying is the method that is being adopted since many centuries for food preservation. The major advantage of drying food products is the reduction of moisture content to a safe level that allows extending the life of dried products. The removal of water from foods provides microbiological stability and reduces deteriorative chemical reactions.

Drying is a process of moisture removal from a product which involves both heat and mass transfer. There are four major drying techniques, namely: open air sun drying, firewood/fuel drying, electrical drying and solar drying [3–5]. The open sun drying is a traditional method practiced widely in the rural areas often yields poor quality since the produce is not protected against dust, rain and wind, rodents as well as other domestic animals while drying. As a result, these produce are often contaminated with micro-organisms and disease causing germs. Additionally, the drying time required for a given commodity can be quite long and result in post-harvest losses.

A portable direct type solar dryer working under natural convection solar dryer has been designed by Othieno [6]. It has rectangular shaped with blackened interior surfaces and transparent