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Multi-shelf domestic solar dryer

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Abstract

The solar dryer described in this paper can be used for drying various products at home under hygienic conditions with the self guarantee of adulteration free product. This solar dryer is of multi-shelf design, consisting of three perforated trays arranged one above the other. The drying air flows through the product by natural circulation. One of its novel features is variable inclination to capture more solar energy in different seasons. Another novel feature is the option to dry product under shade or without shade as per requirement. The rate of drying is uniform in all the trays due to heating of the air by solar energy in between the trays. The maximum stagnation temperature of this solar dryer was found to be 100 °C in the month of November at Ludhiana (31°N). The moisture evaporation on the 1st, 2nd and 3rd drying day for drying fenugreek leaves was 0.23, 0.18 and 0.038 kg/m^2 h. To overcome the problem of reduction in efficiency on the second and third drying day, a semi-continuous mode of loading has been investigated, in which the efficiency remains almost the same on all drying days. The drying rate in the dryer was more than double that in open shade drying. Moreover, the final moisture content of the product was low enough (7.3% wb) for grinding it to a powder form and for good shelf life (1 year). An uncertainty analysis was performed, and the uncertainty in the efficiency was found to be 1.35%. An economic analysis was performed by three methods. The cost of drying fenugreek leaves in the domestic solar dryer turned out to be about 60% of that in an electric dryer. The cumulative present worth of the savings are much higher (18,316 Rupees) than the capital cost of the dryer (1600 Rupees). The payback period is also very low (<2 years) as compared to the life of the dryer (20 years), so the dryer will dry product free of cost during almost its entire life period. The quality and shelf life of the dried products are comparable to those of branded products, while the cost is even less than that of the unbranded products.

Keywords: Solar dryer; Domestic dryer; Natural circulation dryer; Indirect solar dryer; Direct solar dryer; Economics

1. Introduction

A wide variety of products in dried form are used in cooking due to their convenience and availability in off season (e.g. turmeric, chilies, fenugreek leaves etc.). Some products, such as onion, garlic, ginger etc., are currently being used in fresh form due to their higher cost in dried form. In developing countries, commercially

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Nomenclature

b	width of glass cover of domestic solar dryer (m)
C_a	annualized cost of dryer (Rupees) (US$1 ≈ 45 Rupees)
C_{ac}	annual capital cost (Rupees)
C_b	retail price of branded dried product (Rupees/kg)
C_{cc}	capital cost of dryer (Rupees)
C_{de}	cost of drying per kilogram of dried product in electric dryer (Rupees/kg)
C_{dp}	cost of fresh product per kilogram of dried product (Rupees/kg)
C_{ds}	cost per kilogram of dried product for domestic solar dryer (Rupees/kg)
C_e	cost per kW h of electric energy (Rupees/kW h)
C_{fp}	cost per kilogram of fresh product (Rupees/kg)
C_m	annualized maintenance cost (Rupees)
C_{rf}	annual running fuel cost (Rupees)
C_s	cost of drying per kilogram of dried product in dryer (Rupees/kg)
d	rate of interest on long term investment
D	number of days of use of domestic solar dryer per year
D_b	number of drying days per batch
F_c	capital recovery factor
F_s	salvage fund factor
F_{pj}	present worth factor for jth year
i	rate of inflation
I	solar radiation intensity (W/m^2)
I_{av}	daily average solar radiation intensity (W/m^2)
l	length of glass cover of domestic solar dryer (m)
L	latent heat of water (kJ/kg)
m	mass of water evaporated (kg)
m_l	moisture content (dry basis) (%)
M_d	mass of dried product removed from domestic solar dryer per batch (kg)
M_f	mass of fresh product loaded in domestic solar dryer per batch (kg)
M_y	mass of product dried in the dryer per year (kg)
n	life of domestic solar dryer (year)
N	payback period (year)
P_j	present worth of annual saving in jth year (Rupees)
S	solar energy input per kilogram of moisture removal (MJ/kg)
S_b	saving per batch for domestic solar dryer (Rupees/kg)
S_d	saving per day for domestic solar dryer (Rupees)
S_j	annual savings for domestic solar dryer in jth year (Rupees)
S_l	savings during first year for domestic solar dryer (Rupees)
S_{kg}	saving per kilogram in comparison to branded product for domestic solar dryer (Rupees/kg)
t	time during drying day (s)
T_a	ambient air temperature (°C)
T_s	maximum stagnation temperature (°C)
U_l	average overall heat loss coefficient (W/m^2 K)
V	salvage value (Rupees)
V_a	annualized salvage value (Rupees)
w_{x_i}	uncertainty in measurement of independent variable x_i