Renewable Energy 113 (2017) 281–292

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Thermal performance study of a multi-pass solar air heating collector system for drying of Roselle *(Hibiscus sabdariffa)*

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ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form
30 December 2016
Accepted 31 December 2016
Available online 27 January 2017

Keywords:
Multi-pass collector
Medicinal herb
Performance
Roselle
Drying
Payback period

ABSTRACT

This article presents a study on the performance of a forced convective multi-pass solar air heating collector (MPSAHC) system assisted with granite as a sensible energy storing matrix. Experimental drying of Roselle was carried out in August 2015 at Solar Energy Research Site of Universiti Teknologi PETRONAS, Malaysia (4.385693° N and 100.979203 S). The present investigation was conducted under the daily average relative humidity, solar irradiance, ambient temperature and wind speed of 64.5%, 635.49 Wm^{-2}, 32.24 °C, and 0.81 ms^{-1}, respectively. An average drying rate of 33.57 g $(kg\ m^2\ h)^{-1}$ was achieved while the system optical efficiency, collector efficiency, drying efficiency and moisture pickup efficiency of 70.53%, 64.08%, 36.22% and 66.95% were obtained, respectively. MPSAHC dryer was 21 h faster with fair color retention when compared to open sun drying approach (OSDA) that was conducted together under the same weather condition. Techno economic analysis reflected a payback period of 2.14 years. However, drying efficiency could be improved if the inlet air humidity can be controlled to favor drying operation.

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1. Introduction

United Nations has taken a proactive step to make this planet a safe place for the present and future generations through the recent pronouncement of vision 2030 which targets the sustainable development goals (SDG). This noble ideal can only be accomplished if necessary efforts are directed towards research into renewable energy. Based on this global action on checking carbon emission into the atmosphere, it is feasible that renewable energy would replace the hydrocarbon fuels sooner than expected. Therefore innovative ideas are needed more than ever before on reliability and performance enhancement of all renewable energy systems.

Solar drying of material is far from being simple as the general perception of the onlookers if the dried product must possess the high qualities and meet the international market standard. Dryers with the high rate of drying are gaining the attention of users, but they are largely powered by fossil fuels. Drying of edible products such as medicinal herb is difficult because of various conditions attached to its drying process such as drying temperature range, moisture content after drying, color retention, hygienic condition etc. Dubey and Pryor [1] argued that air with temperature of 15–20 °C above the ambient is suitable for drying of grains, herbs and vegetable. Seyfi [2] shared the same view when he used a dryer with air temperature range of 49–51 °C to reduce the moisture of carrot. Kic and Aboltins [3] argued that drying of agricultural product is a complex operation that needs adequate monitoring of the drying system energy balance and the mass transfer of moisture from the inner to the outer part of the product subjected to drying. It was emphasized that the mechanism of moisture transport knowledge is important to achieve improved drying process.

MPSAHC system is an advanced approach of harvesting solar energy flux over double pass solar air heating collector (DPSAHC) and single pass solar air heating collector (SPSAHC) systems. MPSAHC system comprises of transparent covers and a solar absorber. The air from the ambient flows between transparent covers, which eventually pass through the upper and lower planes of the inclined solar collector. The temperature gradient of hot air increases along the flow and thermal losses to the ambient are lower compared to DPSAHC system. Jain and Jain [4] developed a

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http://dx.doi.org/10.1016/j.renene.2016.12.099
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