Renewable Energy 112 (2017) 413–424

Contents lists available at ScienceDirect

Renewable Energy

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

Multi-pass solar air heating collector system for drying of screw-pine leaf (*Pandanus tectorius*)

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ARTICLE INFO

Article history:
Received 6 December 2016
Received in revised form
14 March 2017
Accepted 3 April 2017
Available online 19 May 2017

Keywords:
Screw-pine
Multi-pass
Solar collector
Drying
Performance
Payback period

ABSTRACT

An experimental investigation of solar drying of screw-pine leaf has been conducted in the open space of the solar research site, Universiti Teknologi PETRONAS Malaysia (4.385693° N, 100.979203° E). Screw-pine leaf has been used for handcraft in many villages in Asia and Africa. A transient state lumped element analysis was developed to determine the thermal performance of the multi-pass solar collector system (MSCS) in accordance with ASHRAE standards. The facility was assessed under the average daily solar irradiance of 412.6 Wm^{-2} and ambient temperature of 30 °C over an air mass flow rate range from 0.010 kgs^{-1} to 0.032 kgs^{-1}. Drying kinetics profiles of screw-pine have been obtained and an improved range from 22% to 26% of instantaneous thermal collector efficiency has been recorded over the double pass collector system (DPCS) while thermal energy storage has contributed 5–8% to system performance. MSCS performance has been determined and achieved the thermal collector, pickup, drying and exergy efficiencies of 58.73%, 66.95%, 36.04% and 27.23–86.82%, respectively. The level of risk on the investment in MSCS has been measured using economic indices to obtain a payback period of 0.75 year. The thermal loss through conventional collector back plate has been prevented by integration of collector unit and the drying cabinet of the system. There is still need to further improve the system performance efficiency through enhanced energy saving innovation technique.

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1. Introduction

Global warming is a serious problem that needs mitigation if the earth would be a safer place for the unborn generations. European Commission has set “Europe 2020” as a strategy for sustainable growth to check this ugly trend. Recently, the United Nations has proposed sustainable development goals (SDG) agenda as a means to check the effects of global warming. Immediate measure of reducing carbon content of the atmosphere is through utilisation of appliances powered by renewable energy while the policy that favours clean energy would be a pragmatic and long term approach to achieving global environmental sustainability.

1.1. Solar drying systems

Solar air heater has been reported as a sustainable appliance that is suitable for space heating and drying of many agricultural products at relatively low cost when compared to other conventional energy sources such as hydrocarbon, electrical etc. [1–3]. Drying operation using the hot smoke of burning firewood to preserve fish and crop is common practice in many villages in Asia and Africa [4]. Enormous amount of carbon is deposited into the environment through this process. Inaccessibility of sustainable drying appliances for medium and small scale farmers has contributed to the rise in carbon emission from the agricultural sector.

Drying of fruits and vegetable using solar energy gained by air entering the system through both free and forced convective modes have been widely studied but farmers are still relying on the open sun drying operation due to the level of performance, lack of commercialisation, inaccessibility and high initial cost of the existing solar dryers [2,5]. Al-Jumily et al. [6] tested the thermal performance of a forced convective solar air dryer which consists of collector unit and the drying unit. They achieved a reduced drying time at an optimised air mass flow rate that is sourced from air blower attached to the collector unit. Despite the initial high cost of forced convective solar dryer, it remains the choice for commercial drying purpose.

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http://dx.doi.org/10.1016/j.renene.2017.04.069
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