

ABSTRACT

Under the umbrella of present investigation, a comprehensive assessment of a proposed distributed-type photovoltaic (PV) integrated hybrid solar dryer (HSD) for drying food grains (paddy and wheat) was undertaken. Heat transfer modeling and performance evaluation of photovoltaic system in different seasonal and climatic conditions was conducted. External resistance created by dirt particles can reduce the photovoltaic performance by 4.94% and 7.46% during the winter and summer season, respectively, whereas, wind limited the average panel efficiency up to 10.93%. Therefore, it was evident from the results that obscuring particles negatively influence the PV panel efficiency, especially in hot eastern region of India, i.e. Kharagpur, West Bengal. The panel efficiency in summer and winter season varied in the range of 13-13.9% and 16.0-16.3%, respectively. Additionally, the finite element (FE) based numerical model was developed using COMSOL Multiphysics platform to predict the temperature profile and efficiency of PV panels. Subsequently, optimization of process parameters during drying of paddy and wheat was conducted to obtain standard operational specifications for the HSD. Optimum parameters for drying paddy and wheat were obtained at 700 W, 3.5 m/s, and 12% (wb), and 650 W, 3.5 m/s, and 13% (wb) final moisture content, respectively. Different quality attributes such as thousand kernel weight, milling indices, crystallinity, nano-hardness, micro-structural and topographical properties were evaluated for fresh, dried and stored grains. Nano-indentation test revealed that biomechanical strength of wheat peripheral tissue is higher than endosperm region. A three dimensional FE model for temperature and moisture content prediction of samples stacked in multilayer was validated. Moreover, FE models of HSD at no-load and load conditions were successfully developed. Simulation results of the air distribution profile of the collector and chamber revealed the dead zone, where the air velocity tends to decrease below 0.5 m/s. The system efficiency, specific moisture extraction rate, evaporative capacity and specific energy consumption were estimated to be 62%, 0.27 kg/kWh, 0.39 kg/h and 1448.6 kJ/kg, respectively. HSD's system efficiency was 72% higher than tray dryer and 46% higher than mixed-mode solar dryer. The present study affirms the suitability of PV-assisted HSD for sustainable drying of food grains.

Keywords

Hybrid solar dryer, Photovoltaic, Optimization, Paddy, Wheat, Quality, Modeling, Air distribution profile, Performance