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Finite Element Modeling of Mass Transfer Phenomenon and Optimization of Process Parameters for Drying of Paddy in a Hybrid Solar Dryer

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Abstract : Drying technologies for various food processing operations shares an inevitable linkage with energy, cost and environmental sustainability. Hence, solar drying of food grains has become imperative choice to combat duo challenges of meeting high energy demand for drying and to address climate change scenario. But performance and reliability of solar dryers depend hugely on sunshine period, climatic conditions, therefore, offer a limited control over drying conditions and have lower efficiencies. Solar drying technology, supported by Photovoltaic (PV) power plant and hybrid type solar air collector can potentially overpower the disadvantages of solar dryers. For development of such robust hybrid dryers; to ensure quality and shelf-life of paddy grains the optimization of process parameter becomes extremely critical. Investigation of the moisture distribution profile within the grains becomes necessary in order to avoid over drying or under drying of food grains in hybrid solar dryer. Computational simulations based on finite element modeling can serve as potential tool in providing a better insight of moisture migration during drying process. Hence, present work aims at optimizing the process parameters and to develop a 3-dimensional (3D) finite element model (FEM) for predicting moisture profile in paddy during solar drying. COMSOL Multiphysics was employed to develop a 3D finite element model for predicting moisture profile. Furthermore, optimization of process parameters (power level, air velocity and moisture content) was done using response surface methodology in design expert software. 3D finite element model (FEM) for predicting moisture migration in single kernel for every time step has been developed and validated with experimental data. The mean absolute error (MAE), mean relative error (MRE) and standard error (SE) were found to be 0.003, 0.0531 and 0.0007, respectively, indicating close agreement of model with experimental results. Furthermore, optimized process parameters for drying paddy were found to be 700 W, 2.75 m/s at 13% (wb) with optimum temperature, milling yield and drying time of 42˚C, 62%, 86 min respectively, having desirability of 0.905. Above optimized conditions can be successfully used to dry paddy in PV integrated solar dryer in order to attain maximum uniformity, quality and yield of product. PV-integrated hybrid solar dryers can be employed as potential and cutting edge drying technology alternative for sustainable energy and food security.

Keywords : finite element modeling, moisture migration, paddy grain, process optimization, PV integrated hybrid solar dryer
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