A review on modelling of solar food dryers with thermal energy storage

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Introduction

To sustain the stability between population growth and food supply, food losses during harvesting and marketing should be minimized and drying is one of the important preservation techniques for fruits and vegetables. The energy for drying comes from various sources which includes solar energy. The use of solar energy in such technologies is becoming an environmentally friendly alternative, particularly because of rapid depletion of natural fuel resources, rising fossil fuel costs, and environmentally friendly impacts.

Solar dryers, also known as dehydrators, have been used throughout the ages to preserve grains, vegetables and fruits by removing moisture. Different types of solar dryers have been developed in recent years. The absence of solar energy at night and cloudy periods has led to the development of thermal energy storage (TES) for solar dryers. This stored solar thermal energy can be utilized for drying at night and cloudy periods. In this presentation the review of various thermal energy storage systems used in solar dryers with numerical models aimed to enhancing the efficiency and cost of TES.

Objective

Present a literature review on modelling of solar dryers with the intention of developing a numerical computational fluid dynamics (CFD) model of the solar dryer with latent heat storage at the collector.

Literature Review

- Tripathy et al., (2009)
  - Investigated the application of artificial neural network (ANN) for prediction of temperature variation of food product during solar drying.
  - Mixed-mode solar dryer.

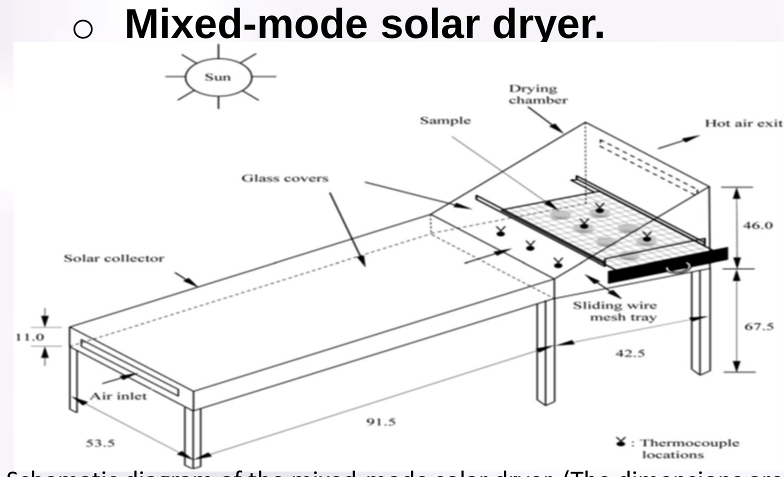

Fig. 1. Schematic diagram of the mixed-mode solar dryer. (The dimensions are in cm.)

  - The artificial neural network (ANN), analytical heat diffusion and statistical models.

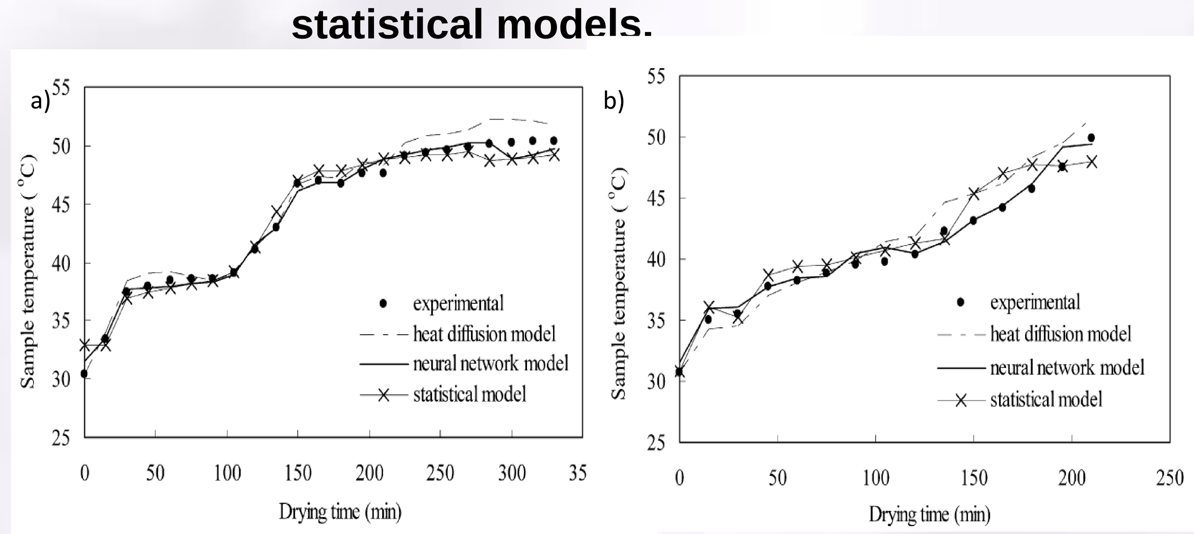

Fig. 2. Comparison between experimental and predicted transient food temperatures obtained from heat diffusion, neural network and statistical models for: a) potato slice and b) potato cylinder.

- Dhalsamant et al., (2018)
  - Carried out natural convection mixed-mode solar drying experiments with potato cylinders of varying diameters and fixed length.
  - Natural convection model

Fig. 3. In-house designed natural convection mixed mode solar dryer.

  - The mathematical model.

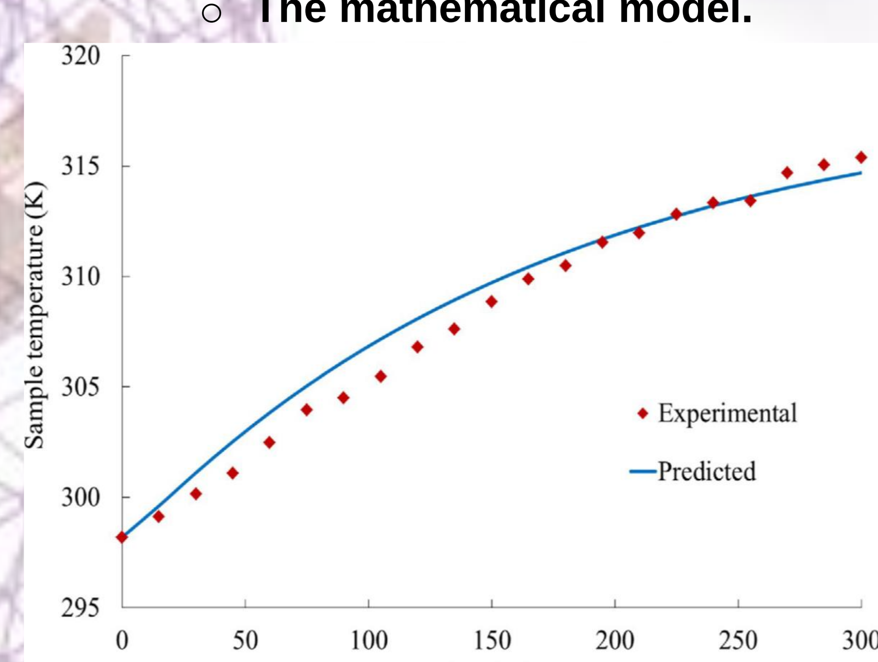

Fig. 4. Validation of predicted sample temperature profile with experimental values for 13 mm diameter potato cylinder

Literature Review Cont.

- Al-Mahasneh et al., (2013)
  - Tested the assumption of open sun drying adequacy to prevent deterioration.
  - Fuzzy and conventional model.

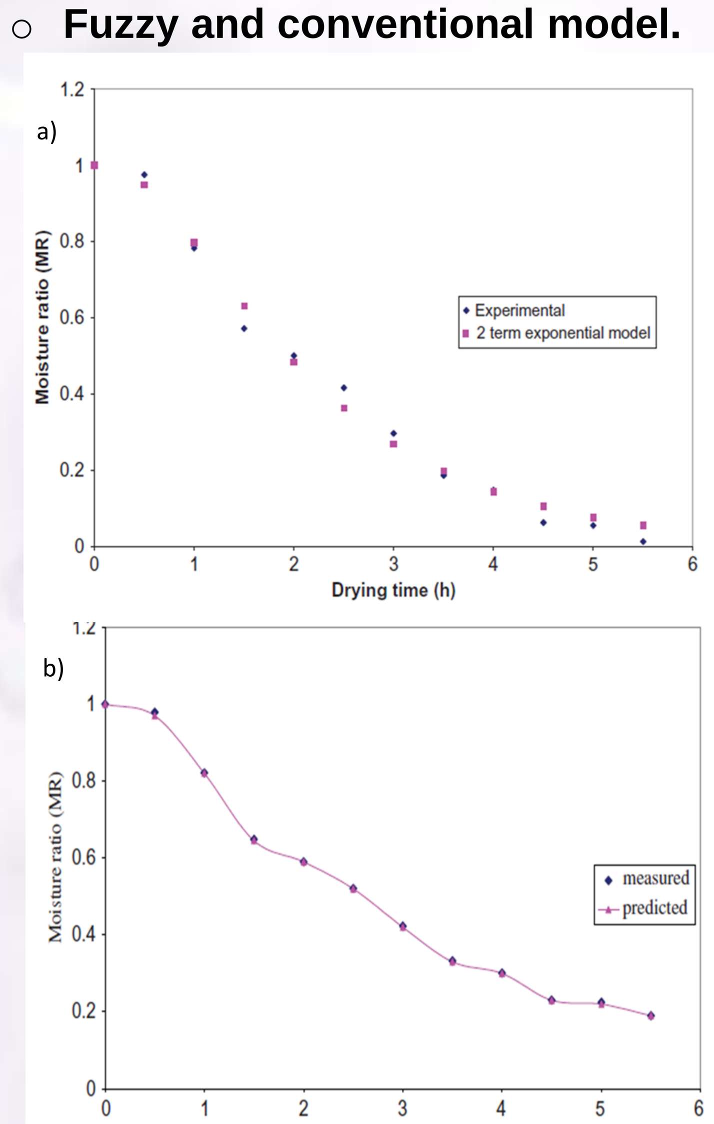

Fig. 5. Comparison between experimental and predicted moisture ratio for roasted green wheat sun drying
Using: a) two–terms exponential model and b) fuzzy modeling.

- Akamphon et al., (2018)
  - Facilitated the design-improvement process of solar dryers.
  - Passive, mixed-mode, thin-tunnel type solar dryer.

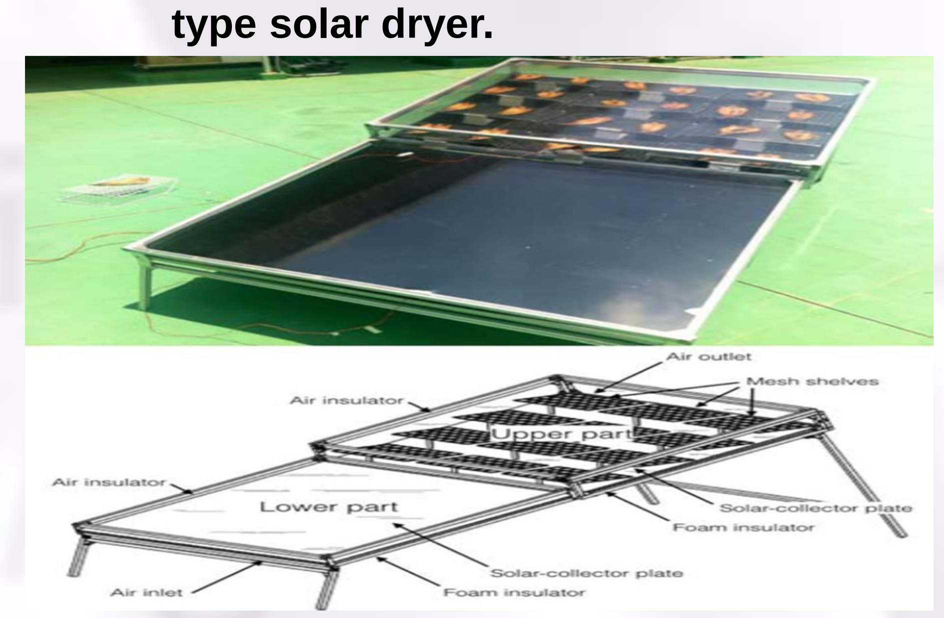

Fig. 6. (a) A photo and (b) schematic of the passive, mixed mode, thin-tunnel solar dryer used for model validation

  - The mathematical and IHTFDMT models.

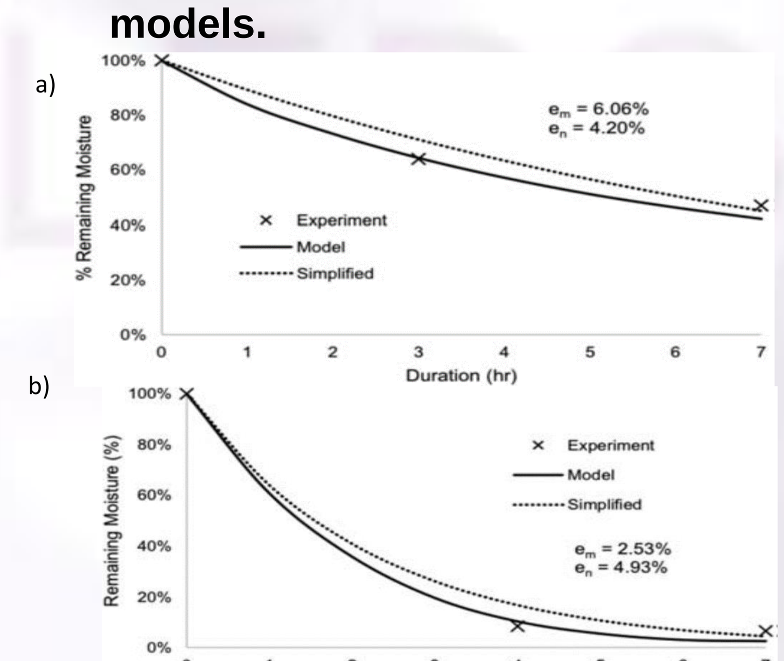

Fig. 7. Remaining moistures in: a) the banana and b) the apple samples from the experiment, IHTFDMT simulation, and simplified equation

Literature Review Cont.

- Kuan et al., (2019)
  - Proposed a numerical model for predicting the energy performance of a heat pump assisted solar dryer under continental climates.
  - Heat pump assisted solar dryer.

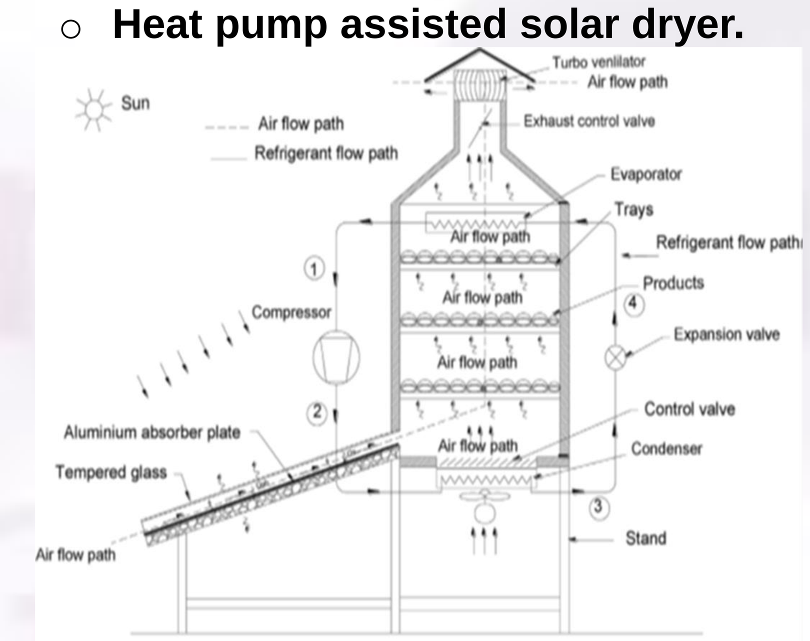

Fig. 8. a. Schematic illustration of heat pump assisted solar dryer. b. Pressure-enthalpy diagram of compression heat pump cycle.

  - The mathematical modelling of a HPASD.

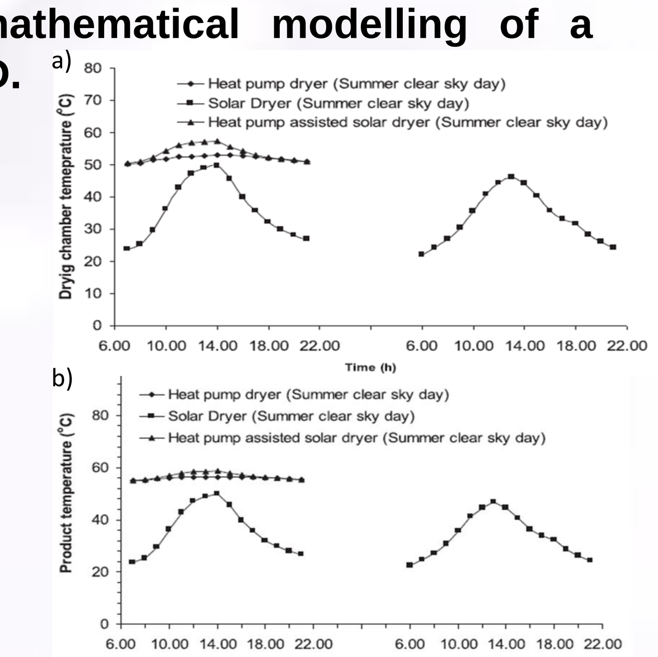

Fig. 9. Comparison of drying method for: a) drying chamber temperatures and b) product temperatures.

- Jain et al., (2019)
  - Focused on CFD simulation, validation of design, energy analysis and numerical computation for domestic direct-type solar dryer.
  - Direct-type domestic multi-shelf dryer.

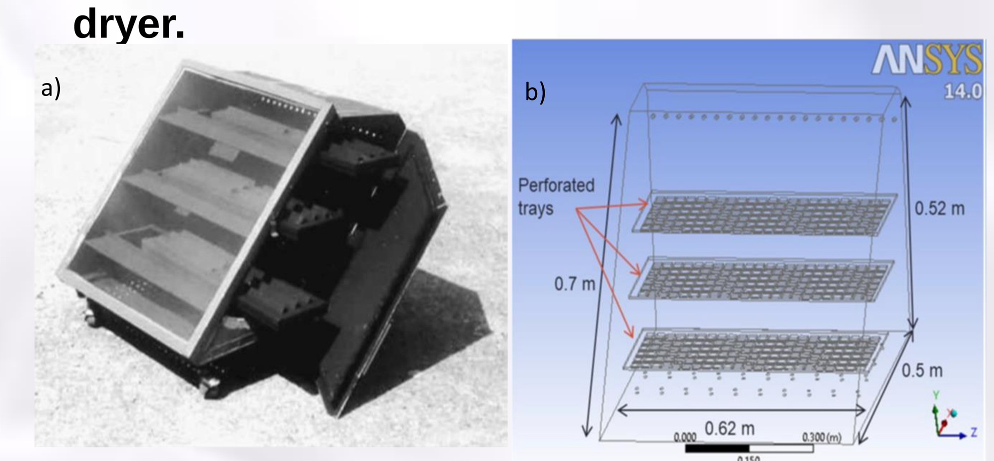

Fig. 10. a) Direct-type domestic multi-shelf dryer and b) its meshed geometry

  - CFD using ANSYS Fluent 14.0 software.

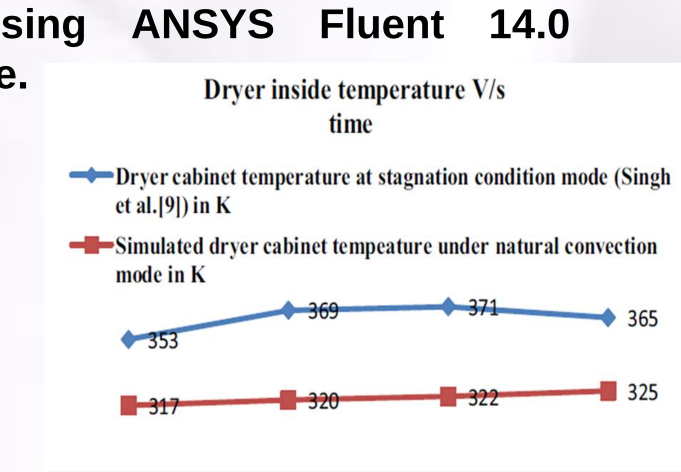

Fig. 11. Comparison of experimental values attained by the multi-shelf solar dryer at no load conditions (Singh et al. (2006)) with the simulated multi-shelf solar dryer at natural convection mode

Conclusion

Modelling helps in simulations, optimization and prediction of various parameters and selection of material for solar dryers. Its application techniques are helpful for drying products in existing solar dryers, they also save time and the capital investment in solar dryers.

Limited studies have been on the modelling of solar dryers with the storage on the collector which is more economical than a separate storage and collection system. Future work intends to do CFD analysis using Fluent on a solar dryer with the storage on the collector after the experimental trials. It will be used to predict and optimize the effect of physical parameters on the solar dryer since fewer experiments need to be done. More insight on thermal processes can be obtained with CFD.

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