A physics-informed neural network-based surrogate framework to predict moisture concentration and shrinkage of a plant cell during drying

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Abstract

This paper presents a Physics-Informed Neural Network-based (PINN-based) surrogate framework, which can couple time-based moisture concentration and moisture-content-based shrinkage of a plant cell during drying. For this, a set of differential equations are coupled to two distinct multilayer feedforward neural networks: (a) PINN-MC to predict Moisture Concentration (MC) with Fick's law of diffusion; and (b) PINN-S to predict Shrinkage (S) with *'free shrinkage'* hypothesis. Results indicate that compared to a regular deep neural network (DNN), the PINN-MC with fundamental physics guidance produces 53% and 81% accuracy values when unknown data has the lowest five timesteps and the lowest 27 data points, respectively. Moreover, its accuracy is 80% better when predicting any unknown spatiotemporal domain variations. PINN-MC further demonstrates stable and accurate MC predictions irrespective of drying process parameters and microstructural variations. In addition, the PINN-S separately proves that utilising a derived relationship based on the 'free shrinkage' hypothesis can improve shrinkage predictions into a realistic behaviour. Also, the PINN-based surrogate framework combines multiple physics for predicting moisture concentration and shrinkage, reassuring its capability as a powerful tool for investigating complicated drying mechanisms. Accordingly, to the best of the authors' knowledge, this surrogate framework is the first of its kind in food engineering applications.