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Drying characteristics of peppercorns in a rectangular fluidized-bed with triangular wavy walls☆

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ABSTRACT

An experimental study on drying kinetics of peppercorns has been conducted in two different drying fluidized-bed configurations: rectangular fluidized-bed (*RFB*) and rectangular fluidized-bed with wavy walls (*RFBW*). In the *RFBW*, two opposite triangular wavy walls with three blockage ratios (e/H) are formed to produce vortex/swirl flows leading to stronger turbulence and longer residence time of the flow in the bed. For each bed, three inlet hot airs (T_{in}) at 60 °C, 80 °C and 100 °C and two superficial air velocity, U^* of 1.2 and 2.0 ($U^*=U/U_{mf}$) are introduced. The experimental results reveal that the air temperature and air velocity show significant effects on the drying rate of both beds, especially at $T_{in}=100$ °C and $U^*=2.0$. The *RFBW* performs much better than the *RFB* due to shorter drying time. The average drying time of the *RFBW* with $e/H=0.3125$, 0.3750 and 0.4375 is, respectively, around 29%, 36% and 43% less than that of the *RFB*. In addition, three mathematical drying models are offered for both the beds and the effect of the air temperature and velocity on the drying model constants was determined by fitting the experimental data using regression analysis techniques. The three models satisfactorily described the drying characteristics of peppercorns especially for the Henderson and Pabis model. The *RFBW* with $e/H=0.4375$ is preferable in the study.

1. Introduction

Drying of food products is one of the most important and well known methods of preserving foods because these materials are highly sensitive to all kinds of microorganism attacks that lead to material deterioration. Drying is the process of simultaneous heat and mass transfer. Heat, necessary for evaporation, is supplied to the particles of the material and moisture vapor is removed from the material into the drying medium. Heat is transferred by convection from the surroundings to the particle surfaces, and from there, by conduction, further into the particle. Moisture is transported in the opposite direction as a liquid or vapor; on the surface it evaporates and passes on by convection to the surroundings. Heat transfer in porous materials with phase change is important in rapid drying of materials and transfer through building thermal insulation. The transfer of heat depends on many factors, such as, air temperature, initial moisture content, desired final moisture content, relative humidity, air flow rate, exposed area of food material, pressure and heat transfer convection coefficient. The physical nature of the food, including temperature, composition, and, in particular, moisture content, governs the rate of moisture transfer. Basically, high temperature air with very low relative humidity is preferable for fast drying processes. However, the maximum temperature of hot air is limited by the quality and application of the products. The highest temperature of hot air is chosen in each application because the use of higher air temperature can lead to the faster in drying and the lower in operation cost.

The application of swirl flows created by wire-coil/twisted tape insert and ribs mounted repeatedly in the chamber [1–3] is one of the commonly used passive heat/mass transfer enhancement technique in single-phase and two-phase internal flows since periodically positioned ribs/coils in the chamber interrupt hydrodynamic and thermal boundary layers, apart from inducing recirculation or secondary flows. Downstream of each rib/coil the flow separates, recirculates, and impinges on the duct wall and these effects are the vital reasons for heat/mass transfer enhancement due to fast mixing of the fluid particles in such chambers. The use of ribs/coils increases not only the heat transfer rate but also gives rise to considerable pressure loss, however.

The drying products such as grains can be divided into two groups: fixed-bed drying and moving-bed drying. The application of a fluidized-bed (*FB*) drying method which is one of the moving-bed drying methods was investigated by Chandran et al. [4] and Thomas and Varma [5]. The *FB* technique has been used widely in dryers for the drying of wet solid particles because of high intensities of heat and mass transfer. The investigation on drying kinetics of bird's eye chilli in a fluidized-bed dryer and on the performance of the *FB* dryer in reducing the moisture content of dried chilli was studied by Tasirin et al. [6]. They reported that the improvement in kinetics of drying for bird's eye chilli depends on the bed depth, air velocity and operating

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