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Experimental Analysis and CFD-based Modelling of Grain Bulk Drying Dynamics

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Abstract

Drying is of great importance in the postharvest processing of agricultural commodities. It refers to the removal of the surplus moisture responsible for biochemical, microbiological, and other moisture-related deteriorative reactions for quality preservation. However, drying is an intricate process comprised of simultaneous heat and moisture transfers, which depend on product and drying air conditions. Therefore, drying practices are oftentimes misused, resulting in serious degradation of product quality. For this reason, modeling can be used to provide a deeper understanding of the air-product interaction and to gain insights into drying processes. Thus, this study focused on developing a CFD systematic approach to model the drying dynamics of wheat bulk (Pioneer A, DSV AG) under controlled conditions. Within the model framework, a porous medium approach with tailored user-defined functions was utilized to represent the grain bulk characteristics. The drying experiments were performed using a high-precision and automated through-flow laboratory dryer. A coherent set of drying air temperatures T = 10–50°C, relative humidity RH = 20–60 % and airflow velocity v = 0.15–1 $\mathrm{m\,s^{-1}}$ were employed for model validation. Afterwards, the validated computational model was used to predict the drying performance at T = 40°C, RH = 40 % and v = 0.15 $\mathrm{m\,s^{-1}}$, where the simulated temperature and moisture content agreed very well with the experimental results ($R^2 \geq 0.98$ and MAPE ≤ 14.93 %). The proposed model proved to be an efficient tool capable of simulating the temperature and moisture dynamics inside the grain bulk with high spatial and temporal resolution. It yielded rapid and in-depth information as compared to laborious physical experiments. In conclusion, the CFD-based approach has demonstrated a great potential to simulate drying processes, thus its capability should be further assessed for various drying technologies, operating conditions as well as agricultural commodities.

Keywords: CFD, drying, grain, high-precision, modelling, three-dimensional

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