Pasta Drying Modeling For Product Quality And Process Optimization

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Abstract

In the field of pasta drying, where accurate prediction of temperature and moisture content distribution is critical, the use of modeling and simulation plays a key role. This study aims to assess operational conditions that ensure the production of safe, high-quality pasta. An advanced two-domain model was developed and solved to estimate transport phenomena in both the food and air domains. Unlike traditional models that rely on predefined interfacial heat and mass transfer coefficients, the proposed model serves as a flexible tool applicable across a wide range of process and fluid-dynamic conditions in real pasta dryers. (1)
A key feature of the model is its ability to describe the glass transition phenomenon, which is crucial for the structure and quality of pasta during drying. Using Kwei's model, the transition of pasta into the glassy state is characterized as a function of local temperature and humidity, offering a detailed view of the interaction between drying kinetics and product structure. (2)
Since food shrinkage during drying greatly affects process performance and final product quality, a structural analysis of the samples is included to enhance the model's predictive accuracy.

The system of nonlinear unsteady-state partial differential equations governing the pasta drying behavior was solved using the finite element method to evaluate how air properties affect drying performance.
To further advance process optimization, we propose a generalized optimization approach applicable to different production lines and pasta shapes. As some input parameters are varied - such air velocity, air flowrate, product shape and quantity - are varied, the model geometry is adjusted into an equivalent geometry.
In particular to represent the dough, the model utilizes the specific surface-to-volume ratio of the selected pasta shape and the weight of the product to be dried to determine the exposed exchange surface area, while the void fraction of the product bed is considered to characterize the number and the proximity of the elements of the equivalent geometry. Regarding the fluid dynamics, the drying duct is rescaled according to the input air velocity and flow rate, ensuring that the process geometry is consistently adapted to the operational parameters.

This flexible methodology ensures that the modeling framework remains robust and representative, regardless of the specific operational conditions.
Furthermore, the model is capable of directly incorporating key drying operational conditions, specifically the air temperature and relative humidity, as input variables. This allows for comprehensive simulation and analysis of drying cycles under both real-scale industrial and pilot-scale conditions. By adjusting these parameters, the framework can replicate and predict the behavior of pasta during a variety of drying protocols, providing valuable insights for process optimization and product quality assurance.
An important advantage of this modeling framework is its ability to perform in silico simulations of pasta drying processes. This capability significantly reduces the reliance on extensive pilot- and industrial-scale trials, leading to considerable savings in time, raw material, and energy consumption. By virtually exploring and optimizing operational parameters, manufacturers can streamline process development and ensure resource-efficient, high-quality production.

Reference

(1) Adduci, G., Petrosino, F., Manoli, E., Cardaropoli, E., Coppola, G., & Curcio, S. (2024). Transport phenomena in pasta drying: a dough-air double domain advanced modeling. Journal of Food Engineering, 376, 112052.
(2) Gaetano Adduci, Francesco Petrosino, Eleonora Manoli, Emily Cardaropoli, Gerardo Coppola, Stefano Curcio (2025), Glass transition in pasta drying: Advanced modeling of the glassy layer evolution, LWT, Volume 218

Figures used in the abstract

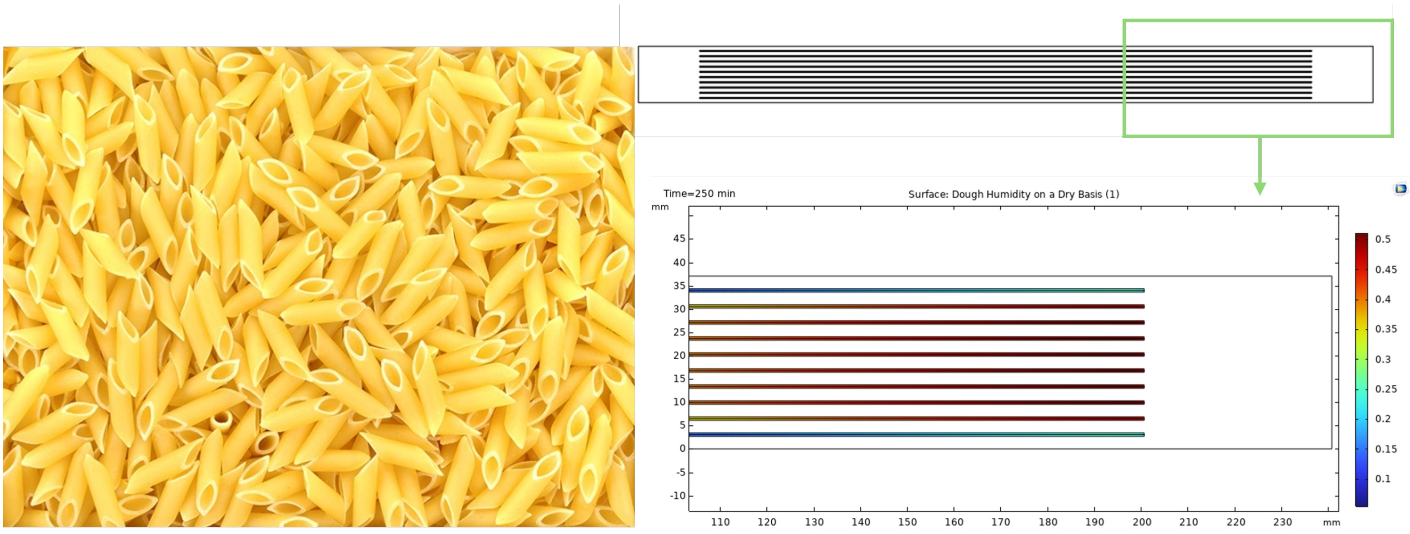

Figure 1 : Equivalent geometry determined by input parameters. The pasta layer is represented by a sequence of lamellar geometries whose size is determined by the surface-to-volume ratio of the selected shape, the void fraction of the layer—defined by the geometry o