Multiscale modeling of strain and stress development in bananas during hot air drying.

Introduction

The strain and stress induced by the drying impact product texture, wholesomeness, crack formation, and various other quality parameters. However, no proper technique for measuring temporal and spatial strain and stress distributions in foods during processing has been developed yet. Additionally, a fundamental understanding of the relationship between process parameters and strain and stress cannot be achieved by purely experimental approaches. In this study, the strain and stress development during banana drying was modeled and simulated by solving the multiscale moisture mass balance equation. The model was validated against experimental moisture data and used to predict strain and stress distribution for different drying conditions.

Methods

The multiscale moisture balance equation was implemented in simulation software. The equation incorporates the generalized Darcy's law and the strain and stress tensors. Banana's transport and viscoelastic properties needed to solve the equation were gathered from the literature and included in the model. To validate the model, predicted moisture values were compared with values measured experimentally at 60, 70, and 80°C and 10 and 20% air relative humidity. The validated model was then used to simulate the strain and stress distributions at 60, 70, and 80°C.

Results

Predicted and experimental moisture data showed good agreement, the root-mean-square errors (RMSE) representing respectively 13.5, 7.9, and 18.9% of the average values at 60°C, 70°C, and 80°C drying temperature. The strain distribution simulation showed a decreasing trend of the strain with the decreasing of drying temperature. The strain also decreased from the surface to the center, and the strain gradient decreased with drying progression. The stress distribution followed a similar pattern. The stress reduced with the decrease of the drying temperature and from the surface to the center. The stress gradient also decreased with drying advancement.

Significance

The multiscale model is based on a mechanistic formulation, thus offering a fundamental understanding of strain and stress development. The strain and stress distributions computed by the model can be used to predictably change drying parameters to minimize strain and stress during processing or product development. Results can be generated for various drying conditions, for any point, direction, or drying time.