A digital shadow to reveal the thermal effect of the drying tray during convective drying of carrot slices

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A key component of a physics-based digital product shadow approach is an adaptive computational model that allows incorporating all relevant physics on the required level of detail. Besides the representation of product specific features, the digital model must also adequately reflect influences of processing equipment, which makes it imperative to understand and model its thermal influence on the product to be dried. To that end, the presented work examines the thermal interaction between the drying produce (carrot slices) and the metal mesh tray it is placed on during a convective drying process. Possibilities to model the influence of this mesh tray on drying behavior are developed, investigated and discussed.
A validated hygrothermal continuous FEM model is applied to study the influence of a metal mesh tray with a bridge width of 2 mm and rectangular cutouts of 10 mm. Effects of heat transfer resistances as well as detachment due to product deformation are approached and their applicability is evaluated. A 2D-axisymetric model is applied. Connecting the digital model to the real world via sensor data – a digital shadow – is accomplished by incorporating the continuously measured infrared surface temperature as Dirichlet boundary conditions to the digital model.
Results show that drying behavior depends on the relative position of carrot slice and metal mesh due to different lengths of diffusion paths. The mesh contact influences the spatial thermal behavior of the material to be dried significantly and must therefore be considered. Detachment of the product from the metal mesh due to deformation plays an important role with respect to prediction accuracy of the digital shadow. It is shown that a sigmoid function is a good approximation to describe and model the detachment behavior.
In conclusion the drying tray, exemplifying general drying equipment design, plays a significant role in the development of a digital shadow/twin and must, therefore, be represented and verified in a suitable manner.
Thus, increasing the prediction accuracy of the digital shadow and quantifying the effect of the drying tray.