Revealing shape variability and cultivar effects on cooling of packaged fruit by combining CT-imaging with explicit CFD modelling

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Abstract

Proper postharvest temperature management is required to maintain the quality of fresh fruit such as pears. Understanding and evaluating the cooling process is crucial. In this context, numerical modelling techniques such as computational fluid dynamics (CFD) can provide complementary insights to experimental measurements. Fruit come in a variety of shapes that are also cultivar-dependent. In this work, CFD modelling was combined with X-ray computed tomography (CT) to explore the differences in cooling characteristics of different pear fruit cultivars in cardboard boxes, as determined by variable fruit shape. First, CT images of boxes randomly filled with pear fruit were obtained. Next, horizontal forced-air cooling experiments with three different pear cultivars (cv. 'Doyenné', cv. 'Conference' and cv. 'Durondeau') were conducted in a pre-cooling setup. After CT image reconstruction of the box and fruit CAD geometry, CFD simulations with the actual pear filling were developed and validated with experimentally-obtained cooling profiles. The experimental data agreed very well with simulation results of three cultivars. Shape differences led to internal porosity variation of the fruit filled box that determined local airflow patterns and cooling behaviour. The cooling time of individual pears in a box differed up to 4 h and large differences in cooling time between the boxes with different pear cultivars were observed. Individual fruit shapes clearly influence cooling behaviour. This work demonstrates that cooling results depend on the filling pattern, so that several fillings need to be accounted for to have a realistic statistical average, which can be achieved by a previously developed shape model combined with discrete element modelling and CFD.