An extended finite element model for fracture mechanical response of tomato fruit

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Abstract

Fresh fruit micro-rupture generally occurs during mechanical handling, which severely affects the product's postharvest quality along the supply chain. An extended finite element (XFEM) model was developed for investigating the fracture mechanical response of tomato fruit under postharvest mechanical compression. A 1/4 tomato fruit was modeled using three parts: exocarp, mesocarp and septa frame, and pre-crack. An amplitude curve-based uniformly distributed pressure load was applied over the internal surface of the locule for replacing the pressure change of the liquid in the fruit locule during compression simulation. The XFEM-based cohesive segments method in conjunction with Phantom nodes was used to simulate the initiation and propagation of the pre-crack in the fruit model. It was assumed that the fruit tissues were linear elastic and ideally brittle solid materials before fracture, the tissue fracture energy was independent of the size and geometry of the cracked tissue specimen, the tissue fracture response met a linear elastic traction-separation behavior, the crack initiation followed the maximum principal stress criterion and the crack evolution followed a linear softening law and a mode-independent and energy-based fracture criterion. The peak force applying over the locule surface was predicted as 0.02 MPa when the crack of the fruit virtually started to propagate. The XFEM model was found to be capable of reproducing the compression force-percentage deformation behavior as well as crack propagation of a tomato fruit in compression up to 28 % deformation with an average relative error was about 8 %. Both XFEM simulation and experiment data showed a rapid pre-crack propagation the percentage deformation was more than 20 %. Furthermore, the propagation length of the crack in the fruit model was sensitive to the peak pressure in the locule and the fracture mechanics (*e.g.*, elastic modulus, Poisson's ratio, failure stress, fracture energy) of the exocarp and mesocarp. This study demonstrates the application of XFEM as a novel tool to understand how fruit rupture under mechanical loading when the fruit mechanics varies at different conditions (*e.g.*, ripeness), and the extent of crack propagation which are important for improving or developing new mechanical handling technologies.