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Integrating Microclimate and Biomechanics to Predict Tomato Cracking in Greenhouse

Srishti Chauhan[1], Prodipto Bishnu Angon[1*]
Institute of Agronomy, Hungarian University of Agriculture and Life Science (MATE), Gödöllő, 2100, Hungary
*Corresponding Author

Abstract

A physiological condition known as tomato fruit cracking drastically lowers commercial yield, especially in greenhouse systems where microclimatic changes are common. The cuticle and epidermis experience a shift in mechanical strain during ripening due to the slow breakdown of pericarp cell walls. The cuticle serves as a defence against stress when internal turgor pressure rises. Crack initiation is by the mismatch between cuticular flexibility and fruit growth. Fruit development dynamics, peel biomechanics, and cuticle composition are all significantly impacted by environmental conditions as temperature, relative humidity, and radiation. Predicting crack start under dynamic greenhouse circumstances is still difficult, despite a wealth of physiological research. High humidity increases internal pressure by encouraging water absorption and cuticular microcracks. Radiation changes the temperature and cuticle biochemistry of fruit, whereas temperature extremes decrease the flexibility of the peel. Furthermore, structural integrity is weakened during ripening by decreases in cellulose, hemicellulose, calcium, and boron. Genetic differences and uneven cracking across the fruit surface make risk prediction and monitoring difficult. The present understanding of fruit biomechanics, microclimate interactions, and physiological ripening processes is summarized in this paper. To explain stress distribution, it combines data from experimental investigations with computational techniques, such as extended finite element modelling. For predictive analysis, the system connects fruit growth sensing, greenhouse climate monitoring, and biomechanical modelling. The study demonstrates how biochemical and structural alterations in the peel interact with mechanical stress caused by the microclimate to cause cracking. It illustrates how predictive modelling may be used to identify crucial risk thresholds and model stress reactions in a variety of environmental settings. Early cracking risk prediction and precise management can be made possible by integrating biomechanical models with real-time greenhouse monitoring. By optimizing irrigation and ventilation techniques and supporting breeding initiatives aimed at crack-resistant cultivars, these methods help reduce preharvest and postharvest losses in a sustainable manner.

Key Words: *Tomato, Physiology, Cracking, Microclimate, Biomechanics, Indoor farming*