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TEN YEARS OF RESEARCH ON SUPERFICIAL SCALD IN APPLES: ELUCIDATING THE LINK BETWEEN ETHYLENE, COLD TOLERANCE, AND GENE REGULATION

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Abstract

Apples are stored under long-term cold conditions to preserve quality and ensure year-round availability. Low-temperature storage is the most common strategy for delaying ripening, but it can interfere with normal fruit physiology, leading to chilling injury disorders such as superficial scald. Effective mitigation strategies include the application of 1-methylcyclopropene (1-MCP), an ethylene competitor, and the use of controlled atmosphere storage, both of which have shown to be effective in preventing such disorders.

The development of superficial scald has historically been attributed to the oxidation of a-farnesene into CT-ols, but over the past decade, experiments integrating RNA-seq analysis, metabolomics, and genetics across various apple cultivars and species have revealed the intricate relationship between ethylene signalling and the induction of cold tolerance phenotypes.

This multifaceted and complex model is enhanced by interference with the ethylene pathway through 1-MCP application and storage under low-oxygen conditions. These treatments drive substantial transcriptional and metabolic reprogramming, including the accumulation of cryoprotectant and antioxidant compounds, the synthesis of fatty acids to stabilize plastid and vacuole membranes against cold temperature, and the activation of genes associated with cold stress tolerance. Moreover, our data also suggest the involvement of programmed cell death in the progression of superficial scald in apples and the expression of negative apoptotic factors appears to limit the occurrence of superficial scald to the outermost epidermal layers.

All these findings highlight the molecular details underpinning superficial scald resistance, cold tolerance and the mechanism of action of postharvest treatment offering insights into optimizing post-harvest storage strategies for apples. Additionally, breeding programs can leverage these information to develop cultivars with enhanced cold tolerance, further supporting the global apple supply chain.