Title Molecular, biochemical and anatomical factors governing ethanol fermentation metabolism and accumulation of off-flavors in mandarins and grapefruit

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Citation Postharvest Biology and Technology, Volume 46, Issue 3, December 2007, Pages 242-251

Keywords Anaerobic stress; Ethanol fermentation; Grapefruit; Mandarin; Off-flavors

Abstract

During postharvest storage or after exposure to anaerobic atmospheres, mandarins develop off-flavors much more rapidly than other citrus varieties, and the occurrence of these off-flavors is associated with increases in juice ethanol and acetaldehyde (AA) levels. However, the reasons why mandarins accumulate more off-flavor volatiles than other varieties are not yet understood. We studied the roles of various molecular, biochemical and anatomical factors in governing ethanolic fermentation in 'Murcott' mandarins and 'Star Ruby' grapefruit under aerobic and anaerobic conditions, and found that exposure to N_2 atmospheres for 24 h increased accumulation of ethanol and AA in the juice and peel of mandarins much more than in grapefruit. However, exposure to anaerobic atmospheres increased pyruvate kinase (PK), pyruvate decarboxylase (PDC) and alcohol dehydrogenase (ADH*)* transcript levels in both cultivars by similar amounts, suggesting that post-transcriptional and perhaps other regulatory mechanisms must be involved in governing ethanol fermentation rates. Exposure to anaerobic atmospheres increased PDC enzyme activity in both mandarins and grapefruit but had only minor effects on ADH activity. Nevertheless, mandarins had much higher (3.8-fold) levels of ADH enzyme activity in their juice vesicles than grapefruit. Anatomical observations revealed that although the total thickness of the peel (comprising the albedo, the white inner layer and the flavedo, the colored outer layer) was greater in grapefruit, the dense flavedo layer was considerably thicker in mandarins. In mandarins, the flavedo also contained more oil glands than that of grapefruit, and the albedo was thinner but more condensed. Accordingly, gas diffusion tests indicated that the peel of mandarins was less permeable to gases, and especially to ethanol vapors, than that of grapefruit. Overall, we conclude that mandarins accumulate larger amounts of AA and ethanol after harvest than grapefruit do because of higher ADH enzyme activity levels in the juice, and because their peel is less permeable to gases. The latter characteristic prevents the release of the produced off-flavor volatiles from mandarins, which results in buildup of ethanol and AA in the internal atmosphere of the fruit and the consequent perception of off-flavors.