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Advances in our understanding of aroma formation in fresh cut products: Genes, enzymes, knife and tooth

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The aroma of fresh cut products is affected by numerous factors that include the condition and developmental stage of the product prior to harvest, storage conditions (atmosphere, temperature and duration) prior to processing, procedures used to process the product (peeling, slicing, use of processing aids), the storage conditions after processing, and by the act of eating the product (mastication). This multiplicity of factors makes it difficult to precisely control the aroma profile and can make it difficult to deliver a product with consistent flavor.

Fruits and vegetables produce compounds autonomously (i.e., spontaneously, without external influence) and also in response to cellular disruption, such as that caused by slicing during processing or mastication during eating. However, our knowledge of the biology of aroma formation is incomplete; there is much to learn regarding the biochemical pathways associated with the formation of the esters, aldehydes, alcohols, acids, terpenes, sulfhydryls, amines and other compounds that act to attract and please consumers.

Our lab has been primarily focused on the formation of alcohols and aldehydes produced following cellular disruption and on the autonomous formation of esters during ripening. We have learned that the production of aroma compounds changes as fruits and vegetables undergo continued development after harvest. In apples, for instance, the number of carbon atoms in the esters tends to decline as ripening progresses postharvest, resulting in the production of copious ethyl esters, especially during the latter stages of fruit senescence. Similarly, we have found that the aldehydes generated by cellular disruption undergo developmentally-dependent changes such that the compounds responsible for green, grassy notes diminish markedly. Optimally, the farmer and the storage operators are able to appropriately manage the maturity to present the consumer with fruit that is neither under ripe, nor overripe. Fortunately, a number of tools exist to limit unwanted changes in ripening associated with ripening. However, some of these tools, including controlled atmospheres and the use of ethylene action inhibitors can further influence the flavor of the final fresh cut product, sometimes in a negative fashion, depending on management practices. Treatment with 1-MCP, for instance, while nicely preserving textural attributes, can also markedly suppress the formation of many of the esters that make an apple taste like an apple.

The compounds synthesized in response to cellular disruption are primarily aldehydes, released by the action of the enzymes of the lipoxygenase (LOX) pathway. This pathway acts upon fatty acids liberated from glycerolipids, but also from any preexisting pools of free fatty acids. The reaction is essentially immediate, requiring only seconds to release copious quantities of highly odor-active compounds like trans,cis-2,6-nonadien-1-ol, hexanal and cis-3-hexenal. The impact of the lipoxygenase pathway on aroma may be both positive and negative for fruits during the eating experience. Interestingly, it appears that for apple, and possibly other fresh fruit, the synthesis of some LOX-derived alcohols and aldehydes shifts as the fruit ripen. In particular, cis-3-hexenal tends to decline while hexanal and the more 'fruity' trans-2-hexenal increases.

The volatile profile of fresh cut produce is also affected by the package. Some packaging films are highly permeable to the volatiles produced by fruit while other polymers are not. Interestingly, the use of modified atmospheres, which successfully controls oxidative browning of cut surfaces, can also alter and/or limit the synthesis of important aroma compounds. For strawberry fruit, we have found that low oxygen, as might be encountered in packaged produce, markedly reduced the synthesis of esters, with the exception of ethyl esters, which accumulate in response to fermentation.

The temperature of the storage environment markedly affects formation of some aroma compounds, especially for those products sensitive to chilling temperatures. Chilling injury can suppress the formation of aroma compounds, sometimes permanently. In tomato, for instance, change in activity of several of the lipoxygenase enzymes is related to the decline in aroma from chilled fruit.

As noted, product condition, handling procedures, and the storage environment all impact the formation of aroma-active volatile compounds. For fresh-cut fruits and vegetables, the challenge is to maintain the fresh-like aroma of the product until it reaches the consumer. Knowledge of the biology of aroma formation will better help us understand how to preserve fresh-like flavors so that the convenience of ready to eat, fresh-cut products is not associated with compromised quality.