

ATTEMPTS TO ELUCIDATE THE COMPONENTS OF TOMATO FLAVOR FOR IMPROVED BREEDING EFFICIENCY

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The chemistry of tomato flavor is not well understood despite considerable literature on the topic (see Baldwin et al., 2000). The reducing sugars fructose and glucose are important as are the acids; primarily citric and malic. Some literature suggests that breeding tomatoes for high levels of sugars and acids will result in varieties with improved flavor (Jones and Scott, 1984; Stevens et al., 1979). A more recent paper indicated that flavor improved with increasing sugar concentration, but that flavor improved with increasing acid concentration only to a point after which it decreased (Malundo et al., 1995). Much molecular marker work for flavor improvement is done with high sugars because they are important components of tomato flavor and because they can be easily measured. One approach to improve flavor is to incorporate a gene that increases the ratio of fructose to glucose since the former is the sweeter of the two (Levin et al., 2000). Another approach is to develop extended shelf life (ESL) tomatoes since this would facilitate breaker harvests and overcome problems associated with immature fruit in the green harvest system. The ESL approach includes use of *rin*, *nor*, or *alc* genes in firm-fruited backgrounds or in developing very firm (ultrafirm) fruit without these genes. There have been flavor problems associated with *rin* and *nor* hybrids Kopeliovitch et al., (1982) and ultrafirm lines are often bland tasting (Scott, unpublished data). There have been unpublished reports that shelf life of *alc* hybrids have not been improved under high temperature growing conditions. On the biotechnological side, PG antisense was used in the FlavrSavr® tomato developed by Calgene, but the shelf life increase was only modest. An alcohol dehydrogenase (ADH) gene has also been modified in 'Flora-Dade' which resulted in increased hexanol and cis-3-hexanol and improved ripe flavor (Speirs et al., 1998).

The other genetic component of flavor are the aromatic volatiles. There are hundreds of these but only 17 were found to be important in tomato based on odor threshold studies by Buttery, (1993). We have found that sugars and acids often do not explain differences in flavor perceived by sensory panels (Baldwin et al., 2000). Volatile levels probably account for these differences. However, it has been difficult to determine consistent volatile patterns associated with superior flavor and at present there is no real selection target.

Our present research on flavor involves attempts to understand the chemistry of some common flavor notes in tomato that we think are analogous to primary colors in that combinations of these notes may be responsible for all the flavors encountered in tomatoes. Six of these flavor notes are clearly undesirable; musty, bitter, astringent (associated with an orange hue), ethanolic, sour (spoiled), and metallic. Another note called vegetative is undesirable if present without enough sweetness to balance it out. A common undesirable flavor is bland and this is thought to result from a lack of sugars, acids, and volatiles. Three flavors; sweet, acid, and balanced probably relate strongly to the sugar and acid content of the tomatoes. Sweet can vary from mild to strong. If mild, this can become insipid or bland under some environmental conditions. Sweet (strong) and acid can be desirable depending on one's taste. Balanced flavor has a good degree of sweetness and acidity and is considered desirable. We have found only one other desirable note and that is fruity-floral. Our hypothesis is that a tomato variety with good

levels of acids and sugars (balanced) and the fruity-floral note would be highly desirable. For three years efforts have been underway to fix lines for strong expression of the above flavor notes so they can be used for training taste panels and in defining their flavor chemistry with the ultimate goal of finding flavor selection targets. However, environmental factors play a profound role in tomato flavor and it has been difficult to fix lines for the flavor notes. This work is ongoing. One method we are using to overcome environmental effects is to taste individual fruit and when a flavor note is strongly expressed, use the other half of the fruit for chemical analysis. It is hoped that enough replications of each note will result in elucidation of the chemistry causing the flavor.

In summary, tomato flavor is a trait that has complex genetic control and strong environmental effects that make selection difficult. There are no acceptable selectable markers, thus the breeder must do a lot of tasting over several seasons and locations in order to define the flavors of a given line. Taste fatigue and time are some of the breeding problems. Of course, flavor must be integrated with other important breeding objectives such as yield, disease resistance, and horticultural quality. There are no easy solutions on the horizon.

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