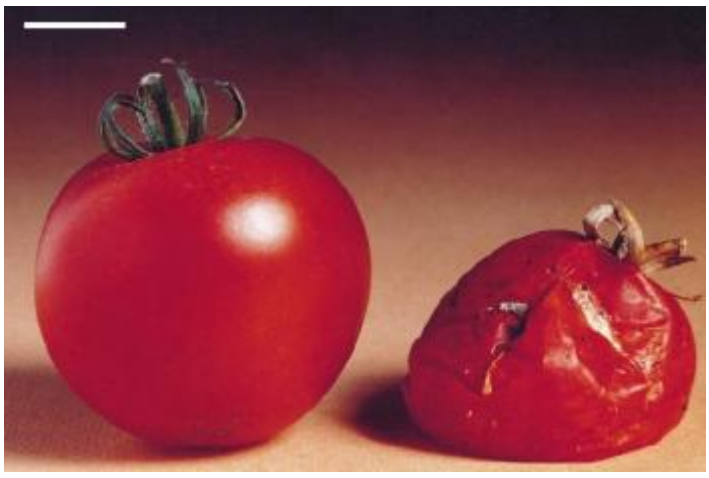
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11.7?Future technologies

Great successes in seed and fruit production have already come from selection of existing genotypes with desirable composition, storage or eating qualities. Can fruit growth, maturation and postharvest physiology be modi?ed even further for human convenience? Examples of genotype x¥ environment interaction are immediately apparent in post-harvest physiology where genetic intervention by conventional breeding has already yielded remarkable dividends with pome- and stonefruits, as well as with citrus and a range of other subtropical species. Persimmon provides an extreme example of existing technology where intense selection of genetic variants has resulted in the non-astringent variant Fuyu. Notwithstanding such positive outcomes, a new generation of ‘designer’ fruit is emerging, and some issues are discussed here.

As our knowledge of underlying physiology has improved, more sophisticated techniques have been applied to regulation of crop yield and postharvest behaviour. We are now entering an era where speci?c events in fruit growth and maturation can be targeted via molecular biology once enzymes in key pathways have been identi?ed. Moreover, given the range of postharvest options outlined above, there has been a major research drive towards genetic manipulation of fresh crops to permit greater flexibility in their postharvest management, and towards producing crops with enhanced flavours.

Almost every aspect of improved product quality and extended postharvest storage life of crops is potentially amenable to genetic engineering. For example, improved tolerance to low temperature would be very desirable in many tropical crops where development of chilling injury below 10°C is a major limit to storage life. Improved tolerance to anaerobic conditions would be valuable in holding fruit at very low O_2 levels, and prevention of fruit softening until an external trigger is provided would simplify postharvest handling. One such instance is outlined below.



[1]

Figure 11.22 Genetic manipulaton can have a profound effect on ripening. Normal tomatoes (right) and Flavr Savr^{TM} tomatoes (left) were picked when both were nearly ripe (light red) and held at room temperature for four weeks. By this time normal fruit had softened and rotted but Flavr Savr^{TM} fruit was still firm and edible. This genetically modified fruit lacked polygalacturonase and had a much better shelf life, as well as improved flavour and handling qualities. Scale bar = 2 cm.

(Photograph courtesy A.J. Conner)

Tomato: a case study

Tomato has characteristics of production, handling and human use that are common to both fruits and vegetables. Tomato also provides an example of a well-documented and well-publicised genetically engineered foodstuff. Tomato is one of the most widely used fruit and vegetable crops internationally. A key to this global adoption is our ability to harvest the fruit in a ?rm state, control postharvest changes long enough for fruit to reach markets without softening unduly and avoid damage from chilling injury or disease.

During past studies on tomato postharvest behaviour, several avenues of research suggested that endopolygalacturonase was responsible for degrading cell wall pectin during softening (Section 11.5.4). A mutant tomato with decreased amounts of this enzyme also displayed delayed ripening. *A priori*, genetic manipulation to prevent this enzyme from forming should prevent fruit from softening and facilitate handling. How could this be achieved?

Three broad approaches are used in manipulating genetic makeup:

1. New genes conferring new biochemical pathways can be brought in from another organism (as in adding a pathway to remove ACC, Section 11.5.6).

2. Expression of an existing gene in the organism can be greatly enhanced (‘sense’ manipulation) (Figure 11.22).

3. A ‘negative copy’ of the plant gene can be introduced to prevent products of the normal gene being expressed (‘antisense’ manipulation).

Two companies (Calgene in the USA and ICI in Britain) were associated with researchers in a race to clone the endopolygalacturonase gene from tomato, to produce its antisense form, and to use that to make transgenic plants that had reduced production of endopolygalacturonase. Initial experiments produced either antisense copies and incorporated these into normal tomato, or sense copies which were inserted into the mutant tomato (Hobson and Grierson 1993). In both cases, fruit ripening was affected due to changed levels of endopolygalacturonase. In the modi?ed mutant, fruit softened and became more like normal fruit. In the antisense plants, fruit softening was delayed (not prevented) and soft fruit did not become overripe and thus susceptible to rots.

These research results were not exactly as expected, but nevertheless had signi?cant commercial value. Inhibiting synthesis of endopolygalacturonase only affected softening and not other ripening indicators. This argued against an earlier hypothesis that all ripening steps would be delayed because all physiological variables were intimately linked. Because transgenic fruits retained their ?rmness, they were left on vines longer, resulting in more carbohydrate accumulation prior to harvest. Moreover, fruit

could be harvested partially coloured rather than mature green, thereby allowing ripening processes to progress more naturally and yielding fruit with markedly better flavour and appearance. To move from experimental results to public availability, the fruit had to go through a series of tests (Redenbaugh *et al* . 1992). Following USDA approval, a transgenic cultivar producing fruit with >99% reduction in polygalacturonase activity was named Flavr Savr^{TM} by Calgene, and was released for marketing to the public under the brand identity of McGregor.

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