# The Transgenic Tomato

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Purpose: To show a general reading audience (perhaps readers of a popular science magazine) that genetically engineered crops are needed and safe to consume by discussing the development of a successful genetically engineered crop, the FLAVR SAVR tomato.

## Background

### I. The Need for Genetic Engineering of Crops

For most Americans, fresh vegetables come from the supermarket. One only has to walk down an aisle loaded with gleaming red tomatoes, juicy melons, fresh potatoes, and a plethora of other vegetables and fruits and gather whatever captures one's fancy or appetite. A person living in a Westernized culture often takes for granted the hard work, resource usage, and waste that occurs to bring food to him. Tomatoes, for example, currently follow a long and difficult route to the supermarket. To begin with, field workers must pick the tomatoes by hand while they are still green. The unripe tomatoes are then trucked to facilities where they are gassed with ethylene to artificially induce ripening (Engel 108). Treating green tomatoes with gas to make the red color appear before the tomato ripens allows them to be shipped with less bruising and spoilage because they are still hard, but this practice detracts from their flavor and makes them taste, as some like to say, like cardboard! After the tomatoes are gassed, the red (but tough) tomatoes are distributed to the supermarkets.

The "cardboard" tomato problem illustrates a larger problem in agriculture - crop spoilage associated with the predations of insects and fungi and with shipping. We saw that picking fruits such as tomatoes while they are green and chemically ripening them is a solution to some of the spoilage problem in crops, while using other chemicals can prevent some damage by pests. However, these chemicals often create environmental hazards in areas where they are used, and pests can often develop resistance to chemicals used to destroy them, making the release of even more pesticides and fungicides into the environment necessary. Also, despite the current practice of picking another fruit, the banana, while it is still green, an estimated 70% of the world's banana crop is lost each year due to spoilage during shipping (Engel 109). These problems are aggravated by the fact that domesticated strains of crop plants tend to be especially vulnerable to disease and insect predation. Biologist E. O. Wilson observed in his book *The Diversity of Life*:

*With cultivation comes evolution by artificial selection of the succulent foliage, large tubers, and tender fruits favored by human beings. Specialization of this kind means a reduced ability to persist unattended in the original habitats…. Domestic strains are also more vulnerable to diseases and plant-eating insects and other pests. Artificial selection has always been a tradeoff between the genetic creation of traits desired by human beings and an unintended but inevitable genetic weakness in the face of natural enemies.*

To compensate for these genetic weaknesses, farmers have applied extensive amounts of pesticides and fungicides to their crops. However, current agriculture has reached a point where the chemicals needed to sustain it are poisoning the environment and the amount of new land that has to be cleared to compensate for the vast wastage associated with pests and shipping spoilage is rapidly closing in on the last of our natural prairies, old-growth forests, and rainforests. Therefore, it is necessary to use the same skills and creativity used to create our crops to recreate them in such a way that will enable them to last from the field to the dinner plate. Genetic engineering is a promising avenue of research that has the potential to solve at least some of the problems of chemical usage and crop wastage by endowing plants with characteristics such as disease resistance, insect resistance, and increased shelf life. In response to the need for less spoilage with good flavor, the tomato became the first crop plant to be successfully engineered. It was called, most appropriately, the FLAVR SAVR tomato. The public and the scientific community have expressed concerns about the safety of genetically engineered (transgenic) crops, but the success of the FLAVR SAVR shows that the creation of a safe transgenic crop is now a reality.

## II. History of the FLAVR SAVR Tomato

Normal tomatoes grown commercially cannot be allowed to ripen on the vine because they soften during the ripening process. Picking them while they are still hard allows them to be shipped, but it also prevents the development of natural flavors. Therefore, supermarket tomatoes generally have little flavor. Scientists at Calgene, Inc. began research in the 1980's on the FLAVR SAVR tomato, a tomato that would not soften while ripening and could, therefore, be left on the vine until it ripened naturally. To create the transgenic tomato, a gene from *E. coli* (a bacterium which occurs naturally in the mammalian gut) called kan(r) and the FLAVR SAVR gene (from a tomato) were inserted into a plasmid (a circular ring of DNA) and plasmids like these were inserted into a group of tomato cells in a growth medium containing an antibiotic (Engel 77). The kan(r) gene, when established in the cell, produced a substance called APH (3') II that gave the cell resistance to the antibiotic. The antibiotic killed cells that did not receive the plasmid. The purpose of the bacterial gene was, therefore, to identify the cells that were genetically transformed. The FLAVR SAVR gene coded for a strand of RNA that was the reverse of a strand of RNA that naturally occurs in the plant. The original RNA strand in the plant is responsible for the production of the enzyme polygalacturonase. Polygalacturonase breaks down pectin in the cell walls of the tomato during the ripening process and causes the entire tomato to become soft (Engel 77). The complementary strand of RNA from the FLAVR SAVR gene binds to the polygalacturonase RNA and the two strands "cancel each other out," preventing the production of polygalacturonase and the softening of the tomato (Engel 77). (For a brief discussion of the relationships between DNA, RNA, proteins, enzymes, and substrates and a diagram of the function of the FLAVR SAVR gene, see Appendices A and B respectively.)

The finished product, the FLAVR SAVR tomato, could be allowed to fully ripen on the vine and develop a more homegrown flavor. However, the introduction of the FLAVR SAVR tomato into the market in the mid-1990's created a good deal of controversy and consumer resistance. Much of the hype surrounding genetically altered crops was created by public misperceptions and fears of "mutant veggies" that were encouraged by various organic and environmental groups. However, the safety of new substances introduced into a food product was a real issue that was brought to the attention of the government and the public. However, after extensive safety research by Calgene and dialogue with the FDA, the FDA found Calgene's tomato to be safe and approved the FLAVR SAVR tomato on May 17, 1994 (Engel 74).

# Transgenic Tomatoes: Are They Safe?

The Calgene Company performed extensive safety and environmental impact tests under the scrutiny of the FDA to assure the public that its transgenic tomato was indeed safe to eat. The company tried to address any relevant concerns that might be associated with eating this genetically altered tomato. Some of the concerns that Calgene's research addressed are discussed below.

## I. All New Substances in the FLAVR SAVR™ Tomato have been Tested and Demonstrated to be Safe

The DNA plasmid that is inserted into the genome of the FLAVR SAVR tomato is not considered to be a new substance since DNA is found in all living things and is destroyed in the human digestive tract. Thus, the only new substance introduced into the FLAVR SAVR tomato by genetic engineering is APH(3')II (Engel 77), the bacterial antibiotic. A substance like APH(3')II is the cause for the greatest concern in genetically altered plants because it is a new chemical not found in the natural varieties that has the potential of being toxic or severely allergenic to humans. For example, a gene from a cold-water fish was introduced into strains of strawberries and citrus to induce frost resistance, but the resulting protein could induce allergic reactions in people who are allergic to seafood (Engel 101). For people with seafood allergies, research is being performed to determine the safety of these crops. Extensive studies of APH(3')II in the FLAVR SAVR tomato, however, show that is safe in normal amounts in humans. APH(3')II was shown to be non-toxic and non-allergenic in humans. This was done by comparing the structure of the APH(3') II molecule to structures of many known toxins and allergens on several computer databases to determine whether the APH (3') II molecule shared any properties or structural similarities with known toxins and allergens. No matches were found (Engel 80).

## II. Transgenic Tomatoes have Comparable Nutritional Values to Normal Tomatoes

Changing the genome of a particular crop plant could theoretically alter the amounts of various nutrients that the plant would pack into parts one would eat. However, in the case of the FLAVR SAVR tomato, no significant alteration of nutrient quality was detected (Engel 78). The amounts of major tomato vitamins (Vitamins A and C), minerals (calcium, magnesium, phosphorus, and sodium), and protein were not shown to be significantly different from the amounts of these substances in normal tomatoes (see Table One).

**Table 1: Comparison of Ranges of Nutrients Between Transgenic and Normal Tomatoes (per 100 g Fruit)**

| Nutrient | Normal Range | Transgenics | Controls |
|---|---|---|---|
| Protein | 0.85 g | 0.75-1.14 g | 0.53-1.05 g |
| Vitamin A | 192-1667 IU | 330-1660 IU | 420-2200 IU |
| Thiamin | 16-80 μ g | 38-72 μ g | 39-64 μ g |
| Riboflavin | 20-78 μ g | 24-36 μ g | 24-36 μ g |
| Vitamin B6 | 50-150 μ g | 86-150 μ g | 10-140 μ g |
| Vitamin C | 8.4-59 mg | 15.3-29.2 mg | 12.3-29.2 mg |
| Niacin | 0.3-0.85 mg | 0.43-0.70 mg | 0.43-0.76 mg |
| Calcium | 4.0-21 mg | 9-13 mg | 10-12 mg |
| Phosphorus | 7.7-53 mg | 25-37 mg | 29-38mg |
| Sodium | 1.2-32.7 mg | 2-5 mg | 2-3 mg |

Note: For Table 1, the "Normal Range" represents values that the researchers looked up in standard references. The "Controls" column represents actual amounts of nutrients found in non-transgenic (traditional) varieties grown by the researchers alongside the transgenic varieties.

Also, it was shown that levels of the naturally occurring toxins tomatine and solanine were not any higher in the transgenic tomatoes than they were in the natural varieties (see Table Two).

**Table 2: Comparison of Tomatine Levels Between Transgenic and Controls Tomatoes (per 100 g fruit)**

| Fruit Stage | Transgenics | Controls |
|---|---|---|

| | | |
|---|---|---|
| Green | 0-8.79 mg | 0-6.48 mg |
| Red | 0-1.09 mg (A)<br><br>A- Only 1 of 38 fruits had detectable tomatine. | 0-2.31 mg (B)<br><br>B- Only 4 of 60 fruits had detectable tomatine. |

### III. The FDA Approved the FLAVR SAVR Tomato for Sale to the Public

The FDA Food Advisory Committee concluded that "the approach used by FDA (Calgene worked in close association with the FDA to devise tests that would prove the safety of the tomato) to evaluate the safety of the tomato, including the safety of the kan(r)) gene, was appropriate and that all relevant scientific questions had been adequately addressed." (Engel 82). On May 17, 1994, the FDA concluded: "FLAVR SAVR tomatoes have not been significantly altered when compared to varieties of tomatoes with a history of safe use (conventional, non-genetically altered tomatoes)" and that they are "as safe as tomatoes bred by conventional means" and would not require any special labeling (Engel 82).

## So What?

Although the main benefit of the FLAVR SAVR tomato is improved flavor for the consumer, the possibilities genetically engineered crops are nearly limitless. Plants can be created that resist spoilage, insect or fungal attacks, or less than ideal weather conditions (as in the case of the antifreeze strawberries) or even create chemicals that can be extracted from the plant tissues and used as pharmaceuticals. Also, the need for clearing new farmland and using pesticides could be reduced if the use of genetically engineered crops became more widespread. However, not all people see genetic alteration of plants from this perspective. One ironic example of resistance to genetically engineered crops came from the Environmental Protection Agency. In a bizarre bureaucratic move, the EPA has designated certain insect resistant crop plants as "pesticides, " thus requiring that they be regulated like chemical pesticides are although there is a tremendous difference between a plant that can make itself not tasty or toxic to insects and man-made chemical pesticides (Nettleton 20). This arbitrary distinction is costing small biotechnology companies thousands of dollars in regulatory costs (Nettleton 20). Groundless bureaucratic decisions such as this reflect the lack of understanding that the government as well as the general public has about biotechnology. The success of the FLAVR SAVR tomato under rigorous testing by Calgene under the watchful eye of the FDA demonstrates that genetically engineered crops have the potential to be safe for human consumption and for the environment. Transgenic plants ought to be tested for safety and regulated by the FDA, but considering the possibilities that the genetic engineering of crops offers and that a demonstrably safe genetically engineered crop (the FLAVR SAVR tomato) has been developed, the public and the government should set aside their concerns, educate themselves on this issue, and give genetic engineering a chance.

## Appendix A

DNA is a double stranded molecule that directs the synthesis of proteins in living organisms. The protein synthesis that occurs in a cell ultimately determines the unique characteristics of that organism. The strands of DNA are composed of thousands of nucleic acids stringed together in particular sequences. A particular sequence of nucleic acids on the DNA molecule codes for the particular sequence of amino acids in a particular protein. When a cell needs a particular protein, the part of the DNA strand that codes for that particular protein "unzips" and allows nucleic acid "pieces" floating in the nucleus of the cell to bond to the exposed nucleic acids in the DNA strand. When the entire new strand of nucleic acids is formed, the new strand, called mRNA, is removed, and the DNA strands "rezip." The mRNA strand will then float through the cell to special protein synthesizing structures called ribosomes and act as a template for production of the protein. As the mRNA passes through the ribosome, it will interact with molecules bearing specific amino acids called tRNA. As each specific tRNA binds to the mRNA, the amino acids will form a string, and the tRNA molecules will be released into the cell. When this string of amino acids is completed, it is called a protein. Some proteins provide structure in living things (such as the protein in muscle tissue), while others can promote certain chemical reactions in cells (such as the breakdown of pectin in tomato cell walls).

The above information was taken from *Biology,* Neil Campbell, et. al., New York: Addison Wesley, 1999, p.316.

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