

How Agricultural Biotechnology Will Alter Food Production

By Jim Kleidon

The dinner table of the future will contain a menu that has high nutritional value, protection against diseases, and is toxin-free. This smorgasbord of food products is being made possible by advances in agricultural biotechnology. Modern crop production is rapidly moving from simple pollination into a complex process empowered by science. During the 20th century, nuclear physics, synthetic chemicals, and high-speed computers provided scientists powerful tools to alter basic crops such as corn, soybeans, and cotton. If science is allowed to push the frontier of biotechnology, the 21st century will see significant changes in global food production.

Background

Humans have been altering their food supply since the earliest attempts at farming. To improve crop resilience and taste, plant breeding through cross-pollination has occurred for thousands of years. In fact, many common vegetables on America's tables such as tomatoes, lettuce, and corn are the result of selective breeding techniques. Colorado State University notes that recognizing valuable plant traits and merging these traits into subsequent plant generations is an "art" developed through generations of horticulture experimentation (1).

As the human population exploded during the 20th century, logic dictated that new scientific techniques would eventually be used to enhance the food supply. According to Dr. Gregory Conko and C.S. Prakash, the U.N. reports that over 1.5 billion people are currently suffering from hunger and malnutrition (3). To combat this challenge, new approaches are envisioned to increase crop yields, reduce farm-generated pollution, and administer vaccines against human pathogens. The goal of agricultural biotechnology is to develop strains of crops to tackle the global food challenge.

Direct intervention into altering plant genetics outside of pollination first became possible with the arrival of the nuclear age. In the 1920's, researchers discovered that pollen exposed to X-rays increased plant mutation rates. Moreover, rates were noted to be

exponentially faster than mutation rates recorded after generations of cross-pollination. During and after World War II, pollens were exposed to gamma rays, protons, and other particles derived from the atomic bomb projects. Based on the results of the atomic experiments, horticulture experts realized that targeted mutation could be used to enhance a plant's native characteristics. Thus, the first seeds of agricultural biotechnology were planted.

Of course, a plant directly subjected to toxic radiation is unsafe for consumption. However, subsequent breeding yields a permanently altered and non-toxic clone. In fact, the common "St. Augustine grass" and "Bermuda grass" that are used widely to sod lawns were initially created through mutation by radioactive gamma rays. Another example of nuclear modification is the "Rio Red" grapefruit grown in Texas. "Rio Red" was created by exposing generic grapefruits to thermal neutrons (IAEA). Pollens from the radiated grapefruits were then bred. The resulting generations of seeds are non-toxic, and exhibit all the characteristics of the precursor "Rio Red" mutation.

Surprisingly, most Americans are already sitting at the future dinner table. For example, scientists have discovered that synthetic chemicals can be used to alter plant genetics. As a result, "Ice Cube" and "Mini-Green" lettuce are hybrids created by using ethyl methanesulphonate to stimulate genetic mutations. Also, the "Above" variety of wheat commonly used in bread was created by mutating generic wheat with sodium azide. Again, even though toxic processes were used to initially stimulate the genetic mutation, the process does not affect humans (IAEA). Without technology and scientific vision, these chemically-altered plants would have been impossible.

The seeds of agricultural biotechnology did not fully bloom until the dawn of the computer age. During the 1980's advances in computing technology enabled the direct study of a plant's DNA sequence through software modeling and simulation. With the proliferation of high-speed computers, researchers were finally able to model and simulate the genetic traits of

individual DNA strands. Scientific techniques developed as a result of the Human Genome project have also helped boost agricultural DNA technology.

In 2003, DNA traits are directly stored in computer databases at corporations, universities, and government research facilities. Scientists can now select genetic traits from one species and merge them into another species. The process of artificially inserting a unique gene protein sequence (transgene) into a host plant is called recombinant DNA engineering. During this process, the transgene can come from either an unrelated plant or an entirely different species. The result is a genetically-modified (GM), or transgenic species. The hybrid plant has a modified genetic structure that contains the traits of the original, plus selected traits from the donor.

Early transgenic varieties were sterile — unable to cross-pollinate, or reproduce. As a result, new seed was required with each planting, making replanting costs prohibitive. However, by the 1990's, new transgenic varieties were developed capable of individual reproduction. Once created, the new characteristics are replicated through natural pollination.

Once armed with DNA splicing techniques, researchers during the 1980's were finally able to customize the genetic characteristics of crops. However, the Consumer Policy Institute notes that genetic modification is not simply an extension of cross-pollination (1). The new "encoded" protein structure allows researchers to target specific attributes such as increased yields, improved growth, and pest immunities. Corporations and government officials immediately realized that transgenic crops could significantly alter the global food supply — for better or worse.

Reducing Chemical Pollution

Imagine a world that no longer requires toxic chemicals to control crop destroying pests. During the 1970's and 1980's, horticulture experts categorized the most destructive pests. Through direct observation, researchers concluded that corn-boring rootworms weaken both corn and cotton, drastically reducing yield and quality. To control the rootworms, scientists leveraged an existing parasite called *Bacillus Thuringiensis* (Bt) because of its basic DNA structure. The results were impressive. Colorado State University describes Bt as a soil bacterium

that when ingested by pest insects, releases a toxin that "creates pores in the intestinal lining, resulting in ion imbalance, paralysis of the digestive system, and after a few days, death" (8).

Prior to the introduction of Bt-hybrids, toxic insecticides were the only way to control corn rootworms and cotton borers. In fact, rootworm insecticides account for the majority of toxins currently applied to U.S. cornfields. Researcher Dan Ferber points out that Bt-hybrid varieties have significantly reduced the use of chemical pesticides, especially on cotton crops (1662). The positive impact of Bt-hybrids has been directly measured. Ferber reports that "in 1999 U.S. farmers used 450,000 kg fewer pesticides on Bt-cotton than conventional varieties" (1663).

Corn and cotton are not the only crops targeting pest resistance. Currently in development is a variety of wheat that contains built-in resistance to plant viruses. If successful, the resulting transgenic hybrid will yield improved wheat production. Given that wheat is the primary ingredient in cereals, baked goods, and many other common products, the impact on the food supply could be significant.

The future is already here when it comes to insect-resistant transgenic crops. Since the insect-resistant hybrids were introduced in 1996, the ISAAA estimates that plantings of these crops are increasing by 11% annually (ISAAA 2). At this rate, insect-resistant corn and cotton will dominate planted acreage by 2006. Moreover, scientists are using the same parasite-splicing techniques to target tomato-boring worms, potato bugs, and other crop-attacking pests. If current research is successful, the salad of the future will truly be pesticide-free.

Improving Nutrition without the Use of Dietary Supplements

Currently, varieties of vitamin and mineral supplements are consumed to improve nutrition. In the future, enhanced-nutrition crops may make dietary supplements obsolete. Scientists have determined that crops can be modified to exhibit improved nutritional value.

One of the first targeted nutritional enhancements was vitamin A. Conko and Prakash state that more than 3 billion people ingest insufficient levels of beta carotene — a precursor to vitamin A (3). The natural DNA of rice was found to be receptive to genetic splices that improved beta carotene production. As a

result, Golden Rice was developed by scientists at universities in Switzerland and Germany and funded by the Rockefeller Foundation. Given the proliferation of rice in the diets of millions of Asians, Golden Rice could substantially alter the food supply of that region.

Beyond Golden Rice, the food supply will also be enhanced by other new varieties of nutrition-boosted crops. Another strain of rice is being developed that photosynthesizes sunlight and carbon dioxide into natural sugars — promoting faster growth. Improved plant maturity rates will facilitate an extra crop season in temperate regions such as India, Bangladesh, and Indonesia. Currently, typical rice growing areas yield only one annual harvest on average. With improved maturity rates, rice harvests may double.

Tomatoes are another popular crop targeted by transgenic research scientists. Traditionally, farmers have cross-pollinated tomatoes to boost flavor, increase size, and thicken skins for improved sunlight tolerance. Lycopene, a naturally occurring constituent of tomato, is another nutritional factor related to Vitamin A. Scientists are currently investigating tomatoes gene-spliced with transgenically enhanced lycopene. The result is a tomato variety that yields a higher nutritional value than the generic strains. Delayed ripening is yet another trait under research. Fruits and vegetables that are allowed to ripen slowly generate sugars boosting flavor. In contrast, generic commercial varieties are picked while the crop is still green (USDA).

Globally Available Edible Vaccines

Beyond improving the nutritional value of crops, research into “edible vaccines” has recently made significant progress. Today, traditional vaccines need to be manufactured, stored, and transported prior to use. Unfortunately, many vaccines arrive too late to prevent incapacitation and death. Genetic scientists believe that by inserting specific vaccines into common food crops, a renewable vaccine source would be readily available in developing countries. The vaccine-characterized plants could then be grown and harvested locally using the prevalent farming methods of the region. As a result, logistical issues currently encountered with the transportation and refrigeration of vaccines would be eliminated. Also, since the vaccine is eaten, health risks

associated with vaccine injections and syringes would be eliminated.

Initial edible vaccine research has been targeted at the most widespread pathogens affecting humans. Topping the list are bacteria that cause diarrhea such as cholera and E-coli. Left untreated, diarrhea will dehydrate a human in a matter of days. According to Langridge, diarrhea causing pathogens currently account for 3 million infant deaths a year in developing nations (2). Edible vaccine research could help pave the way to help build future generations.

To verify the edible vaccine theory, potatoes were selected due to their simple genetic structure. The primitive DNA sequences found in white potatoes are easier to gene-splice than most other plants. In 1995, the first live tests on humans involved a benign segment of the E-coli toxin spliced into white potatoes (Langridge 4). A test group of subjects were fed the peeled, raw transgenic potatoes. For comparison, a control group was provided the non-transgenic potatoes. As expected, only the test group displayed immune responses consistent with the creation of E-coli antibodies. In 1997, tests with potatoes spliced with Cholera antigens and the Norwalk vaccine, also demonstrated positive results with human subjects (Langridge 4).

The second most destructive pathogen is the hepatitis B virus. Hepatitis infections are spreading globally, and have the potential to become epidemic during the 21st century. Hepatitis B damages the liver and if left untreated, can cause liver cancer. This variety of hepatitis is found naturally in streams and rivers in tropical and subtropical environments. Genetic researchers are studying bananas and papayas modified to carry the hepatitis B vaccine. Both fruits are native to tropical and subtropical climates and do not require cooking prior to ingestion — thereby eliminating the risk of vaccine degradation.

Genetic scientists admit that commercial deployment of edible vaccines is still several years away (Langridge, 5). But, initial results to date have been encouraging. By 2003, studies completed with animals and humans have demonstrated that edible vaccines are feasible. However, many challenges still lay ahead. First, the vaccine levels produced by the modified plants are currently sub-optimal. To be effective in combating the pathogen, plant-borne vaccines must have a predictable dosage. Determining to what extent the vaccines are degraded by cooking is yet another challenge. Also,

pathogens could develop their own immunity, rendering the vaccines ineffective.

However, the methods used to treat disease would change significantly if edible vaccines are proven safe and effective. Primarily, the logistics of perishable vaccine distribution and storage would be eliminated. Also, varieties of primary crops such as rice, potatoes, corn, and soybeans would be developed to contain one or more key vaccines. As a result, a “cocktail” of vaccines would be available to treat multiple pathogens. To ensure proliferation, farmers in regions vulnerable to frequent pathogen outbreaks would be encouraged to grow vaccinated crops.

Mankind has benefited from mass vaccinations in the past. Due to widespread efforts during the 20th century, outbreaks of smallpox and polio are now a distant memory. Once scientists can identify, isolate, and synthesize a vaccine against a pathogen, mass inoculations typically stop the disease from spreading. A similar effect would occur if the food supply of the 21st century was enhanced with vaccines. As a result, outbreaks of cholera,

hepatitis, E-coli, and perhaps even AIDS may become a distant memory. Without the future deployment of edible vaccines, infectious diseases will need to be treated by current methods of distributed vaccines. As a result, millions of people may perish because vaccines were unavailable in their region.

Conclusion

Agricultural biotechnology has the potential to significantly alter the food supply of the future. Given transgenic crop's positive track record, deployment will continue globally. In fact, peer-reviewed data from the British Royal Society concludes that transgenic crops do not pose risks to humans greater than conventional crops (15). In the coming decades, advances in computing technology will enable even more exotic types of crop modifications than those currently under research — radically changing the global dinner table.

Works Cited

Colorado State University. Department of Soil and Crop Sciences. Transgenic Crops. 28 Sept. 2003
<<http://www.colostate.edu/programs/lifesciences/TransgenicCrops/index.html>>.

Conko, Gregory and C.S Prakash. “Battling Hunger with Biotechnology.” Economic Perspectives Report. Washington: U.S Dept of State, May 2002.

Ferber, Dan. “Risks and benefits: GM crops in the cross hairs.” Science 26 Nov. 1999:1662-1666

Food and Agriculture Organization of the United Nations. Plant Breeding and Genetics Section. FAO/IAEA Mutant Germplasm Repository. Vienna: United Nations, 2001. 6 Dec. 2003
<<http://www-infocris.iaea.org/MVD>>

Hansen Ph.D, M. “Genetic Engineering is not an extension of conventional plant breeding'.” Consumer Policy Institute/Consumers Union, USA, January 2000
<http://www.biotech-info.net/wide_crosses.html>

James, C. “Global review of commercialized transgenic crops: 2003.” ISAAA Briefs No. 29: Preview. ISAAA. Ithaca, NY. 2 Dec. 2003
<http://www.isaaa.org/Press_release/Briefs29-2003/GMReview_Nov6.htm>

Langridge, William. “Edible Vaccines.” Scientific American 283 no3 (2000).

United Kingdom. Science Advice Section. Genetically Modified Plants or Food Use and Human Health. London: The Royal Society, February 2002. 2 Dec. 2003 <<http://www.royalsoc.ac.uk/files/statfiles/document-165.pdf>>.

United States. Department of Agriculture. Transgenics for a Better Tomato. Sept. 2000. 5 Dec. 2003
<<http://www.ars.usda.gov/is/AR/archive/sep00/tomato0900.htm>>