are usually difficult to treat for flame retardancy.

ARS scientists in New Orleans have developed a new type of cotton/polyester yarn that eliminates most of these deficiencies. During spinning of staple-fiber core yarns, the synthetic staple core is twisted while simultaneously being wrapped with cotton. This results in a yarn with a cotton surface and a synthetic interior. A comparison of the cross sections of intimate blend and staple-fiber core yarns is shown in figure 1.

In staple-fiber core yarns the cotton surface has a natural appearance, feels comfortable when worn, is dyeable with cotton dyes, and can be otherwise chemically modified. The synthetic interior provides strength and dimensional stability.

This process has been patented and is licensed to one company. Potential uses include apparel and home furnishing.

Conclusion

Consumers appreciate the properties of goods made from natural materials such as hides, wool, and cotton. At the same time, the public holds the manufacturers of these goods responsible for meeting ever-increasing environmental standards. ARS continues to maintain an awareness of these two needs in its research. ❑

Biotechnology for Tailoring Old Crops to New Uses

27

by Daniel D. Jones, Office of Agricultural Biotechnology, USDA, Washington, DC, and Susan K. Harlander, Associate Professor of Food Science, University of Minnesota, Minneapolis

The new tools of molecular biology, with their capability for effecting genetic changes that are precise and rapid, can help significantly in the development of new uses for agricultural crops. As used here, the term "biotechnology" refers to these new methods of molecular biology—techniques that use living organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses.

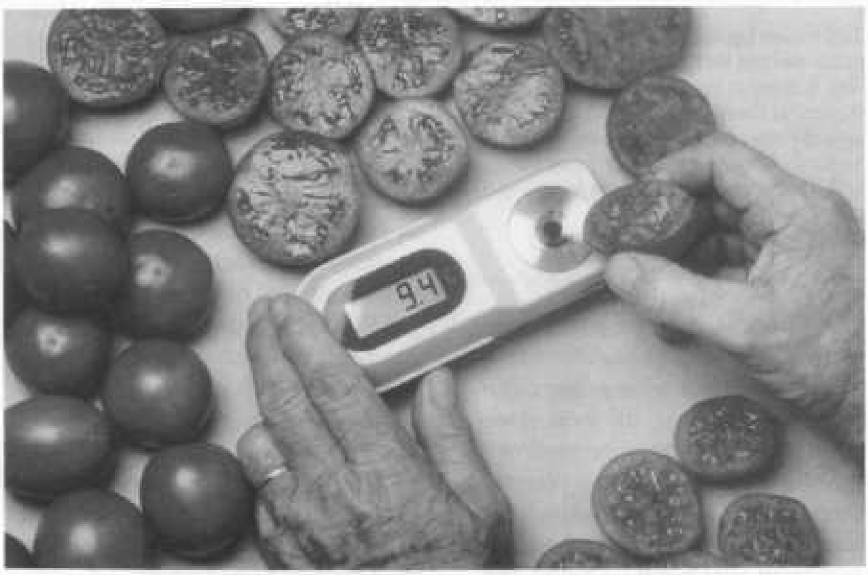
The development of new products from nontraditional plants—such as kenaf, guayule, and crambe—has been proceeding for a number of years. For the most part, these plants have been produced and propagated by traditional methods of natural variation and artificial selection followed by economic assessment. These methods can be both labor-intensive and time-consuming. By comparison, the methods of modern molecular biology offer the prospect of introducing precise, well-characterized, and timely genetic changes into plants, animals, and microorganisms for the specific purpose of expanding their utilization for new food and nonfood uses.

Food Uses

In the area of new uses of crops for the food industry, biotechnology promises an impact on custom-designed ingredients, production of useful substances by plant tissue culture, and improvement of microbiologically produced enzymes used in food processing.

Custom-Designed Food Ingredients. Historically, food processors have been largely limited to purchasing the materials that are readily available at a particular time. In order to compensate for inconsistencies in the quality of these materials, they have often had to modify their manufacturing techniques, thus adding to the cost of food processing.

The tools of biotechnology offer the potential to custom-design agricultural commodities with improved nutritional or functional characteristics that make them more valuable to the processor. This allows the food processor to design and tailor products to fill a specific market niche. Examples include tomatoes with increased solids content, carrots with a longer shelf life, rapeseed with decreased levels of saturated fatty acids, and corn with increased levels of specific amino acids and altered levels of starch, protein, and oil.



With a digital refractometer, ARS scientists can measure soluble solids in field-grown crosses of high-solids variants and commercial tomatoes. This single application of biotechnology offers the potential to custom-design agricultural commodities with improved nutritional and processing characteristics.
Scott Bauer/USDA 92BW0835

Technician Louisa Ling prepares a tomato paste sample for flavor analysis by chemist Ron Buttery at the ARS Western Regional Research Center in Albany, CA. Microbiologically derived enzymes help control texture, appearance, and nutritive value, as well as flavors and aromas in food processing.
Jack Dykinga/USDA 89BW1901-23

As scientists and the public begin to understand more about the role of diet in health and disease, one can easily imagine using the tools of biotechnology to enhance the level of specific nutrients or certain components, such as soluble or insoluble fiber, or specific vitamins and minerals associated with healthier foods. The digestibility and absorption of nutrients could be enhanced, and natural toxicants or antinutrients in foods could be eliminated. Availability of fruits and vegetables with improved flavor, texture, aroma, and shelf life would lead to the inclusion of more fresh produce in the diet.

Producing Useful Substances With Plant Cell Tissue Culture. Plant cell tissue culture offers an alternative to the use of whole plants as a biological source of useful substances. Tissue can be removed from the root, stem, leaf, or fruit of plants, and the undeveloped cells can be grown in the laboratory in gels or liquid solutions containing all the essential nutrients required for growth. The useful substance can then be extracted and purified.

Plant tissue culture for production of natural food ingredients offers several distinct advantages over extraction of these components from whole plants. Seasonal variations, unfavorable weather conditions, and epidemic diseases are not problems when plant tissue is grown under well-defined and controllable laboratory conditions. Plant cell culture allows the processor to control the quality, availability, and processing consistency of the ingredients. Examples of high-value food ingredients which could be produced by plant cell suspension cultures include food colors, fruit and vegetable flavors, oils, spices, antioxidants, and non-nutritive sweeteners.

The discovery of plant cell fusion also permits the combination of plant cells of different genetic makeup to produce new hybrid plants with unique characteristics. New breeding lines have been produced between cultivated crops and closely related disease-resistant wild species. The hybrids produced by plant cell fusion contain a mixture of genetic information from each parent, and this opens the door to the transfer of new traits that are not accessible using conventional breeding approaches.

Enzymes Used in Food Processing. Microbiologically derived enzymes are used extensively by the food processing industry to perform many valuable functions in food systems. They help control texture, appearance, and nutritive value, as well as the generation of desirable flavors and aromas. Most enzymes are used in food processing to break down large molecules such as proteins, carbohydrate polymers, or lipids to their component parts.

Many enzymes do not perform well during food processing because of high temperatures and acidic conditions, as well as other factors. Modern techniques of protein modification provide the necessary tools for modifying the specificity, tolerance to acid, and temperature stability of enzymes, as well as their resistance to digestion by other enzymes. These improvements will expand the uses for enzymes in food processing and increase the kinds of raw materials that can be utilized as food for animals and humans.

Plant physiologist Merle Weaver examines tomatoes grown using a technique know as somaclonal variation, which can produce high-quality hybrids that have high solid content.
Scott Bauer/USDA 92BW0834

Nonfood Uses

For centuries, products of the farm and forest have been used for purposes other than human food or animal feed. Examples include cotton for fiber and absorbants; wood cellulose for paper, cellophane, textiles, and plastics; corn and potato starch for adhesives, binders, insulating foams, textile sizing, and paper coatings; and vegetable oils for lubricants, paints, and varnishes.

With some exceptions, such as wood, cotton, flax, and oilseed crops, few crops have been grown specifically for nonfood uses. Now, however, the intentional cultivation of agricultural crops for nonfood uses is a potential growth industry, and the tools of biotechnology can help to tailor crops for such uses in ways that were not possible before.

This application of biotechnology to the development of new crops to supply industrial products or raw materials is in its infancy, but it promises broad new roles for agriculture as a provider of energy, materials, and specific chemicals.

Somaclonal Variation: Increasing the Solids Content of Tomatoes

Merle L. Weaver, a scientist at the ARS Western Regional Research Center, Albany, CA, is employing a technique known as somaclonal variation to produce new tomatoes with less water and more solids—the compounds used for making catsup, soup, and other familiar tomato products. He says the same approach might also be tried to yield tastier, redder tomatoes for tomorrow's consumers.

Weaver begins the process by placing disks cut from leaves of tomato plants onto a special gel of nutrients and other compounds. In the laboratory, the disks produce tiny clumps of tissue that he coaxes to form plantlets. The plantlets may have genetic characteristics that differ from those of their parents, hence the term "somaclonal variation."

Some of the compounds to which the plantlets are exposed apparently influence the amount of solids they produce. Only those plantlets that over-produce solids survive. Weaver then grows them into full-size tomato plants for further experiments. He has provided some of his high-solids tomatoes to a company that supplies seeds to farmers and gardeners. If the tomatoes pass further tests, the company may use them to produce new commercial varieties for farm and home.

Crops That Produce Value-Added Products. Some plants are particularly valuable for the manufacture of processed or value-added products. Biotechnology is able to alter the genetic structure of these plants, modifying their servicable components; this makes them more desirable for use as value-added products and stimulates development of new or larger markets for them as raw agricultural commodities. Oils and starches derived from plants are promising examples.

Oils. The major oils used by both food and nonfood industries are soybean, corn, cottonseed, rapeseed (canola), sunflower seed, castor bean, linseed, palm, coconut, and tung oils. Potential sources of new oils are jojoba, evening primrose, borage, blackcurrent, crambe, sal, mowrah, and mango. Promising applications of biotechnology in this area include alteration of proportions of fatty acids in current oilseed crops; production of oil containing specific fatty acids by bacteria, yeast, fungi, or microalgae in fermenters; and modification of oils by enzymes produced by micro-organisms in bioreactors.

Starch and Cellulose. Starch and cellulose are used extensively in nonfood applications. Both are very large molecules made up of simple sugar glucose units joined together in chains. For industrial uses, starch and cellulose molecules are often modified through chemical reaction. This provides a broad range of products with applications in many industries, including the chemical, food, pharmaceutical, cosmetics, detergent, paper, and petroleum industries. For example, starch, ordinarily *soluble* in water, can be modified to make it water *insoluble* so that it can be incorporated into plastic trash bags to make them biodegradable. Cellulose, ordinarily *insoluble* in water, can be modified to make it water *soluble* and useful for improved oil recovery.

Fermentation Products. Carbohydrates are a preferred source of energy for producing useful substances from fermentation (the growth of microorganisms such as bacteria and yeast in the absence of air). Thus, glucose and corn syrup (made from corn starch), sugar, and other carbohydrates are used in fermentation to make a variety of useful products. Among these are ethanol for fuel; enzymes; water-soluble gums such as xanthan, which is used in oil recovery as well as in prepared foods; citric acid, which is used as an acidulant in the food and chemical industries; and polyhydroxybutyrate (PHB), a biodegradable plastic that can be molded or made into fiber or sheets.

Pharmaceuticals From Plants. It is possible to modify plants genetically so they will produce specific proteins and peptides. This would allow high-value pharmaceutical peptides such as blood factors, growth hormones, and monoclonal antibodies to be obtained from plants. As scientists become more proficient in plant genetic engineering, it may be possible to harvest nonprotein pharmaceuticals such as the cancer therapeutic agents vincristine (periwinkle) and taxol (yew tree) from plants other than the ones in which they naturally appear.

Protoplast Fusion: Increasing Insect Resistance of Plants

To breed tomato and potato plants that are naturally resistant to insect pests is the goal of Anthony C. Waiss, Carl A.Elliger, and Judith A. Eash at the ARS Western Regional Research Center in Albany, CA.

Conventional plant breeding relies on crossing plants within a species, such as one tomato with another. But Waiss and his colleagues are examining more distant relatives that offer complete resistance to insects that ordinarily attack tomato or potato plants. They exposed a number of plants to insects such as the tomato fruitworm, then selected those plants with leaves toxic to the pest. Petunia was one plant chosen. Another was cape gooseberry.

In one experiment, the researchers combined cells from cape gooseberry with cells from tomatoes through a process called protoplast fusion. First the scientists used a chemical to remove the walls from cells of both "parent" plants. These naked cells are called protoplasts. Then they zapped protoplasts with an electric shock, causing them to fuse together. They next grew plants from the fused protoplasts.

Through protoplast fusion, the scientists have produced several hundred healthy plants that are the offspring of a cape gooseberry and a tomato or potato parent. Other plants are the progeny of a petunia crossed with a potato or a tomato. Several plants produced by fusing potato and cape gooseberry are showing very promising resistance to insects.

The Gene Gun: Taking Aim at Cereal Improvement

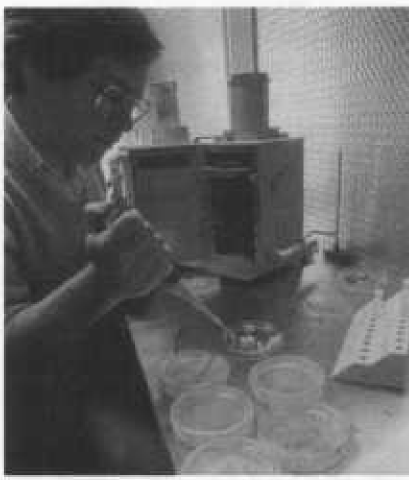
Unlike some plants, cereals such as corn and wheat have been very difficult to improve with the modern tools of biotechnology. To overcome that obstacle, Michael E. Fromm, formerly of the University of California/ARS Plant Gene Expression Center in Albany, CA, and now with Monsanto Company, St. Louis, IL, took aim at corn with a specially developed "gene gun" that fires DNA bullets.

The gene gun used the force of .22-caliber cartridges to fire tungsten particles, coated with DNA, into special clusters of corn cells developed by researchers at Monsanto. The DNA integrated into some of the cells to become part of their genetic code. Some of the genetically engineered cells were nurtured into full-fledged plants by the research team.

In other biotech experiments with corn, cells from corn kernels are serving as miniature labs for ARS researchers Olin D. Anderson and Ann R. Blechl at the Western Regional Research Center, Albany, CA. They are using the cells to conveniently test portions of wheat genes known as promoters. Promoters switch genes on and off. The experiments could lead to new, more powerful promoters to activate genes in wheat grains. These improved genes would confer valuable traits. One of the most sought-after traits for tomorrow's wheat? Grains that yield more nutritious flour.

Conclusion

The agricultural and forestry industries have experienced a decline in profitability because of excess production. This has provided the opportunity for product uses other than as traditional foods, feed, and fibers. These uses include feedstocks for industrial processes, as well as useful substances isolated directly from the plant material. New crops can be developed to meet specialized industrial and energy needs. Molecular genetics can direct modification of proteins/enzymes, bacteria, yeast, and molds for improved or expanded applications in food bioprocessing. The techniques of biotechnology will be very important for targeting genetic changes in food and fiber raw materials, in order to enhance their processing potential and the manufacture of value-added products. ❑



At the Plant Gene Expression Center, Albany, CA, a microbiologist uses a pipette to place the gene and tungsten mixture that will be blasted into plant cells within the gene gun.
USDA/ARS 89BW0445-32