Food Innovation

GMOs, CRISPR & BEYOND

In this issue:

- A Dietitian Talks About GMOs
- GMOs and Food Allergies
- Ensuring the Sustainability of the Banana Split
- Surrounded by Acres of Biotech Corn
- There are Hormones in a Carrot?!

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Plant Breeding Innovation

From Gregor Mendel's peas to CRISPR and beyond...

KAREN BATRA

BETHANY SHIVELY

MICHAEL STEBBINS

For thousands of years, humans have used selection and breeding techniques to develop crops and animals and improve their contributions to mankind. Centuries ago, Central American natives used **selective breeding** to transform a spindly grass called teosinte into the plant that eventually became the productive corn plant we know today.

In the late 19th century, Austrian scientist Gregor Mendel discovered the fundamental laws of inheritance by working with pea plants. That led to **traditional crossbreeding** which combines the desirable traits of two organisms to create a new, improved variety. Honeycrisp apples are a good example. Chickens with large, meaty breasts are another.

A technique called **mutagenesis** uses radiation or physical or chemical agents to induce random mutations in plants. Seedless watermelons were created in this manner back in the 1930s.

The 1990s brought us **genetically modified organisms**—or GMOs—obtaining a beneficial trait from one organism and transferring it into a crop plant. This "transgenic" process has been used to create papayas that resist disease, potatoes resistant to Colorado potato beetles and two plant viruses, cotton that resists pink bollworm, corn hybrids that fight rootworm, plus other significant crop improvements.

Today, new **gene editing tools,** such as CRISPR, act like a pair of molecular scissors, capable of targeting strands of DNA within an organism—allowing precise edits or deletions to achieve a desired result. "You can't get any closer to nature than by using science to improve an organism within itself—and that's what the new gene editing tools allow us to achieve," said Bethany Shively, vice president of strategic communications for the American Seed Trade Association.

Many in the scientific and agricultural communities admit that advocates have done an inadequate job of communicating the benefits—and the safety—of these innovations. As a result, science has outpaced consumer understanding and acceptance—and opponents of these advancements have eagerly filled that vacuum with scare tactics and misinformation.

Social media has added fuel to the GMO fire, says Michael Stebbins with the Council for Biotechnology. "We're all familiar with Ruby Red grapefruit. It was created years ago by bombarding it with radiation in order to develop that pink hue we all know and love," he said. "If we had social media back then, we likely wouldn't enjoy that product today. In fact, we may not even have microwave ovens in our homes."

The confusion and controversy around plant breeding innovation is hindering efforts to address key challenges such as feeding a growing global population, loss of agricultural land and improving human health.

GMOs such as Golden Rice, with higher levels of beta carotene that converts to vitamin A to help prevent blindness in undernourished populations, have hit roadblocks caused in part by activist groups. "I'm concerned that the opposition to this technology is poisoning the well among decision-makers in developing countries, whose citizens could really benefit from these innovations," Stebbins said.

"The impact is really felt in developing countries where smaller farmers are battling bad soils, inconsistent rainfall and disease," said Karen Batra, managing director of agriculture and environment communications for BIO. "GMOs and genetic engineering could make a huge difference in the lives and diets of people around the world."

There is NO GMO wheat

Some people blame the increase in celiac disease on GMO wheat, when in fact no GMO wheat varieties are currently in the marketplace.

A Dietitian Talks About GMOs

If you're looking for expertise on food and nutrition, a Registered Dietitian such as Amber Pankonin is a pretty good resource. She places a great deal of trust in the safety of food products containing genetically modified organisms (GMOs).

AMBER PANKONIN

"Many people are surprised to learn that I am very comfortable eating GMO foods and feeding them to my family," she said. "I know there are some 1,800 studies that have looked at the safety of GMOs and they have not found any cause for alarm or concern."

It takes an average of 13 years for a GMO to go through the approval process before being released. "There is a lot of money, time, research and safety tests that must be completed in order for a GMO to be brought to market," Pankonin added. "I tell consumers that, when it comes to safety, GMOs are safe to eat."

Pankonin urges consumers to take time to understand food labels, especially those from brands that engage in "absence labeling." "Some labels tend to be sneaky," she said. "I have seen a 'non-GMO' label appear on certain products that do not have a GMO counterpart, and that can be confusing and misleading." (One of the most amusing—and egregious—examples is "non-GMO" bottled water!)

Discover more about GMOs at: ***GMOAnswers.com***

And learn about gene editing at: ***Innovature.com***

GMOs and Food Allergies

AMBER PANKONIN

RICK GOODMAN

According to Registered Dietitian Amber Pankonin, the perceived increase in and awareness of food allergies over the past few years are likely due to a couple of factors. "First, the technology to diagnose food allergies has improved dramatically," she said. "Second, there is a misperception and confusion between food allergies and food intolerance. A person who is sensitive to a certain food may self-diagnose that sensitivity as a food allergy, when it really isn't."

Food allergies are a reaction to specific proteins in a food source. The body is somehow "tricked" into producing antibodies against specific food proteins—antibodies that are typically produced to fight parasites or other invaders. In other words, a food allergy is a misguided immune response—one that produces histamines that can lead to serious reactions.

Before a GMO can be introduced into the marketplace, it must be tested to prove that it does not include allergens that do not exist in the non-GMO version of that food.

"If you're not allergic to a certain food in non-GMO form, then you are not going to be allergic to its GMO counterpart."

Are GMOs contributing to the perceived increase in celiac disease? "Celiac disease is not an allergy, it's an autoimmune disorder," Pankonin said. "While some folks might be sensitive to wheat or gluten, the fact is there is no GMO wheat on the market today. So there is simply no way that genetically modified wheat has anything to do with the rise of celiac disease or gluten intolerance because that type of wheat simply doesn't exist."

Dr. Rick Goodman, research professor with the Food Allergy Research and Resource Program (FARRP) at the University of Nebraska–Lincoln, specializes in the assessment of potential allergens in genetically engineered crops. He offered an example of a GMO that was pulled from the market for that very reason.

In the early 1990s, a major seed company was using genetic information from Brazil nuts to create a soybean variety with a better nutritional profile. At the time, the allergens in Brazil nuts were not known. Food scientists at FARRP organized a study in cooperation with the seed company to conduct tests using antibodies obtained from people allergic to the nut. FARRP scientists then performed skin prick tests to demonstrate that the GM soybean variety would have caused an allergic reaction in those allergic to Brazil nuts.

"As a result, further development of that soybean was halted and the product was never made available to farmers," Dr. Goodman said. "That meant a loss of several million dollars in the development of that product to that point, but it would have never gained approval and could have posed a threat to humans. It's proof that the approval system works."

How Gene Editing Could Reduce Food Waste & Loss


BETHANY SHIVELY

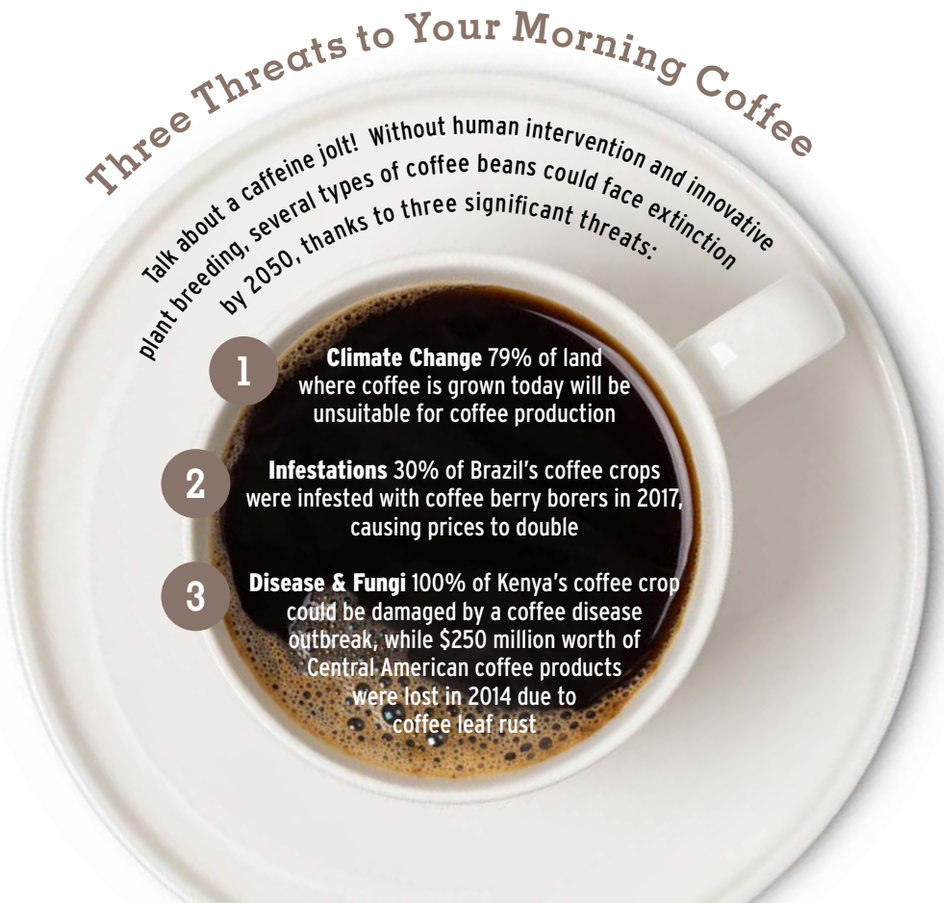
"Globally, the carbon footprint of wasted food exceeds 3 billion tons annually, creating about 7% of greenhouse gas emissions," said Bethany Shively, vice president of strategic communications for the American Seed Trade Association. In the U.S. alone, 133 billion pounds of food are wasted annually, contributing to 18% of total U.S. landfill methane (greenhouse gas) emissions.

"Plant breeding innovations such as new varieties of potatoes and mushrooms that don't bruise and turn brown could go a long way in significantly reducing food waste," Shively said. "That new potato alone could eliminate 1.5 billion pounds of wasted potatoes each year."

Some 20 to 25% of crop yields in the U.S. are lost to pests, disease or post-harvest losses. That number is as high as 50% in the developing world. GMOs and other plant breeding innovations are key to reducing those losses and increasing the world's food supply.

"Nobody is developing a GMO just for the heck of it. As with any science, you look at a problem; you develop a hypothesis; and then you test it. It's less about demand as it is about finding solutions to existing problems and challenges."

Michael Stebbins
Council for Biotechnology



"The genetically-engineered crops on the market today are really helping produce an abundance of food at an affordable price. Some of them also help benefit the environment by reducing pesticide use and protecting groundwater quality."

Dr. Richard Goodman
Food Allergy Research and Resource Program (FARRP)
University of Nebraska—Lincoln

Plant breeding innovation could have a direct impact on many of the foods we all love, including these ingredients in a delicious banana split:

The Race to Save Bananas from Extinction

Nearly half of the 100 billion bananas eaten each year are the same variety—and that variety makes up 99% of the banana exports to the U.S. This makes those bananas highly susceptible to diseases, especially two new diseases that are rapidly killing banana plants around the world. By making tiny changes to a banana's genetic code, scientists are using innovative breeding methods to develop disease-resistant varieties that will help save bananas from the very real threat of extinction.

Ensuring the Sustainability of the

Dark Days for Chocolate?

Chocolate comes from the delicate cacao tree, which is vulnerable to pests and fungal infections. Cacao trees in west and central Africa, where 60 to 70% of the world's cacao beans are produced, are especially at risk. Scientists are using CRISPR gene editing tools to tweak the tree's genomes to help the tree survive in environments affected by climate change, pests and diseases—and that means more chocolate for everyone.

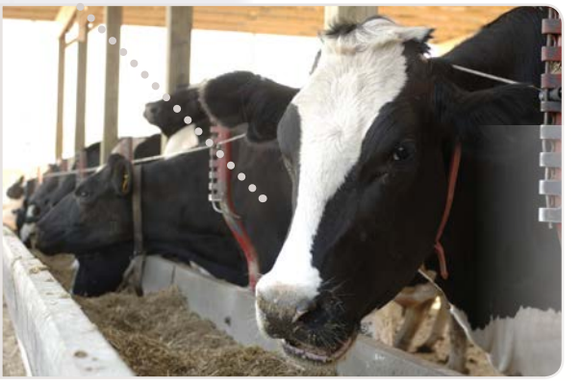
Creating a Safer Peanut

Peanuts are one of the most common—and dangerous—food allergens. While there are no GMO peanuts on the market today, scientists are working on varieties that target the proteins that cause the allergy. That would allow huge numbers of people to enjoy this food without worrying about their personal health and safety.

Saving the Strawberries

Almost 90% of U.S. strawberries are grown in California, where growers are constantly fighting disease without using chemicals. Scientists are unraveling the strawberry genome to pinpoint specific genes that can protect the plants. Other research may lead to strawberries that are even sweeter, more firm and have longer shelf life.

Banana Split



More Milk from Fewer Cows

The nation's dairy herd has fallen from 26 million cows in the 1940s to about 9 million today. But thanks to a wide range of breeding technologies, today's dairy cow produces over four times more milk than in the 1940s—and that means more than enough milk to make ice cream for your delicious dessert. These advancements have also reduced the environmental impact of producing a glass of milk by nearly two-thirds!

The Complete List of Genetically Modified (GM) Foods

These are the ONLY approved genetically-modified/genetically-engineered foods on the market as of this publication.

Corn (field & sweet) The GM version of field corn protects the crop against corn rootworms and the Asian corn borer. Like GM field corn, GM sweet corn also protects the crop against destructive pests.

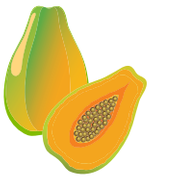
Soybeans The GM soybean plant is resistant to pests and disease as well as being tolerant of herbicides that are most effective, allowing for less herbicide use overall.

Cotton GM cotton requires fewer pesticides and protects against the cotton bollworm.

Canola Canola has been modified through biotechnology to make it tolerant to some herbicides. This allows for a reduced amount of chemicals needed for weed control. The modified plant also has resistance to pests and fungus.

Alfalfa The GM version of alfalfa is tolerant of some herbicides, allowing for a reduced amount of chemicals needed for weed control.

Sugar Beets The GM sugar beet has increased tolerance to some herbicides, allowing for a reduced amount of chemicals needed for weed control. GM sugar beets also have virus and pest resistance traits.



Papaya The GM version of papaya makes the plant resistant to the prevalent Papaya Ringspot Virus, which once threatened the very existence of the Hawaiian papaya industry.

Squash GM squash has traits that improve the plant's defense against viruses.

Arctic Apple This new fruit was developed by turning off the enzyme in apples that cause them to brown when cut, bruised or bitten thereby reducing food waste.

Innate Potato This new potato resists browning and has fewer unsightly bruises, thus reducing food waste. It has been approved by USDA for commercial planting.

Aquabounty Salmon This new salmon is genetically engineered to reach market size more quickly than non-genetically-engineered, farm-raised Atlantic salmon. It is available to consumers in Canada.

Source: BestFoodFacts.org

Improving Animals Through Genetic Innovation

ALISON VAN EENENNAAM

Breeding practices have been used for centuries to improve the usefulness of animals to humans—as sources of food, as a means of transportation, a way to get work done, or simply for companionship. "If we hadn't used selective breeding to modify the behavior of dogs, you wouldn't leave your kids alone with them because the dogs might consider them a food source," said Dr. Alison Van Eenennaam, a professor of animal biotechnology and genomics at the University of California-Davis.

Dr. Van Eenennaam uses the latest in gene editing technology in her research to improve dairy cattle. "Breeders' objectives don't change much. They just adopt the most efficient tools to achieve those objectives—and gene editing is one of those tools," she said.

"Gene editing is a much more precise approach than conventional breeding," said Dr. Van Eenennaam. "With conventional breeding, we pretty much hope for the best in terms that the bull is going to bring genetic superiority in his offspring. Gene editing allows us to be much more precise—turning off a specific gene that makes an animal susceptible to disease, for example."

It's all about improving the health, performance and productivity of the animal. "Whether we do it by mating a good bull with a cow, using genomic selection or using genome editors, all we're trying to do is introduce useful genetic variations that give us the characteristics we want in our production animals," she added.

Dr. Van Eenennaam notes that genetic improvement is a key driver in the sustainability of animal agriculture. "The environmental impact of producing a glass of milk today is about one-third of what it was in the 1940s. That is because, although the number of U.S. dairy cows has decreased from 26 million to 9 million, the yield per cow has increased and hence milk production has almost doubled. That's why genetics is a critically important component of sustainability."

Many genetic engineering initiatives are focused on animal wellbeing including:

- **Creating dairy cows born without horns.** This will prevent young cows from enduring a process to remove their horn buds in order to protect other animals and human workers in the dairies.
- **Producing male pigs that don't achieve sexual maturity.** This will eliminate the need for castration as well as eliminating "boar taint"—the offensive odor or taste that can be evident in pork products derived from post-pubescent male pigs.
- **Developing a heat-resistant "cow of the future."** By introducing the "slick" allele commonly found in Senepol cattle into dairy cattle via genome editing, it may be possible to adapt these animals to thrive in warmer conditions without affecting milk yield.

"We can either put more land under the plow and grow more animals—or we can find ways to improve the productivity and efficiency of the land and animals without increasing acres or livestock numbers. We lose about 20% of our animals to disease. If we could prevent that, then obviously we would have more production from the existing animals we have on Earth—but we can only do that if we allow the best innovations in breeding."

Dr. Alison Van Eenennaam
Professor of Animal
Biotechnology and Genomics
University of California-Davis

More "fuel-efficient" chickens

Today it takes some **five weeks to raise a broiler chicken** to reach a 5-pound market weight, compared to 40 years ago, when it took a 10-week timeframe to produce a 4-pound bird. "We've developed more 'fuel-efficient' chickens that require **5 pounds less feed** to get to market weight," Dr. Van Eenennaam said. "It's not obvious that chicken breeding would have such a huge impact on the footprint of production. That's the hidden benefit of continuous genetic innovation."

Wait a minute. There are

JOAN RUSKAMP

Carrots. Apples. Pigs. Dogs. Cats. Humans. They all depend on hormones to grow and function.

Hormones occur naturally in every living thing, acting as messengers to regulate a wide variety of metabolic processes. "Everything we eat that was once living—from a plant to an animal—contains hormones. Hormones are the messengers in the body that help living things grow," said cattle producer Joan Ruskamp. "Understanding how hormones work is important to understanding why we use added hormones in cattle."

Ruskamp and her husband Steve run a cattle feeding operation near Dodge, Nebraska. Hormones are provided to the cattle under the skin behind the ear and stimulate the gland that produces natural hormones in the animal's body. "Through this implant, we're supplementing naturally what the animal already has in its own body and it helps steers convert feed to protein more efficiently," Ruskamp said. "Any added hormone has to be safe for the humans who are going to consume the meat and safe for the environment. We wouldn't put anything in an animal or our own bodies that is unsafe."

Ruskamp said the use of hormones provides benefits for cattle, cattle producers and consumers. "We can use 10% less feed to produce the same amount of beef—and that efficiency translates into a lower cost for high quality, nutritious beef for consumers," she said. "It also means we're responsibly using the land and water required to raise those animals to market weight. It's a win-win for consumers and producers."

"Everything we eat that was once living—from a plant to an animal—contains hormones. Hormones are the messengers in the body that help living things grow."

hormones in carrots?

How much is a nanogram?

A nanogram is one-billionth of a gram or one-25 billionth of an ounce. A small paper clip is 1 gram. Cut that into 1 billion pieces and you get a nanogram. Beef from an implanted steer will have about 2 nanograms of estrogen in a quarter-pound burger. That's miniscule compared to beef from a non-implanted animal at 1 nanogram for the same sized serving.

By contrast, women naturally produce 513,000 nanograms of estrogen daily and men produce 136,000 nanograms of estrogen daily—equivalent to eating more than 15,000 pounds of hormone-implanted beef every day!

"If you're diabetic and choose not to take insulin—which is a product of genetic engineering—you increase your risk of death. In that case, the benefit of genetic technology is very obvious. With food applications, the benefits are less transparent to consumers, even though they are very real."

Dr. Alison Van Eenennaam
Professor of Animal Biotechnology and Genomics
University of California-Davis

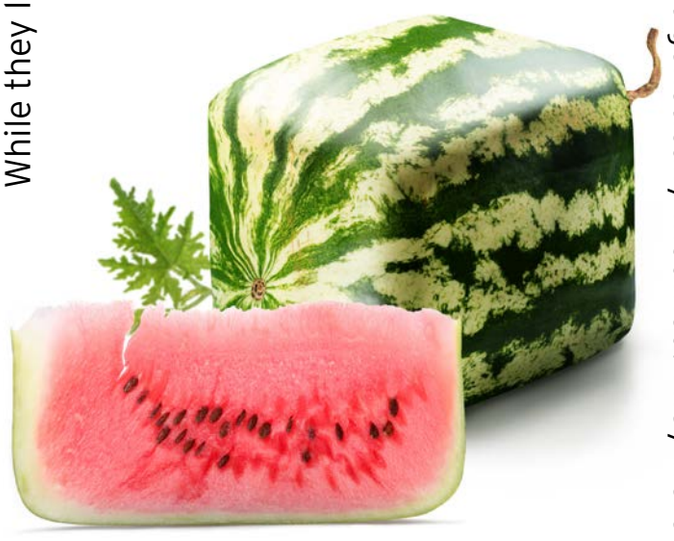
GMO? Or No?

Guess which products contain GMOs:

1. Seedless Watermelon
2. Rainbow Papaya
3. Cotton T-Shirt
4. Tomato
5. Whole Wheat Pasta
6. Strawberry
7. Bottled Water
8. Ruby Red Grapefruit
9. Sweet Corn

1. NO 2. YES 3. YES 4. NO 5. NO 6. NO 7. NO 8. NO 9. YES

While they look weird, these square watermelons are not genetically modified. They were simply grown in a box.



Surrounded by Acres of Biotech Corn

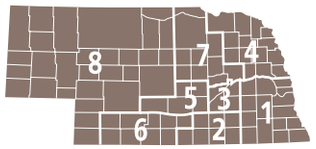
DEB GANGWISH

The Shelton, Nebraska farmstead on which Deb Gangwish and husband Paul raised their children is surrounded by cornfields—acre upon acre of biotech and GMO-enhanced corn hybrids. "It takes up to 13 years and $300 million to bring a new genetic trait to farmers—and that includes an exhaustive review by FDA, EPA and USDA," Gangwish said. "I can tell you I feel pretty darned safe with that."

Gangwish says biotechnology and GMO traits in crops such as corn and soybeans have yielded tremendous benefits. "The overarching theme is being able to do more with less," she said. "We use fewer chemicals, less fuel and less water. We don't have to till the soil, so the carbon stays in the soil. These advancements in technology are good for us and good for consumers."

Biotech genetics and GMOs are just one tool in farmer's toolbox. "We use a lot of digital and precision technology," Gangwish added. "We are able to monitor almost every practice on our farm—from exact placement and depth of seed...to how much force it took to get that seed in the ground...to how much water and fertilizer we're using...to harvest data that tells us how we're doing in every section of the field."

While most of the GMO/biotech field corn grown at the Gangwish farm is not used for food, it still makes its way into the consumer marketplace. "There are almost 4,000 products that come from the field corn we grow—products that are integrated into everyday life," she added. "To have 4,000 products grown efficiently and safely through technology is a huge benefit to the consumer in terms of product choices, price and environmental stewardship."



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