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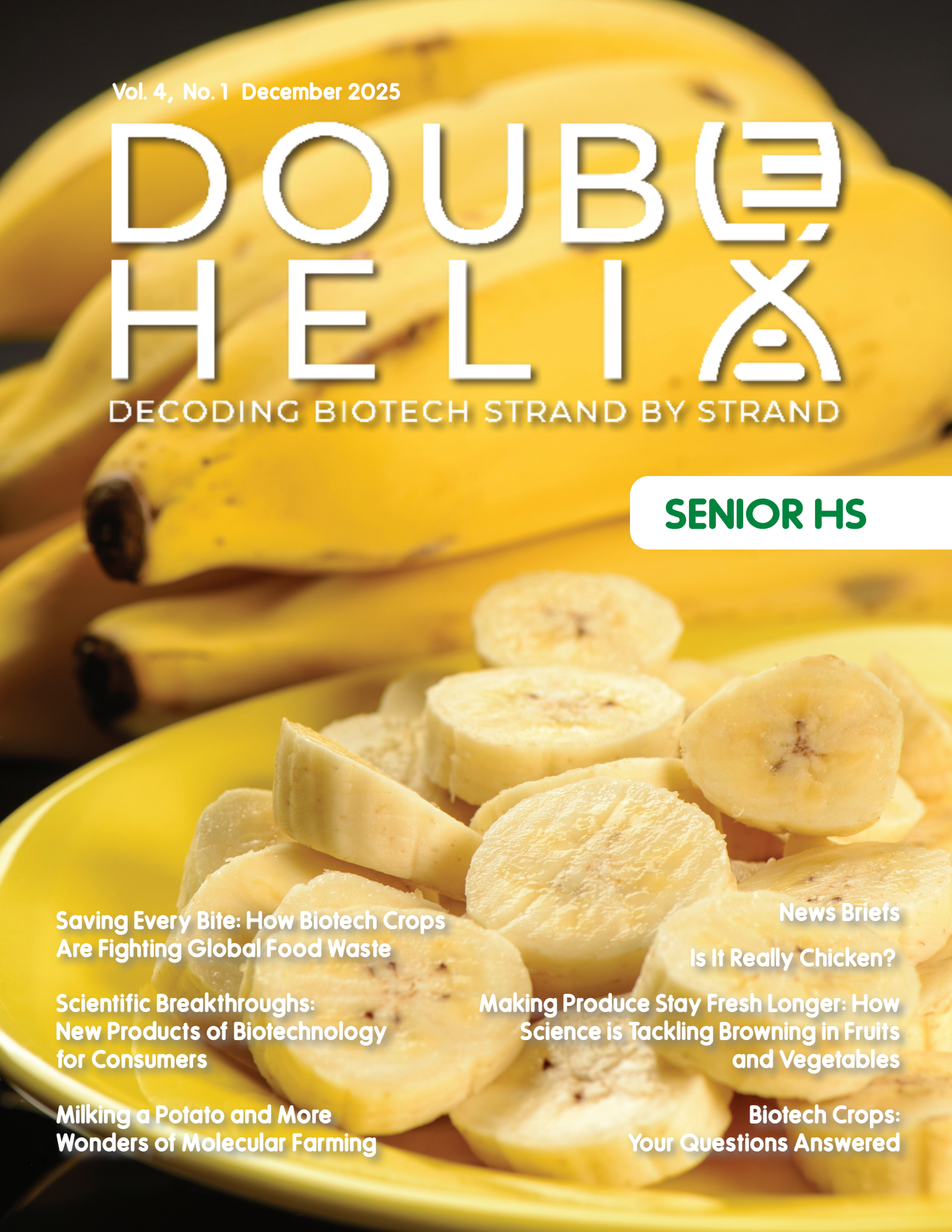
DOUBLE HELIX

DECODING BIOTECH STRAND BY STRAND

SENIOR HS



DOUBLE HELIX
DECODING BIOTECH STRAND BY STRAND

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The *Double Helix* is a magazine supplement for senior high school students taking the Science, Technology, Engineering, and Mathematics (STEM) strand. This magazine is published by ISAAA Inc. and available for free download in the ISAAA Inc. website at www.isaaa.org. Send all inquiries to double.helix@isaaa.org

Welcome!

Dear Teachers, Students, and Readers,

Welcome to the fifth issue of the *Double Helix*, the only magazine on agricultural biotechnology for senior high school students in the Philippines!

Biotech crops are an important part of the modern agricultural landscape, aiming to support sustainable farming and help feed a growing global population.

Biotech crops make farming more efficient and sustainable. For consumers, this translates to several key benefits: increased food security from more reliable harvests, and in some cases, improved nutrition, such as Golden Rice engineered to produce higher levels of beta-carotene (a precursor to Vitamin A), or reduced browning banana to help reduce food waste, to name a few.

This issue of the *Double Helix* presents biotech products developed for consumers, how biotech crops help fight global food waste, reduced browning products, and an infographics on biotech FAQs.

If there are topics that you want to be covered in the *Double Helix*, send us a message at double.helix@isaaa.org. Please share the *Double Helix* with your family and friends!

— *Double Helix* Editorial Team

NEWS BRIEFS

PHILIPPINES CLEARS GENE-EDITED BANANAS DEVELOPED TO REDUCE FOOD WASTE

New banana varieties with improved reduced-browning trait have been determined as non-genetically modified organisms (GMOs) in the Philippines. The Certificates of Non-Coverage from JDC No. 01 s. 2021 was granted by the Department of Agriculture – Bureau of Plant Industry (BPI) on June 21, 2024. The reduced browning bananas (TRB011001 and TRB011002) were developed by Tropic Biosciences using the CRISPR-Cas9 gene editing system. These bananas have the potential to reduce food waste and CO2 emissions equivalent to removing 2 million cars from the road per year.

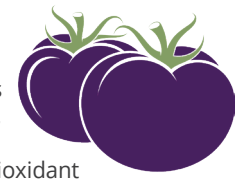
SCIENTISTS GROW MEAT INSIDE RICE GRAINS

Scientists from Yonsei University developed cultured beef rice, rice grains with animal muscle and fat cells inside. The findings of their study, published in *Matter*, show that cultured beef rice has 8% more protein and 7% more fat than regular rice. The researchers used rice grains to house animal-derived cells. After coating the rice grains with fish gelatin, cow muscle and fat stem cells were seeded into the rice and allowed to grow in a petri dish for nine to 11 days. The cultured beef rice could significantly reduce its carbon footprint at a cheaper price once commercialized.

HIGH GABA TOMATO DETERMINED AS NON-GM IN THE PHILIPPINES

The Philippine Department of Agriculture – Bureau of Plant Industry (DA-BPI) released a Certificate of Non-coverage from JDC No. 01 s.2021 for gene-edited high GABA Silician Rouge Tomato developed by Japan-based Sanatech Seed Co., LTD. High GABA tomato was first released by Sanatech in Japan in 2021. It was developed using CRISPR-Cas9 technology to contain high levels of gamma-aminobutyric acid (GABA), an amino acid that helps lower blood pressure. The gene-edited tomato has four to five times more GABA than conventional tomato varieties.

GE PURPLE TOMATO SEEDS NOW AVAILABLE TO HOME GARDENERS IN THE US



Norfolk Healthy Produce announced the online seed sales of their first product, the genetically engineered high-antioxidant purple tomato, in the United States. Seeds will be available to home gardeners only in the U.S., where the biotechnology regulatory process has been completed. The new tomato variety contains purple antioxidants called anthocyanins, also found in blueberries, blackberries, and eggplants. Norfolk's tomatoes are the only varieties that have purple antioxidants in the flesh and the skin, thanks to biotechnology, which allowed the combination of tomatoes with two genes from the edible flower snapdragon.

PAIRWISE DEVELOPS FIRST GENE-EDITED SEEDLESS BLACKBERRY

Pairwise, a US-based company pioneering the application of CRISPR technology in food and agriculture, has developed the world's first seedless blackberry using the company's proprietary Fulcrum™ Platform, a complete suite of novel tools for CRISPR application in plants. The breakthrough is the first time seedlessness has been achieved in any caneberry. The berry variety that Pairwise edited is consistently sweet year-round and holds up well during shipment. Pairwise has also successfully edited the same blackberry variety to eliminate thorns and create a more compact plant that delivers benefits for harvesters, growers, and the environment.

MOOLEC GETS FIRST US APPROVAL FOR ANIMAL PROTEINS IN PLANTS

Moolec Science's genetically engineered soybean with pork proteins known as Piggy Sooy has received a response to their request for regulatory status review from the USDA Animal and Plant Health Inspection Service (APHIS). APHIS concluded that Piggy Sooy is unlikely to pose an increased plant pest risk compared to the conventional soybeans. In June 2023, Moolec Science announced that their genetically modified soybeans contain up to 26.6% pork protein, a significant increase from earlier projections.

Saving Every Bite: How Biotech Crops Are Fighting Global Food Waste

By Clement Dionglay

In 2022, global food wastage reached approximately 1.05 billion tonnes, or 132 kilograms waste per person annually, with households contributing the largest share at 79 kilograms per capita. This is on top of the 13% of food lost before it ever reaches the retail stage.

Food wastage is a major driver of climate change, generating 8-10% of the world's greenhouse gas emissions, which, in turn, fuels an unstable climate leading to extreme weather events like droughts and floods. This creates a destructive feedback loop, as the climate is disrupted, it further impairs our food system by reducing crop yields and nutritional value, ultimately threatening global food security.

Enter biotech crops, also known as genetically modified (GM) crops. Often lauded for their role in increasing yields and reducing pesticide use, these scientific innovations are also playing a crucial, often overlooked role in a different kind of food security: reducing food wastage.

Insect Resistant Biotech Crops

Insect resistant crops, using genes from the bacterium *Bacillus thuringiensis* (Bt), are highly effective biotechnological tool for directly reducing pre-harvest food loss by providing the plant with its own continuous, internal defense against specific pests such as the corn borer or cotton bollworm.

These crops are engineered to produce proteins that are toxic only to target insects, yet safe for humans and beneficial organisms, offering 24/7 protection. By preventing insects from damaging stalks, tunneling into fruit, and spoiling seeds, Bt technology significantly increases marketable yield, helps the produce maintain higher quality, and improves its shelf stability, ensuring that a greater percentage of the harvest is healthy enough to meet consumer standards and decrease global food waste.

Non-Browning Crops

Non-browning and reduced-browning crops, such as bananas and Innate® potato, reduce global food waste by preventing the cosmetic damage that triggers consumer and retailer rejection of otherwise perfectly edible produce. This is accomplished using genetic engineering or gene editing to suppress the enzyme responsible for the browning reaction and decrease black spot bruising caused by physical impact during handling and transport.

Since browning and bruising are often mistakenly perceived as spoilage, these enhanced traits ensure the produce remains visually appealing and stable for much longer during storage, transit, and on the shelf. By delaying the damage, non-browning crops extend the window of marketability, allowing more time for the food to reach the consumer and reducing the impulse to discard items prematurely.

Delayed Ripening Crops

Delayed ripening crops reduce global food waste by extending the marketable life of perishable produce, such as fruits and vegetables, giving them more time to move safely through the supply chain before spoilage. This is achieved through genetic modification that regulates the production or signaling of the plant hormone ethylene, thereby slowing down the natural ripening process. By extending the window from harvest to full ripeness, these crops—like certain tomatoes—are less susceptible to quality degradation during long-distance shipping or minor logistical delays. This is crucial for reducing spoilage and ensuring fresh produce reaches consumers reliably, especially in developing regions.

By making crops more robust against threats, extending their freshness, and reducing spoilage, biotech crops are an indispensable tool in the global fight against food waste. and in making our food systems more sustainable, feeding more people with the same resources, and reducing the environmental footprint of agriculture.

LEARN MORE, SCAN THIS!

Scientific Breakthroughs: New Products of Biotechnology for Consumers

By Clement Dionglay

Since the first year of commercial planting of biotech crops in 1996, more than 70 countries have planted or imported biotech crops with increased yield, insect resistance, and herbicide tolerance. Three decades later, scientists are now focusing on developing new products for consumers. Previously developed crops and plants include purple tomatoes, soybeans with high levels of pork protein, rice with animal muscle and fat cells within the grains, rice that grows in the ocean, and a bioluminescent glowing petunia. In addition to these products are bioengineered Pothos, golden lettuce, and the first banana resistant to Fusarium Tropical Race 4 and Black Sigatoka disease.

Biofortified lettuce with 30 times more beta carotene, giving the leaves a nutrition boost as well as a golden hue. Photo Source: IBMCP

Bioengineered Pothos

Paris-based start-up Neoplants started selling bioengineered pothos called Neo Px in the United States. Neo Px is the first bioengineered air purifier developed through synthetic biology, and a solution to fight indoor air pollution known as Volatile Organic Compounds or VOCs. Neo Px is up to 30x more efficient at purifying air compared to regular houseplants and is designed to fight against the most prevalent, harmful, and difficult-to-target indoor air VOCs, including Benzene, Toluene, Ethylbenzene, and Xylene (BTEX).

Golden Lettuce

Researchers from Spain developed an innovative method for the biofortification of leaves and other green plant tissues with increased healthy substances such as beta-carotene, the main precursor of vitamin A in the human diet. The biofortified lettuce has up to a 30-fold increase in beta-carotene levels compared to untreated leaves. The massive accumulation of beta-carotene also gave the lettuce leaves a characteristic golden color.

QCAV-4 Banana

Queensland University of Technology was given the license to commercially cultivate QCAV-4, a GM Cavendish banana resistant to the fungal disease Fusarium wilt tropical race 4 (TR4), also known as Panama disease. The QCAV-4 banana is the world's first GM banana to be approved for commercial production and also the first Australian GM fruit approved for growing in Australia. QCAV-4 offers a potential safety net against the devastating TR4 which threatens the global US$20 billion banana industry.

Yelloway One Banana

Researchers developed a new hybrid banana plant named Yelloway One that is resistant to two of the most destructive diseases for bananas, TR4 and Black Sigatoka. In recent years, TR4 and Black Sigatoka have caused significant damage, resulting in losses of millions of dollars. Yelloway One is resistant to TR4 and Black Sigatoka, a leaf disease that drastically reduces yields. Both diseases have been long-standing threats to the banana industry, particularly to the widely exported Cavendish banana. The plants will soon be sent to regions where TR4 and Black Sigatoka have caused significant damage, such as the Philippines and Indonesia.

Read More

Bioengineered Pothos
https://bit.ly/4abCafv

Golden Lettuce
https://bit.ly/GoldenLettuce

QCAV-4 Banana
https://bit.ly/QCAV4Banana

Yellow One Banana
https://bit.ly/YellowOneBanana

Milking a Potato and More Wonders of Molecular Farming

By Kristine Grace Tome

Can you make dairy from a potato? The answer to this question may seem obvious but with the wonders of molecular farming, this question may be answered with, "Why not?"

Molecular Farming

Plant molecular farming involves genetically modifying plants to produce substances they don't naturally create. Molecular farming uses plants as living factories to generate valuable ingredients such as vaccines, growth factors, and even dairy proteins.

This technology has gained traction, particularly with the emergence of companies producing "animal-free" proteins through molecular farming. The approach offers a more sustainable, ethical, and potentially more efficient alternative to traditional animal agriculture.

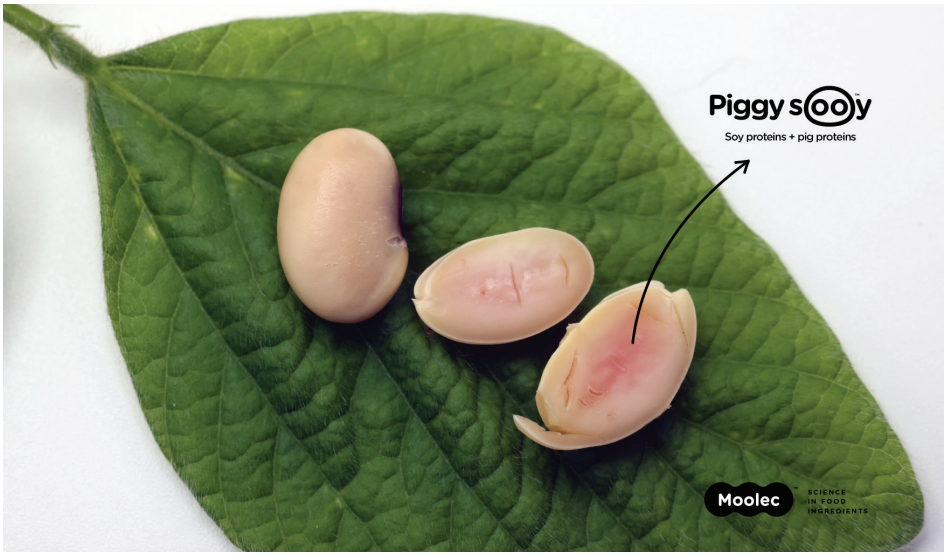
Casein from Potatoes

Finally Foods, an Israeli molecular farming startup, is producing real cow milk proteins (casein) by genetically engineering potatoes to act as bioreactors. They use proprietary AI engines to plan and produce the casein, resulting in lower environmental costs compared to conventional dairy. The company has already developed "Finally Cheese" from this casein and is preparing for its first field trial in Israel, asserting that their product is the "real thing" rather than a substitute.

"We've seen what it takes to make cheese from a cow, and tasted current substitutes. We know that when we launch our casein, we'd make a case for a new generation of plant based products that are not 'almost' or 'taste like' but finally, the real thing," according to Finally Foods.

Soybean with Pork Proteins

Moolec Science's genetically engineered soybean, Piggy Sooy contains 26.6% pork proteins, has received USDA APHIS approval and secured a patent. It is currently seeking FDA approval as a nutritious meat substitute that provides the same iron, color, and flavor as traditional meat.



Bioengineered Soybean with Pig Proteins Inside. Photo Source: Moolec Science

"When you use Piggy Sooy as a meat substitute, you can get the same iron and the same color as meat. When you're cooking it, it provides the same flavor as well," said Moolec Science Chief Scientific Officer Dr. Amit Dhingra.

Pea with Beef Proteins

Aside from Piggy Sooy, Moolec also developed GE pea (PEEA1) which contains iron-rich beef protein. PEEA1 contains myoglobin, a heme protein present in mammalian muscle cells responsible for oxygen storage and diffusion. It is also the protein that gives color and iron content to meat and seafood. Moolec has also received regulatory clearance for PEEA1 from the USDA APHIS in October 2024.

Meaty Corn

Molecular farming company IngredientWerks is harnessing the potential of plants to develop animal proteins for human health and nutrition. In 2023, IngredientWerks produced high levels of bovine myoglobin (heme) in corn using a proprietary production platform. This led to significantly exceeding its initial target expression level of heme at 10mgs per gram of corn, a level which confers an unprecedented low cost for heme production.

"This achievement is to the alternative protein industry as is the advancement in lithium-ion battery technology to the electric vehicle market – an engine that creates quality, affordable, and sustainable value and helps drive consumer adoption," said Matt Plavan, CEO of IngredientWerks in a press release.

LEARN MORE ABOUT MOLECULAR FARMING
SCAN THIS!

Is It Really Chicken?

By Clement Dionglay

A March 2023 report from leading data and analytics company GlobalData identifies cellular agriculture as a key emerging technology for decarbonizing global protein production. This is achieved by allowing products to be grown directly from cells, bypassing the traditional methods of raising animals for slaughter or cultivating crops.

Given the urgent need for sustainable food systems driven by a projected global population of 10 billion by 2050, GlobalData business fundamentals analyst Misa Singh noted that cellular agriculture is a sustainable option for limiting greenhouse gas emissions. It is also an alternative protein solution receiving promotion and investment from both governments and companies.

In June 2023, the United States Department of Agriculture (USDA) gave the final approval to two companies, UPSIDE Foods and Good Meat to sell lab-grown meat in the United States. With these approvals, the US became the second country after Singapore to allow the sales of cultivated meat.

UPSIDE Foods Cultivated Chicken

California-based food technology brand UPSIDE Foods achieved a significant milestone in November 2022 by becoming the first company globally to receive a "No Questions" letter from the U.S. Food and Drug Administration (FDA) for its cultivated chicken. FDA's acceptance signifies that the product, grown directly from chicken cells in a lab is safe to eat. While UPSIDE Foods emphasizes that its cultivated meat is not vegan or vegetarian, the company promotes the technology as a method for producing delicious meat without raising and slaughtering billions of animals. Furthermore, a large-scale production is projected to use less land and water than conventional methods while also potentially reducing the risk of bacterial contamination due to the controlled environment.

After the final approval in June 2023, three-star Michelin chef Dominique Crenn added a dish made with UPSIDE Foods' chicken to her Bar Crenn's menu, marking the first time the product was served to consumers in the US.

GOOD Meat cultivated chicken skewers. Photo Source: GOOD Meat/Eat Just Inc.

GOOD Meats Cultivated Chicken

In March 2023, California-based food technology company GOOD Meat, a division of Eat Just, Inc., received a "No Questions" letter from the FDA for its cultivated chicken. It is now one of the first companies to complete the agency's pre-market consultation for cell-based meat and confirming the product's safety for consumption. Dedicated to creating a more sustainable future, GOOD Meat grows chicken directly from cells, building on its prior regulatory success in Singapore, where its cultivated chicken has been continuously approved since 2020. The chicken has been featured in thousands of highly-rated dishes across fine dining and popular food stalls.

After receiving the final approval in the US, production started for the first batch of cultivated chicken that was sold to restaurateur and humanitarian Chef José Andrés. Andrés, the owner of José Andrés Group, is the first chef to serve GOOD Meat's chicken when he served the meat marinated with anticucho sauce to a select group of people in his restaurant China Chilcano in Washington DC.

The approvals for cultivated chicken in the US usher in a new era for meat production, promising benefits like improved food security, elimination of animal cruelty, and reduced environmental impact. However, food technology companies face significant hurdles, including high production costs, challenges in scaling manufacturing, and concerns that the product might remain a niche item for wealthy consumers. As these first products hit the market, key questions remain regarding consumer acceptance, willingness to eat the product, and its true identity compared to conventionally raised chicken.

For further reading

World's First-to-Market Cultivated Meat
https://bit.ly/CultivatedMeat

Cellular Agriculture Key to Food Security
https://bit.ly/CellularAgri

Making Produce Stay Fresh Longer: How Science is Tackling Browning in Fruits and Vegetables

By Dr. Gabriel O. Romero

Garden-fresh fruits and vegetables are prized ingredients in the kitchen and a delight on the table. But brown spots and discoloration can quickly make even the best produce unappealing. While careful handling, storage, and transport can slow down browning, these measures are only effective up to a point.

Today, scientists have pinpointed the root cause—and are using modern biotechnology to keep produce fresh-looking for longer.

Polyphenol oxidase (PPO), an enzyme important in plant defense, growth, and development, is responsible for browning in damaged tissues. When fruits or vegetables are cut, peeled, or begin aging, PPO reacts with oxygen to produce quinones, which eventually form brown melanin pigments. By turning off or reducing the activity of PPO genes, researchers can significantly delay this browning reaction.

Innate Potato

Potatoes have long shelf lives, but once peeled or sliced, they brown rapidly unless submerged in water. The non-browning potato uses RNA interference (RNAi) to reduce PPO gene expression. These engineered potatoes can remain fresh for up to 48 hours after peeling at room temperature and even longer when chilled—all without being soaked. Approved by the U.S. Department of Agriculture (USDA) in 2014, they are marketed in the U.S. as Innate Potato by J.R. Simplot.

Arctic Apple

Although apples store well, peeling or slicing leads to browning within minutes. Using RNAi, scientists have developed a non-browning apple that can maintain its fresh appearance, flavor, and crisp texture for up to 28 days after being cut. In 2015, the USDA approved the Arctic Apple, while additional FDA clearance is being sought before broader market release.

Tropic Biosciences' Pomona Cavendish. Photo Source: Tropic

White Button Mushroom

Using the Nobel Prize-winning gene editing tool CRISPR-Cas9, scientists disabled a PPO gene by deleting a few bases in the DNA sequence. This small edit extended the mushroom's visual quality for up to 15 days under refrigeration. In 2016, the USDA approved the non-browning mushroom as non-GM. Penn State, its developer, is currently pursuing U.S. FDA clearance before commercialization.

GreenVenus Lettuce

Intrexon Corporation used CRISPR to switch off the lettuce PPO gene, resulting in GreenVenus, a variety that stays fresh and resists tip burn for up to two weeks. It received USDA approval in 2024 and is already available to home gardeners, with commercial production expanding.

Pomona Banana

Tropic Biosciences in the United Kingdom switched off a PPO gene highly active in banana flesh, creating a non-browning Cavendish variety. Named Pomona, it has received approvals in the U.S., Honduras, Colombia, Canada, and the Philippines, and was recognized in Time Magazine's Best Inventions of 2025. Pomona bananas maintain their appearance and texture for up to 12 hours after peeling and hold their quality for hours, even when blended into shakes.

Avocado

Scientists at GreenVenus used CRISPR to disable the PPO gene in avocado, significantly slowing the browning process. The gene-edited avocado can stay fresh for up to 10 days in the refrigerator. Regulatory approvals are still pending before market introduction.

More Than Freshness: A Boost for the Entire Value Chain

These upgraded produce varieties offer far more than improved aesthetics. They bring convenience to food preparation—salads stay vibrant longer, and delicate fruits can be pre-sliced without compromising quality. As gene-edited crops continue to advance, they promise a future where freshness lasts longer, preparation is easier, and sustainability improves across the food system.

Dr. Gabriel O. Romero is a Consultant at the UK-based NorthHill Group.

BIOTECH CROPS:
Your Questions Answered

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What are biotech/GM crops?

A biotech or genetically modified (GM) crop is a plant that has a novel combination of genetic material obtained through the use of modern biotechnology.

For example, a GM crop can contain a gene(s) that has been artificially inserted instead of the plant acquiring it through pollination.

The resulting plant is said to be "genetically modified" although in reality all crops have been "genetically modified" from their original wild state by domestication, selection, and controlled breeding over long periods of time.

The modifications are done to give the plant new or improved characteristics that are advantageous for agriculture or nutrition.

What are the benefits of biotech/GM crops?

Biotech crops are being adopted globally because of the enormous benefits to the environment, health of humans and animals, and contributions to the improvement of socio-economic conditions of farmers and the general public.

Biotech crops contributed to food security, sustainability, and climate change solutions by:

- increasing crop productivity
- conserving biodiversity
- providing a safer environment
- reducing CO2 emissions
- helping alleviate poverty through uplifting the economic situation of farmers, their families and communities.

Where are biotech/GM crops grown?

In 2024, there were 32 biotech crop planting countries, 19 of which were growing 50,000 hectares or more, 27 developing countries, and 5 industrial countries. They were: USA, Brazil, Argentina, Canada, India, Paraguay, China, South Africa, Pakistan, Bolivia, Uruguay, Philippines, Australia, Myanmar, Sudan, Mexico, Spain, Colombia, Vietnam, Honduras, Chile, Malawi, Portugal, Indonesia, Bangladesh, Nigeria, Eswatini, Ethiopia, Costa Rica, Kenya, Ghana, and Burkina Faso.

Who plants biotech/GM crops?

Since 1996, biotech crops have provided food, feed, and shelter to the world's 8.2 billion population.

Biotech crops help farmers earn reasonable incomes and have better livelihoods from higher yields.

In 2020, biotech crops helped uplift the lives of 17 million farmers and their families, totaling more than 65 million people.

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