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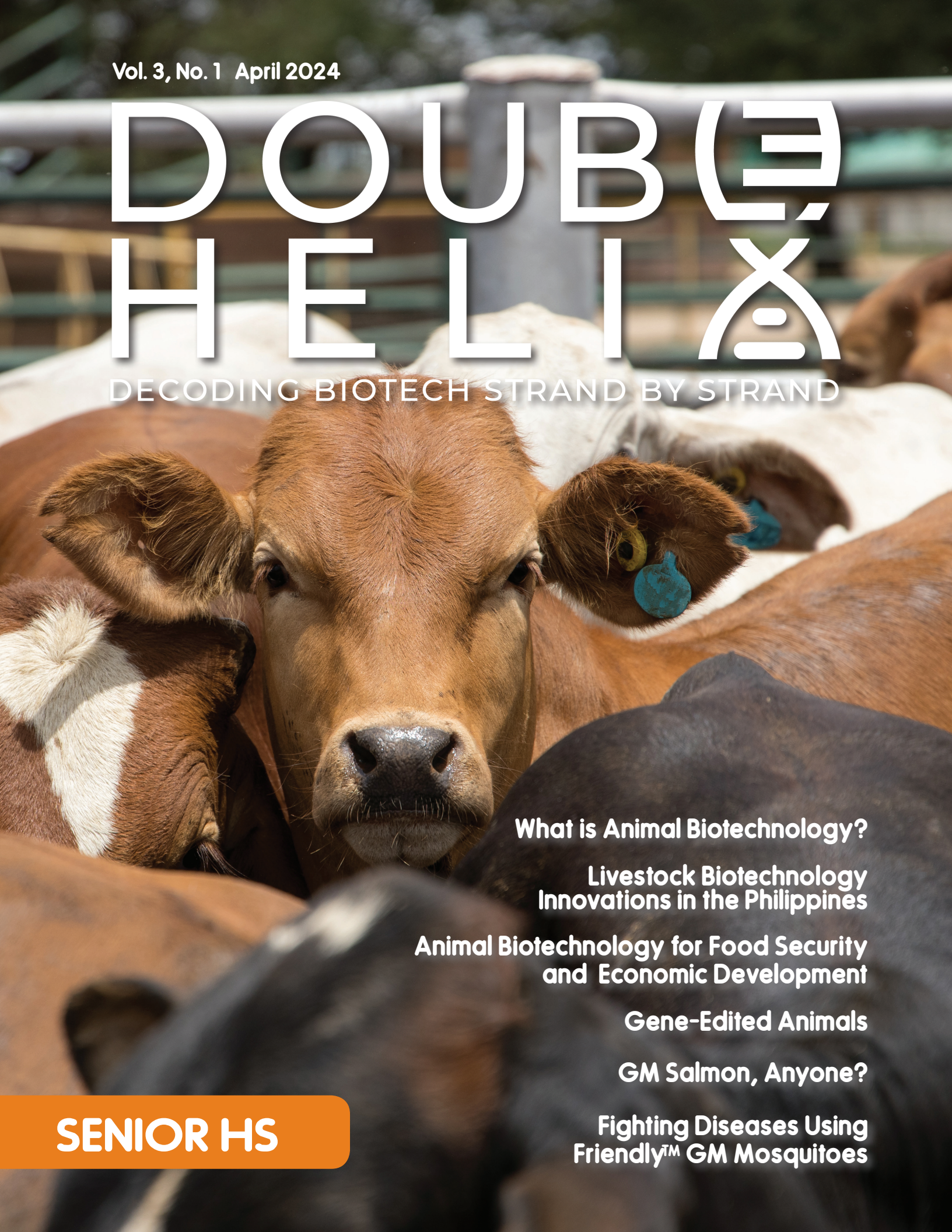
DOUBLE HELIX

DECODING BIOTECH STRAND BY STRAND



What is Animal Biotechnology?

Livestock Biotechnology Innovations in the Philippines

Animal Biotechnology for Food Security and Economic Development

Gene-Edited Animals

GM Salmon, Anyone?

Fighting Diseases Using Friendly™ GM Mosquitoes

SENIOR HS

DOUBLE HELIX
DECODING BIOTECH STRAND BY STRAND

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Welcome!

Dear Teachers, Students, and Readers,

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

As the world faces major challenges to feed its increasing population, innovative tools for crop and animal biotechnology become key to achieving food security and sustainability. Scientists and researchers use modern biotechnology tools to develop crops and animals with desirable traits. They have modifed fish, chicken, pig, cattle, and even mosquito to help increase our food supply and help fight life threatening diseases.

This issue of the *Double Helix* features animal biotechnology, including livestock innovation in the Philippine pipeline, GM-improved animals, gene-edited animals, GM salmon, and Aedes Friendly™ mosquitoes. We also included fun science activities for all of you to enjoy in school or at home.

Through the *Double Helix*, we hope to share with you how biotechnology helps in enhancing animals for food production, health, and the environment.

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

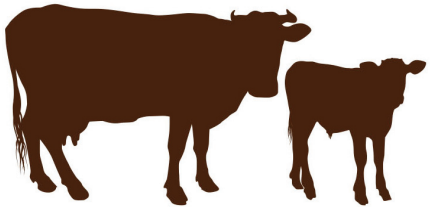
What is Animal Biotechnology?

In the past three decades, biotechnology has provided new tools for the improvement of human health, crops, and livestock. Biotechnology has been used to improve the quality of the foods we eat, including grains and vegetables from plants, and meat, eggs, and milk from animals. Biotechnology has helped scientists and researchers detect, treat, and prevent diseases and reduce animal impact on the environment.

Animal biotechnology, as defined by the U.S. Department of Agriculture, is a branch of biotechnology in which molecular techniques are used to genetically engineer animals to improve their suitability for agriculture, industrial, or pharmaceutical applications.

Animal biotechnology has been used to produce animals that can synthesize therapeutic proteins, have improved growth rates, tolerant to heat, or are resistant to diseases.

Using biotechnology in animals produce advances in animal health and welfare, enhance animal products, promote environmental conservation, and also help develop



advances in human health.

While farmers have improved livestock herds through their practices, modern biotechnology can enhance animal breeding to produce healthier herds. Biotechnology also helps in developing treatments to prevent and treat animal disease. Vaccines and diagnostic tests can help treat animal diseases and reduce food borne pathogens at the farm level.

Improved animal health aso help produce safer foods for human consumption.

In the future, meat, milk and egg products from animals can be nutritionally enriched using biotechnology.

The recent progress in sequencing of animal genomes, gene expression, and metabolic profiling of animal cells have made possible the advances in animal biotechnology. More recently, genome editing technologies (CRISPR-Cas systems, TALENs, and Zinc Finger Nucleases) have created new opportunities to easily develop genetic variations in animals that can improve their health and well-being, agricultural production, and protection against diseases. DH

Learn more! Visit ISAAA's Animal Biotech Resource Page

bit.ly/ISAAAAnimalBiotech

Read more about Animal Biotechnology

Animal Biotechnology
https://tinyurl.com/2whvf5ua

What is Animal Biotechnology?
https://tinyurl.com/4ecj67fu

Biotech-Improved Animals
https://tinyurl.com/4znrnsmd

Livestock Biotechnology Innovations in the Philippines

By Dr. Marvin A. Villanueva

Livestock are domesticated animals raised for food (meat, milk, and eggs) and other purposes (wool, leather, and draft). Local livestock production is an important source of income and food for millions of Filipinos, especially in rural areas. According to the Philippine Statistics Authority, the livestock sector accounted for 4.8% of the country's GDP in 2022.

The livestock industry faces many challenges, such as pest and diseases, climate change, high input costs, low productivity, and market competition. To overcome these challenges, Filipino scientists apply modern biotechnology innovations to improve the performance and sustainability of the livestock sector.

The whole genome sequence of the Philippine swamp buffalo was released in 2023.
Photo Source: Knowledge and Management Division, Philippine Carabao Center

Animal health

Researchers from the Philippine Carabao Center (PCC) and Livestock Biotechnology Center are developing lateral flow assays for *Mycoplasma bovis* and *Mycobacterium avium* subsp. *paratuberculosis* using nanotechnology. They also created a rapid test kit to detect Caprine Arthritis Encephalitis Virus (CAEv) using Loop-Mediated Isothermal Amplification (LAMP) Assay.

A project of researchers from the University of the Philippines Los Baños (UPLB) and allied universities developed a low-cost portable molecular diagnostic platform for poultry pathogens using LAMP technology for rapid detection of three viral poultry pathogens in the Philippines. Some of the diagnostic kits are now in the product commercialization stage.

Animal nutrition

Feed additives and supplements can enhance livestock animals' growth, health, and quality. Researchers from UPLB are studying the effects of probiotics and prebiotics on pigs' gut microbiota and immune system. PCC recently developed a microbial inoculant (*Lactobacillus plantarum*) to improve the fermentation quality and aerobic stability of corn and sorghum silage and is working on mining alternative feed sources using seaweeds for ruminants.

Animal breeding and genetics

In 2023, the PCC released the whole genome sequence of the Philippine swamp buffalo. The team is also working on the screening for genetic defects in buffalo and cattle and development of multiplex panel of microsatellite markers for routine parentage testing in buffalo and cattle. The PCC team is also studying PRLR Slick mutation, a PCR-based genetic screening test in cattle, and exploring heat shock proteins (HSP70) in ruminants to develop thermotolerant animals.

For pigs, PCC was tapped to establish a DNA marker tool using genetic markers (estrogen receptor gene, leukemia inhibitory factor gene, and prolactin receptor gene) for commercial and native pigs to assist the farmers in the selection of individual pigs with good fertility that would be the parents for the next generation.

Animal reproduction

The PCC has been utilizing Fixed-Time Artificial Insemination (FTAI), Embryo Transfer (ET), and *in-vitro* Fertilization (IVF) in ruminants. FTAI, a reproductive technology, helps determine the best time to perform a single artificial insemination. ET involves collecting fertilized eggs from a female animal and transferring them to another female. IVF involves fertilizing eggs with sperm outside the body and implanting them into a female animal. These techniques can increase the chances of conception and produce offspring with desirable traits.

In 2022, PCC embarked on the use of sexing semen technology to produce more females for dairy production. This technology separates male and female sperm using a machine that detects the difference in DNA content between X and Y chromosomes.

These are some of the livestock biotechnology research on the pipeline in the Philippines. Government agencies acknowledge the opportunities of animal biotechnology as ongoing efforts to improve research are made through collaborations with local and international experts. DH

Dr. Marvin A. Villanueva is Scientist I and Chief of the PCC's Livestock Biotechnology Center

LEARN MORE ABOUT BIOTECH IN THE PHILIPPINES

SCAN ME!

Animal Biotechnology for Food Security and Economic Development

By Kaymart A. Gimutao

The Food and Agriculture Organization (FAO) recognizes the significant contribution of the livestock production systems to healthy diets for improved nutrition and health. Food from animal sources can provide high-quality proteins, important fatty acids, and various vitamins and minerals.

With the significant contribution of biotech crops in achieving food security, scientists are now exploring the potential of genetic engineering in animals and livestock to emulate the success stories of the former.

Improvement of animal species using genetic modification is performed by altering its genetic material through deliberate addition, modification, or removal of certain DNA sequences. The goal is to change specific characteristics of an animal either by improvement or introduction of a new trait (e.g., disease resistance, enhanced growth) or reversing the animals' undesirable trait (e.g., hornless cattle to avoid injury).

Genetic modification among animals was first introduced in the 1970s when geneticist Rudolf Jaenisch integrated a foreign DNA with the DNA of early mouse embryos. The mice derived from these embryos carried the foreign genes in all of their tissues. Since then, a wide variety of genetically modified (GM) animals have been developed, including rabbits, pigs, cows, sheep, goats, and fish.

GM animals are now being used in a variety of research applications, including the study of human diseases and the development of new drugs and therapies. The technology is also hoped to further boost the second sustainable goal (SDG 2) which is to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture in the near future.

A lot of genetically-improved animals that were approved for commercial release are intended to improve the food supply available in the market, particularly meat derived from livestock and fish.

These include the *AquAdvantage Salmon*, which has been genetically engineered (GE) to reach a growth marker important to the aquaculture industry more rapidly than its non-GE farm-raised counterpart and the *GalSafe pig*, a GM-improved swine that lacks alpha-gal sugar, a molecule that can cause allergic reactions in individuals with Alpha-gal syndrome (AGS). This sugar is commonly found in red meat such as beef, pork, and lamb.

GM-improved animals in the pipeline include the bird-flu resistant chicken that could limit the spread of the bird-flu virus in the animals.

Photo Source: Getty Images

Meanwhile, GM-improved animals in the pipeline include the bird-flu resistant chicken which was developed by identifying and modifying parts of chicken DNA that could limit the spread of the bird flu virus in the animals; the gene-edited calf with resistance to bovine viral diarrhea virus (BVDV), a virus that costs the cattle sector billions of dollars annually; genome-edited dairy bull to prevent it from growing horns and thus protect other cattle and human handlers from injuries; and the transgenic goats that can produce an improved version of cetuximab (a therapeutic monoclonal antibody in milk.

In the Philippines, the Philippine Carabao Center has incorporated somatic cell nuclear transfer (SCNT) technology among its existing reproductive tools for buffaloes; and researchers have successfully developed in vitro production of buffalo clone embryos. The country has also started to develop a regulatory policy on GM Animals through a joint effort by the Department of Agriculture, the Department of Health, the Department of Science and Technology, the Department of Environment and Natural Resources, and the Department of Interior and Local Government.

The regulatory framework that was drafted in the Philippines is applicable to GM-improved fisheries and other aquatic resources; domesticated animals and biological products used for animal husbandry or veterinary purposes; and biological agents derived from the use of modern biotechnology and containing novel combinations of genetic materials. DH

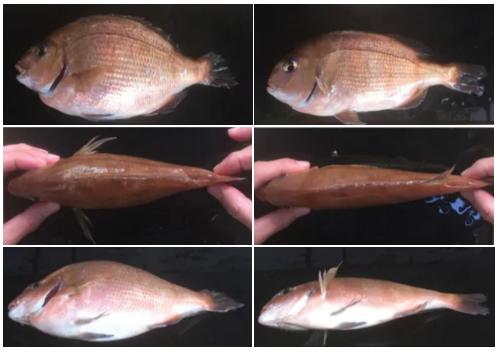
Kaymart A. Gimutao is a freelance science writer and previously worked at ISAAA Inc.

LEARN MORE! SCAN ME!

Gene-Edited Animals

By Janine Cyren Escasura

Today, we are faced with looming global threats of increasing world population, depletion of natural resources, and intensified climate issues. In an era where sustainability plays a vital role in almost every aspect of human life, scientists and researchers use modern biotechnology to help reduce the negative effects of these pressing problems. To continuously feed the world in the future, experts maximize the potential benefits of biotechnology through gene-edited animals.



Gene-edited red sea bream (left), unedited versions (right). Photo Source: Dr. Masato Kinoshita, Kyoto University and Dr. Keitaro Kato, Kindai University

RED SEA BREAM

In 2021, Kyoto-based startup company, Regional Fish Co., Ltd., developed the gene-edited red sea bream in partnership with Kyoto and Kindai Universities, the Ministry of Health, Labor, and Welfare, and the Ministry of Agriculture, Forestry, and Fisheries in Japan.

Red sea bream, also known as Madai and the King of Fish, is the world's first gene-edited aquatic food product available in the market. Myostatin, a protein that limits muscle growth, was deleted in the gene-edited red sea bream through CRISPR. Madai contains up to 1.6 times more edible parts and increased feed utilization efficiency by about 14% compared to its conventional counterpart.

In October 2021, Regional Fish accepted reservations for 190 meals of "Eatable Red Sea Bream" in a crowdfunding campaign.

TIGER PUFFERFISH

A two-year-old genome-edited tiger puffer (top) and a conventional fish of the same species (bottom). Photo Source: Regional Fish Institute Ltd.

Along with gene-edited red sea bream, the Regional Fish Co., Ltd. also developed the gene-edited tiger pufferfish, called "22-seiki fugu," and was approved for sale in 2021. Tiger pufferfish, known as fugu, is a luxury food in Japan.

Using CRISPR gene editing technology, four leptin receptor genes responsible for controlling the appetite of the fish were knocked out. The gene-edited tiger pufferfish had an increase in food uptake and weight by up to 90%, resulting in shorter farming periods and an increase in yield.

These gene-edited fishes aim to contribute to the decreasing seafood market and worker shortage in Japan.

PRLR SLICK CATTLE

Beef cattle. Photo Source: Getty Images

In a 2022 study published in *The Lancet Planetary Health*, cattle production losses due to heat stress are estimated to rise up to $39.94 billion per year at the end of the century. In response to the devastating effects of climate change, a gene-edited beef cattle, known as "PRLR-SLICK cattle," was developed by Acceligen, Inc.

Using CRISPR, intentional genomic alteration (IGA) was introduced to the two "founder" beef calves, resulting in a short, slick-hair coat. The gene-edited cattle has a high tolerance to temperature-related stress thanks to their extremely short, slick-hair coat that can withstand the hot weather.

More than its tolerance to heat, the IGA conferring the slick-hair coat trait can also be passed on to their offspring, which further accelerates the efficiency of cattle production.

Janine Cyren Escasura is Project Assistant at ISAAA Inc.

For further reading

Japan's Three Genome-Edited Food Products Reach Consumers
https://tinyurl.com/yc8k634k

Japan Begins Sale of Genome-Edited "Madai" Red Sea Bream
https://tinyurl.com/2636mrhh

Genome-Edited Cattle Soon to Hit the US Market after FDA Rules it Low-Risk
https://tinyurl.com/bdhm6u6s

Plant Breeding Innovation: CRISPR-Cas9
https://tinyurl.com/53svfz7z

GM Salmon, Anyone?

By Dr. Casiano H. Choresca, Jr.

The research and development of genetically modified (GM) Salmon started at the Memorial University Newfoundland, Canada, in 1989. In 2013, Health Canada, a federal department responsible for helping Canadians maintain and improve their health, granted authorization for the production of the AquaAdvantage® Salmon (AAS) eggs at AquaBounty hatcheries, facilitating their commercial distribution. It was approved for food and feed in 2016, but the United States Food and Drug Administration (US FDA) released an import alert preventing its sale in the US. Three years later, in 2019, the US FDA removed the import alert and allowed the importation, raising, and selling of AAS in the US. The GM Salmon was developed to address issues on food supply and fish sustainability.

AquaBounty salmon (back) has been genetically modified to grow bigger and faster than the conventional Atlantic salmon of the same age (front).

Photo Source: AquaBounty Technologies, Inc.

What fish species are involved in the genetic engineering of the GM Salmon?

The AAS, a product of AquaBounty Technologies Inc., was engineered through the incorporation of growth genes derived from a Pacific chinook salmon (*Oncorhynchus tshawytscha*) — housing a growth hormone gene — and a cold-resistant species known as ocean pout (*Zoarces americanus*) into the farmed female Atlantic Salmon.

How was the AquaBounty Salmon produced?

Genetic modifications were introduced into the genetic makeup of the Atlantic salmon, endowing it with the capacity to achieve a growth rate twice that of the non-GM salmon. This innovative genetic manipulation enables GM Salmon to attain market size in 18 months compared to conventional non-transgenic Atlantic salmon, which typically requires 36 months for comparable growth.

What are the pros and cons of the GM Salmon?

The production of AAS has its advantages and disadvantages. This GM product aims to help address food supply issues and sustainability and could meet the rising consumer demand for fish. Additionally, AAS production in regulated hatcheries will reduce the pressure on wild fish stocks, which have been dwindling due to several reasons, such as exploitation, overfishing, pollution, environmental changes, habitat deterioration, and disturbances of migration. In terms of profitability, the AAS consumes 25 percent feed less than the non-transgenic salmon, resulting in reduced feed costs.

Among the disadvatanges of AAS production are the limited science on its long-term effects, its escape from the farms that can affect the population of wild salmon, and the concern of the food safety activists and fishermen on the proper labeling of the product.

Is GM Salmon safe for the environment?

Competent authorities have thoroughly evaluated AAS biological traits, food safety, and environmental effects before approving it for human consumption. In 2012, the FDA published an environmental assessment identifying that AAS is equivalent to conventional farmed Atlantic salmon and is safe for human consumption and the environment. Multiple containment strategies are in place to avoid any potential environmental impact from the fish. To prevent AAS from escaping into the Pacific Ocean, a natural thermal barrier created by extremely high water temperatures downstream of the facility is a strong containment measure. This barrier is lethal for Atlantic salmon, ensuring that any escaped AAS cannot survive and make its way to the Pacific Ocean.

Notably, the AAS, bred through genetic modification, received acknowledgment as posing no discernible risk to the environment. The US FDA culminated its safety approval for GM Salmon after two decades, encompassing rigorous research, systematic testing, comprehensive evaluations, developmental initiatives, and regulatory measures. DH

Dr. Casiano H. Choresca, Jr. is Scientist I and Center Chief of the National Fisheries Research and Development Institute.

Read more about AquAdvantage Salmon

Chronology of AquAdvantage Salmon and AquaBounty Technologies
https://tinyurl.com/4u22w7t9

Nine Things You Need to Know About GMO Salmon
https://tinyurl.com/4u22w7t9

Fun Facts About Amazing Atlantic Salmon
https://tinyurl.com/4u22w7t9

Genetically Modified Salmon Head to US Dinner Plates
https://tinyurl.com/4u22w7t9

Fighting Diseases Using Friendly™ GM Mosquitoes

By Zabrina J. Bugnosen

Mosquitoes have been a constant threat to the health of many Filipinos. Each year, thousands of Filipinos get infected with mosquito-borne diseases such as malaria, Zika, chikungunya, Japanese encephalitis, and dengue. The situation is also prevalent in other parts of the world. In Africa, more than 200 million people were infected by malaria in 2021, and more than 600,000 died. Mosquito-borne diseases affect not only public health but also have a negative impact on families, society, economies, and the overall stature of a nation.

Experts have identified methods to control mosquito populations, including spraying insecticides, fogging, maintaining clean surroundings, and removing stagnant water where mosquitoes lay eggs. While these methods can be effective, some can harm the environment. Fortunately, scientists from Oxitec, a company based in the United Kingdom, offer a more efficient and sustainable solution to mosquito-borne diseases in the form of genetically modified (GM) Friendly™ mosquitoes.

Friendly™ *Aedes aegypti* mosquito.
Photo Source: Oxitec

Oxitec's Friendly ™ technology and GM mosquitoes

Oxitec developed a platform called Friendly™ technology. It features a self-limiting gene that the male individuals of a species carry. When the male is released to mate with a female, the offspring inherits the gene. However, the offspring is less likely to survive into adulthood because the gene prevents it from growing normally, as it is meant to interfere with its cells' ability to produce vital proteins for development. Hence, the pest's population growth becomes limited, and the spread of vector-borne diseases becomes easier to manage.

Oxitec claims that the platform can deliver a targeted, non-toxic, and environmentally sustainable solution to control mosquitoes, some crop pests, and cattle ticks. The Friendly™ technology is self-limiting and specific to its target species; thus, it is not expected to spread in an ecosystem. Unlike pesticides, it does not use chemicals, deeming it non-toxic and more environment-friendly than conventional pest control methods. It was also designed to be a stand-alone or a component of integrated pest management programs.

Oxitec genetically engineered the Friendly™ *Aedes aegypti* mosquito in 2013 and has since conducted field trials in Brazil and the United States. Data from the 2016 Brazil trials showed a 91% reduction in dengue fever cases and zero transmission of Zika virus in the country's CECAP/Eldorado district. The results proved that using GM mosquitoes to fight diseases is feasible and effective and has paved the way for scientists to take their research further. In 2021, Brazil allowed GM mosquitoes in São Paulo. Oxitec's pilot projects in Florida and California were allowed by the U.S. Environmental Protection Agency in 2022.

Potential use of GM mosquitoes in the Philippines

Dr. Nina G. Gloriani, a clinical microbiologist at the St. Luke's Medical Center, explained that GM mosquitoes enhanced with gene drive technology have the potential to reduce the number of dengue cases in the country, which has already reached more than 80,000 in just the first eight months of 2023. The technology can also be applied to help manage chikungunya, Zika, malaria, and Japanese encephalitis cases in the country.

Researchers in the Philippines are encouraged to explore different solutions to control mosquito-borne diseases, including GM mosquitoes and gene drive technology. Their passion for using new technology and the steady progress of science-based biosafety regulations in the Philippines are vital in improving the health of Filipinos, especially those in rural areas. DH

Zabrina J. Bugnosen is a freelance science writer and previously worked at ISAAA Inc.

For further reading

Dengue Prevention and Control Program
https://tinyurl.com/4u22w7t9

Why Malaria Matters
https://tinyurl.com/bdfurrr9

Mosquito-Borne Diseases
https://tinyurl.com/mvpfm96w

Oxitec Friendly™ Technology Platform
https://tinyurl.com/2rytshfc

ISAAA Inc. Pocket K No. 55: Biotech-Improved Animals
https://tinyurl.com/4znrnsmd

Oxitec Launches Home Use of Its GMO Mosquito Control in Brazil
https://tinyurl.com/5n6s4whu

US EPA Approves Oxitec's Mosquito Pilot Projects in California and Florida
https://tinyurl.com/5n6s4whu

Major Health Challenges in the Philippines (Gene Drive Possibilities) [presentation in webinar]
https://tinyurl.com/5dzbcaks

SCIENCE ACTIVITY

CITIZEN SCIENCE

Doing a scientific research can be hard, but scientists also say that it is fun!!! Do you want to do scientific research? Why don't you enter the world of science by joining a research team for a day? Here's how you can do this:

1. Contact a nearby research lab and ask if you could visit to find out more about their research.
2. Ask the researchers if you could try out any of their lab equipment or field instrument.
3. Share your experience on Facebook, Instagram, YouTube, or any social media platform, tag ISAAA, and get the chance to be featured in one of our campaigns!

SPOT THE 5 DIFFERENCES

These differences are the big changes happening on our planet that impact our way of life. Scientists use tools such as gene editing to help plants and animals cope with these changes.

ANSWERS: 1. mosquitoes 2. less animals 3. less plants 4. hotter temperature 5. dry soils/drought

WRITE THE DIFFERENCES THAT YOU OBSERVED:

FOR MORE COOL SCIENCE ACTIVITIES, SCAN THIS!

Illustrations in this page by Steph Bravo-Semilla and PNGTree.