CATEGORY: CONSUMER EDUCATION

A Brief History Of The Controversial Genetically Modified Food Technology, And The Advent Of GMO Salmon

Dr. Bill McGraw
Aquaculture and Environmental Scientist
Boquete, Panama
www.newaquatechpanama.com
billmcgraw29@hotmail.com

Summary:
Genetically modified foods or GM foods, also referred to as genetically engineered foods, are foods produced from organisms with changes introduced into their DNA through genetic engineering. Various genetic engineering techniques permit the introduction of new traits and more control over traits than other more traditional methods like selective breeding. Foods from genetically modified organisms (GMOs) are still highly controversial in regards to their safety to humans, and with the possibility of GMO aquacultured species reaching seafood markets, there are public concerns regarding safety, labelling, regulations, possible environmental impacts and other issues.

Keywords: GMO, DNA, coding, food technology, transgenic, gene transfer, gene expr4ession, hybridization, mass selection, crop production, herbicide

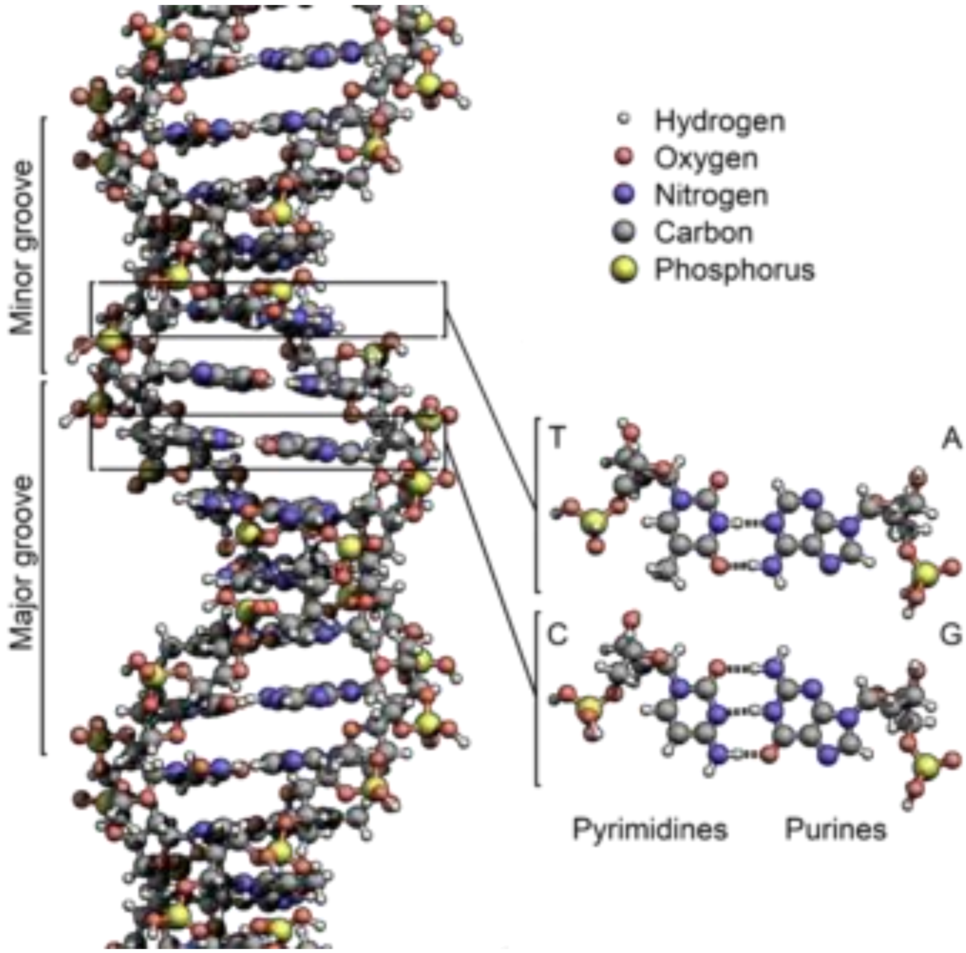

Figure 1. The structure of the DNA double helix. The atoms in the structure are color-coded by element and the detailed structure of two base pairs are shown in the bottom right. Credit: By Zephyris - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=15027555 (unmodified).

As transgenic salmon have been reported to be in development for over 20 years and are slated to be the next great development in genetically modified organisms (GMOs) food science, there is little information available regarding the history of actual transfer of genes from one distant species to another.

Hybridization and mass selection have been used for hundreds of years as a natural method for increasing production and desired traits in plants and animals. This natural method excludes the possibility of gene transfer between distant, related animals as a way of preserving species integrity, and is indeed part of the definition of a species itself.

The political controversy engulfing GMOs is complex and exists on many levels, and is far too much to be discussed here. An accurate description of the facts and history is greatly warranted, because for the first time in history an animal with the genes of two foreign species is nearing the stage of consumption by humans. A description of the actual process in creating genetically modified foods or GMOs is important to understand the rapid development and timeline of transgenic organisms into everyday food consumption. Lessons learned from the incorporation of GMO food into traditional crop production in soil can provide insight into the potential problems that may be encountered with the advent of GMO technology into aquaculture.

A description of the current technology

Transfer of DNA fragments coding for a particular protein or group of proteins that provides a specific trait from a foreign species or from the same species, randomly forced into the normal genetic makeup of an organism, can be termed genetic modification or more commonly a Genetically Modified Organism or GMO.

Although a piece of DNA from a foreign species that codes for a specific valuable protein can be injected into a recipient bacterium, it will still need an attached DNA fragment called a promoter, which turns on the production of the desired protein. An extreme amount of desired protein is often needed and DNA promoter sections are taken from viruses or bacteria, which then turn on the DNA section to produce aberrant excessive amounts of the protein at the expense and welfare of the recipient organism. Normal promoters from the recipient are not used as they only produce normal amounts of the protein, and often times will not promote foreign gene activation.

Other necessary fragments inserted into the recipient to produce excessive amounts of protein are a terminator section, which ends the code for the protein formation, and a visible marker protein that allows readily visible proof or "marker" that signals the recipient organism has accepted the various pieces of DNA added to the normal DNA of the host. The promoter fragment along with the DNA section producing the protein - the terminator piece which ends the DNA coding - and the marker section form a hyperactive combined grouping called a "cassette". This cassette is then blasted into a host cell, inserted into holes forced open using high voltage or forced into host DNA by infection with a pathogenic bacterium or virus that transfers the foreign DNA. In certain instances, this requires tissue culture because the GMO organism cannot develop normally. Some transgenic plants actually deactivate the foreign DNA, which is not transferred into subsequent generations, and the process must be repeated.

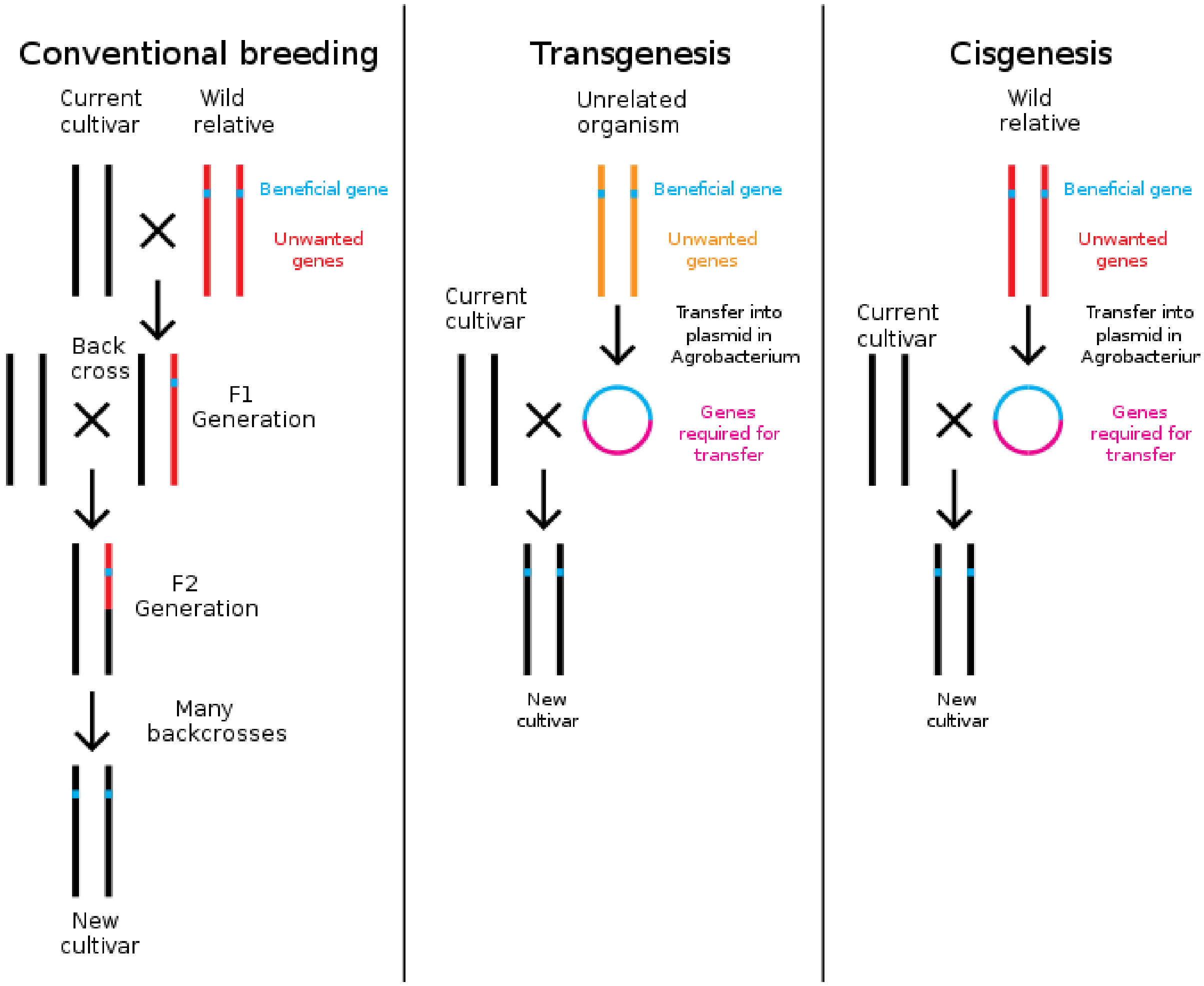

Figure 2. Comparison of conventional plant breeding with transgenic and cisgenic genetic modification. Credit: By Smartse (talk) - Own work (Original text: I created this work entirely by myself.), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=7528981 (unmodified).

When the DNA cassette is randomly inserted into the host genome, it disrupts the natural organization of the host DNA causing significant expression changes in genes of a normally functioning host. This can result in imbalances in normal gene expression and the increase in the production of known toxins and unintended toxins, as each cell type in the host organism responds differently to the disruption of the DNA. This can and does create an increase in allergenic reactions in animals and humans alike that consume the GMOs.

More intriguingly, foreign promoters attached to other species genes may activate dormant metabolic pathways. Further changes to the host include aberrant levels of amino acids, protein contents, fat, fiber and ash. Once assembled, the aberrant DNA proteins formed in the host may not fold into the correct shapes, causing deactivation or yet another disruption of the host metabolism. Rearrangement of the DNA sequence can occur during the insertion of the gene into the host genome, and incredibly enough, the insertion can rearrange the host DNA, (or cause it to jump) surrounding the randomly blasted or infected insertion of foreign DNA. This in turn may contribute to the toxin development that can escape any detection, which is currently possible considering the insufficient, classic 90-day toxicity research used in GMO studies.

The actual expression of a gene and the development of an organism is based on far more complex mechanisms than just DNA sequencing. Intricate and unexplainable regulatory mechanisms, possibly involving epigenetics (environmental influence on gene expression), require something akin to quantum acknowledgement, or better yet, something far too complex to be understood with our present knowledge. For example, during natural genetic combination within a species, or more rarely in closely related species (hybridization), chromosomes break off and reattach to other chromosomes during crossing over, which is what happens in natural sexual reproduction. This has the appearance to be random, but is actually mind boggling in its organization, coordination and yet continually unpredictable outcome.

The history of GMOs, and the attempt at commercialization results in disaster

The first genetically engineered bacteria was produced in 1974, and the implications it engendered were a cause of concern for the scientists involved, who advocated great caution with its development. The first guidelines banning the release of any GMO into the environment were promulgated by the National Institute of Health in 1976. Research into GMOs at that time required a special "weak" version of a common bacteria, *E.coli*, which was singled out to be an exclusive agent to protect against environmental contamination.

As early as 1977 one of the first great controversies regarding genetic modification began with GMO advocates stating that gene splicing of foreign DNA into the genome of another species was no more different than what occurs by natural means. This crude analogy would be a great bone of contention in the development and regulation of GMOs, as well as the current GMO labeling quagmire.

In the very first instance, for a bacterium to accept a DNA fragment from another species, the application of heat and chemical shock of the recipient of the DNA fragment was necessary in order for the foreign DNA to be randomly accepted into the host genome. This is something that obviously does not happen in normal DNA conjugation through sexual reproduction, or in other words, in "nature." Furthermore, it was openly admitted that it was unknown how this GMO bacterium would react in "nature" if it was ever to be released.

The first functional GMO plant was reportedly produced in 1982 through the use of a bacterium that infects plant cells, which was then replaced by a promoter from a Cauliflower Mosaic Virus that was more powerful, and so versatile, it has been included in nearly every GE food currently on the market. That same year, the first transgenic mouse was produced along with transgenic trout and goldfish following in the years 1984 and 1985.

In 1989, the first commercial GMO product involved the production of the common amino acid tryptophan from a bacterium that was designed to produce excessive amounts of it by incorporating a promoter section from a virus. Regrettably, this GMO-created supplement caused excessive pain and a vast variety of degenerative body impairments in those people who ingested it. Advocates of its production explained it away as a problem with the processing of the bacteria, rather than any novel or expected toxic compound that was produced by the bacteria itself. Even more shocking is the fact that it took months to recognize the symptoms as a specific toxicity, and even more time to identify the source that was responsible for 37 deaths and about 1500 permanent disabilities.

Figure 3. Tryptophan is an α-amino acid that is used in the biosynthesis of proteins, and the first commercial GMO product. Source: https://commons.wikimedia.org/wiki/File:L-Tryptophan_-_L-Tryptophan.svg (unmodified).

Allergic responses from altered GMO proteins have been shown in studies to have the potential to produce an allergic response to non GMO similar proteins as well. Allergens are dangerous at incredibly low levels and the proteins produced using GMO technology are almost always physically different from their normal counterparts.

The first genetic recombinant food launched in 1994 was milk in the form of recombinant bovine growth hormone, or rBGH, which caused cows to produce 30 percent more milk and was found to be linked to cancer. When administered, it caused the cows to burn out two years sooner and have increased infections that required more treatment with antibiotics. At the end of the 1990s, 70 percent of all antibiotics were used in animal production. In 1999, a moratorium was upheld banning rBGH from the EU.

The first whole food agricultural GMO product was the Flavr Savr™ tomato, approved by the FDA in 1994. It was engineered to suppress the production of an innate protein that causes the fruit to grow increasingly soft. This was supposed to enable the tomato to be picked after it had ripened and to last longer during shipment. This required a clever insertion of a reversal sequence of the protein to negate its expression, which required a virus promoter and tissue culture. Lab tests showed that 10 percent of the rats consuming the GMO tomatoes developed stomach lesions, with a third of the animals dying within 2 weeks. The foreign marker gene was antibiotic resistance, which raised many red flags as there was a concern of transferring this resistance to the normal bacteria in the human gut. Surprisingly, despite the great promotion the first commercially developed GMO produced plant for human consumption folded quickly due to its lack of taste and its inability to survive shipping and handling to market.

GMO commercialization continues despite mixed results

One of the most important research studies on the safety of GMOs was conducted in Scotland from 1995-1998 by the prominent scientist, Arpad Pusztai, who had been employed for 32 years at the facility, Rowett Research Institute, where the research was conducted. The GMO crop tested was the common potato, engineered to produce a lectin pesticide toxic to aphids, by incorporating a gene from the snowdrop plant that produced it. Unfortunately, when the GMO potato was fed to rats, they developed abnormal growths and were smaller in size and had smaller hearts, livers and kidneys. The study was eventually published in the world renowned Lancet Journal, and Pusztai was subsequently fired. Similar studies demonstrated abnormalities in the liver, kidneys, immune systems, pancreas and enzymes in animals fed GMO corn and soy, with some results only apparent after the typical 90-day trial. An yet other studies show no toxicity when feeding animals GMOs leading some researchers to state that strains of plants used are just as relevant as the inclusion of GMO ingredients.

The first mass experiment for GMO crops took place in the early 1990s in Argentina. In 1991, Argentina granted licenses for 569 field trials of GMO crops, with emphasis on Glyphosate herbicide resistant (Roundup Ready) soybeans. Roundup-ready soybeans that were not GMO and any non GMO traditional crops were killed by the Glyphosate , as well as much wildlife in local waterways. By 2004, 48 percent of all agricultural land in Argentina was dedicated to GMOs, with more than 90 percent being Roundup-ready soybeans. The US, Brazil and Argentina would have 81 percent of all GMO soybeans grown by 2006. Surprisingly, the GMO soybeans were reported to produce between 5-15 percent lower yields than traditional soybeans. New superweeds, discussed below, created by the 72 percent increase in Roundup use, required up to three times the amount of spraying.

GMO corn (1996) and cotton (1995) genetically modified with a natural pesticide, referred to as BT from a common soil bacterium, were developed to reduce the overuse of pesticides, which they eventually did; however, there were many consequences. The GMO producing BT caused a reduction in beneficial soil fungi and, unlike naturally produced BT, the GMO produced BT existed in the soil for months and contaminated local waterways being toxic to aquatic organisms and having negative effects on beneficial insects. Regrettably, pest insects developed resistance to the GMO pesticide and farmers had to resort to further application of pesticides to reduce infestation.

Scientific research into feeding cows with GMO corn has shown that it is toxic over the long term. The U.S. Center for Veterinary Medicine had stated that residues from unexpected toxicants in animal feed can appear in meat and milk products, making them unfit for human consumption. What is worse and likely the most frightening aspect is that whole, intact DNA fragments from GMOs resist breakdown in human digestion and have actually entered into the bloodstream of the people who ingest them.
Approximately 84 percent of all genetically engineered crops have been developed so that they can resist the application of herbicide. This has increased the use of herbicides by 383 million pounds from the period of 1996 to 2008. This amount is destructively overwhelming when compared to the reduced amount of insecticides used from GMOs containing BT.

From 1996 to 2004, the global area devoted to GMO crops grew an astoundingly 40-fold to 167 million acres, or 25 percent of all the agriculture land in the world, with Argentina second behind the US with 34 million acres. In 2005, the biggest producing GMO countries were the US, Canada, South Africa, China and Brazil, which account for 96 percent of all GMO crops grown.with the total area devoted to GMO crop production increasing by 2.5x by 2015.

Superweeds

As expected, a few weeds developed resistance to the Glyphosate tpromoting the development of superweeds. Thanks to the excessive use of herbicides, superweeds had no other weeds to compete against and grew explosively. Worse yet would be the fact that a transfer of GMO herbicide resistance to weed-related crops such as canola, via pollen to its relatives, is possible, adding fuel to the superweed fire. In turn and as anticipated, stronger, more toxic herbicides were then needed to help control the new superweeds. It took a total of 14 years for 10 superweeds to infest a total of 10 million acres in 22 states in the U.S. Other herbicide resistant crops include alfalfa, which has contaminated all organic and non GMO alfalfa in the U.S. Contamination of crops from GMO pollen is rampant, with most all of the corn and rice grown in the U.S. permanently affected.

Scientists have modified the DNA of rice plants to make them genetically modified.
Source:
https://commons.wikimedia.org/wiki/File:Genetically_Modified_Grain_Rice.jpg.
(unmodified).

GMO rice was developed in 2005. Vitamin A deficiencies kill 2.5 million people per year. About half of the world's population relies on rice as their main source of sustenance, Rice is void of carotenoids, which help humans make vitamin A. Rice provides 80 percent of the calories to the two biggest countries in the world, India and China. By inserting two genes from a daffodil and one from a bacterium, GMO "golden" rice that creates carotenoids emerged. Regrettably, it has been determined that a human would have to eat over 3 kg of rice per day to satisfy vitamin A requirements, and the standard intake of 300g would only supply 8 percent of the much needed vitamin. Thus, Golden Rice "2" was developed, which produces 23x more beta carotene than previously, but it has yet to be established on a commercial scale.

GMO animals and plants under development

Other new GMO animals on deck are pigs that have reduced phosphorous excrement, which would appear to have an incredible ecological advantage. Genes have been inserted into the pigs from *E. coli* bacteria and mice, which allow better digestion of phosphorous in the diet. And chickens resistant to the avian flu and others that produce unlimited amounts of eggs are being entrained. Plants genetically engineered to provide novel or extra amounts of a specific nutrient to meet species specific demands of fish are being developed.

GMO organisms in aquaculture

The involvement of aquatic species in transgenic research is far too vast to list here, but there are over 50 species reported to have undergone genetic modification since the first transgenic fish was produced in China in 1985.GMO salmon are touted to grow twice as fast as current farmed salmon, due to an inserted promoter gene from a coldwater fish that activates a growth hormone from a different species of salmon.

Investigation into the impact of feeding GMO ingredients in respect to the health and metabolism of fish has received insufficient attention. Rainbow Trout fed a diet containing RoundUP Ready Soybean meal had intact Viral Promoter fragments found in the digestive system for three days and in the head, kidney, muscle and leukocytes for five days, after the GMO diet was discontinued. A GMO diet fed to salmon showed intact GMO fragments in the intestine of the fish but not in the organs examined, while another found intact foreign DNA in all tissues. Similarly, tilapia had GMO fragments in internal organs for two weeks after fasting. A special concern here would be the incorporation of the GMO DNA from feed to bacteria in the intestine or to the fish itself, and/or the release of intact DNA fragments into the environment via excrement to be absorbed by bacteria (via plasmids) and incorporated into the genotype (horizontal transfer) resulting in unintended contamination.

Morphology and physiology of fish fed GMO ingredients has been reported to be different than those fed non-GMO ingredients. Growth studies using GMO corn, soy, cotton seed meal are contradictory, but research has shown that fish can grow equally as fast or faster when fed GMO compared to non-GMO feed. Furthermore, some studies related the differences found in morphology and physiology of fish receiving GMO ingredients to be related to the strain of the plant itself rather than genetic modification.

Several sources have stated that farmed salmon have interbred with wild salmon and altered the wild genetic pool, as has been well documented in traditional plant culture. The same has happened with shrimp. This threat is obviously relevant, because genetically modified salmon have been stated to be far more aggressive than their "natural" counterparts and not 100 percent sterile. GMO shrimp are being developed to grow faster and more disease resistant, while the determination of their market approval will hinge on the acceptance by the unknowing buyer as labeling is currently optional.

Perspectives

Foods from genetically modified organisms (GMOs) remain highly controversial in regards to their safety to humans. The possibility of GMO aquacultured species reaching seafood markets raises public concerns regarding safety, labelling, regulations, possible environmental impacts and other issues that must be properly addressed.