Special Topic Review Paper
Genetic Modification

Rationale

Up until a few weeks ago, I had a very minor understanding and knowledge of what genetic modification (GM) really was. For all I knew, it was a label that could be found on some food products and usually read, GMO free! Until that one day. That one lecture in my Public and Environmental Health class when we discussed the concerns of genetic modification. Immediately I was hooked, I wanted to learn more about these concerns and why our world was still producing food this way. The two broad concerns discussed in lecture that day were allergic reactions to GM foods and GM foods and their spread of antibiotic resistance. “Allergic reactions to GM foods?” Questions were spiraling in my head, “Does this mean my sister might not actually be allergic to tree nuts? Is it just the way they were grown?” I have many family members who have severe allergies to soy, peanuts, and beef protein. Also, if genetic modification is a major contributor to the antibiotic resistance epidemic, what is being done to control the GM food industry? I choose to research genetic modification to get to the bottom of the many potential risk factors and to understand the secretes involved in genetic modification.

Introduction

The intentional manipulation of genetic material, specifically DNA, describes the science behind genetic engineering (GE) or genetic modification (GM) of organisms (Uzogara, 2000). The manipulation of DNA allows for genes to be transformed, or transferred from one organism to another, to produce new variations of life (Uzogara, 2000). These transgenic organisms allow the largescale production of medical related contributions, commercially produced food, and plant biotechnology. Through the use of the recombinant DNA technique, many substances are able to be genetically modified with one main purpose, to benefit mankind (Uzogara, 2000).

As the human population continued to increase so did the demand for food, resulting in a boom in the agricultural industry (Halford, 2006). Many years later the world finds itself in a great public debate, regarding the advances in technology being applied to GM, safety and regulatory issues that have since emerged (Halford, 2006). The domestication of crops and livestock resulted in an agricultural revolution that still impacts the way we live today. It is hypothesized that farming life first began in Mesopotamia around 8000 BC (Halford, 2006). The transition from nomadic life to farming resulted in the growth of villages, towns, and cities; ultimately, laying the foundation of modern civilization (Halford, 2006). It is noted that wheat was the first crop to take part in a form of GM. This demonstrates how the cultivation of wheat became a systematic process in order to meet demand (Halford, 2006).

Charles Darwin and Gregor Mendel are credited with revolutionizing the science of genetics. Darwin's theory of evolution put forth the idea that species will adapt and evolve through the production of new genes in order to survive (Halford, 2006). Over time some species will evolve while others will die out and become extinct (Halford, 2006). Natural selection was the ability of species to pass down the best suited gene to future generations and thus promote the colonization of new environments, and ultimately new species (Halford, 2006). However, a problem with this theory arose when Darwin noticed an intermediate gene after two dominate genes were mixed. Mendel proposed a solution by experimenting with pea plants (Halford, 2006). During his research he noted that sometimes offspring would develop the same characteristics as their parents, but not always. He concluded that genes were randomly shuffled and passed down in pairs. The characteristics that appeared were a combination of traits from both parents and the randomization of sequence and dominance (Halford, 2006). These genes were carried out in what was later coined, genetic material, consisting of Deoxyribonucleic acid

(DNA) (Halford, 2006). Since these early discoveries, even more research on the structure and function of DNA and RNA has come out, resulting in complex technological advances, one in particular, the ability to alter genes (Halford, 2006).

Different forms of genetic engineering of food exist and have proven to be a resourceful tool for the agricultural and food industries (Halford, 2006). GE practices include, gathering and planting the seeds of fatter grains, selecting meatier and hardier animals for breeding, and the cross-fertilization of different plant species, are all done to reach a desired, better suited characteristic trait. However, there is a dark side to the GM of organisms. First, in 1967 a potato was genetically modified into a new variety called the Lenape potato (Uzogara, 2000). It consisted of a high solids content that was successful in making the potato chip. Two years later, a toxin, solanine, developed as a result of genetic modification, the USDA removed it from the market (Uzogara, 2000). Then in 1979, a synthetic growth hormone for cows, recombinant bovine somatotropin (rBST) was engineered to increase milk production in cows (Uzogara, 2000). The exciting discoveries involved in GM were on the rise worldwide. The rBST hormone was eventually regulated by the FDA as, "as safe as untreated cow." It revolutionized the dairy industry until recently, when research showed an increased risk between rBST consumption and pre-menopausal breast cancer in women (BCPP, 2019). In summary, genetic modification was good until it was too good, resulting in overuse without extensive research and effective regulatory measures.

Discussion

There are three types of GM for crops, traditional crop modification, genetic engineering, and genome editing. The traditional crop modification method refers to selective breeding and crossbreeding of plants; it has been around for years and is the result of many of the foods

consumed today (FDA, 2022). This conventional plant breeding practice involves the phenotypic assessment of plants to boost farm productivity and increase yield (Rommens et al., 2007). Some traditional crop modification techniques include introgression breeding, induced mutagenesis, and the somatic hybridization of genomes (Rommens et al., 2007). GE, developed in the 1970s, permits scientists to replicate a gene with a desired trait in one organism and put it into another. For example, modifying the DNA of corn by inserting a gene from *Bacillus thuringiensis,* a soil bacterium, to produce an insect-resistant corn variant (FDA, 2022). GE in animals is commonly used to promote disease resistance. Breeders benefit from GE by having access to genetic variations that are not typically found in a specific species (Eenennaam, 2017). Genome editing is a more efficient and precise way to develop new crop varieties because it consists of the tools needed for the removal of an unwanted gene (FDA, 2022). It is the latest technology and is carried out through the use of the CRISPR-Cas9 gene (Yin, Gao, and Qiu, 2017). Basically, the CRISPR-Cas9 system is the usage of sequence-specific nucleases and transcription activator-like effector nucleases to repair double-stranded breaks by targeting either non-homologous end joining (NHEJ) or homologous recombination (HR), resulting in gene knockout or gene replacement (Yin, Gao, and Qiu, 2017). Homologous recombination is a method used to introduce foreign genes into microbial strains that promotes the development of an artificially acquired function (Bai, Hong, and Wu, 2021).

The process of genetically modifying foods has developed concerns in human safety, allergenicity, toxicity, the nutritional quality of foods, and the environment (Bawa and Anilakumar, 2013). A study was done to test the nutritional quality and safety in GM soybeans in comparison to conventional soybeans (Bawa and Anilakumar, 2013). A synthetic gene from Agrobacterium is used to make soybeans herbicide resistant, a gene that safety tests claim to be

"substantially equivalent" to naturally grown soybeans. However, the study showed statistically significant content changes in genistein (isoflavone) and an increased content in trypsin inhibitor (Bawa and Anilakumar, 2013). Genistein is important in controlling blood glucose, reducing the symptoms of menopause, and lowering the probability of developing prostate and breast cancer. Trypsin is an enzyme that is involved in the breakdown of many proteins, primarily through the process of digestion. Trypsin inhibitor when consumed acts as an irreversible and competitive substrate, thus inhibiting the binding ability of other digestive proteins, resulting in an interference with digestive activities, ultimately causing metabolic and digestive diseases (Bawa and Anilakumar, 2013). This is a contributor to the alteration in nutritional quality of food.

Food safety has been a growing concern for many years, herbicides, pesticides, antibiotics, and hormones in animals are all contributors to the distrust of consumers and food hazards that have increased the overall toxicity content in food (Uzogara, 2000). Herbicide use in particular appears to have increased (Pretty, 2001). The reason for herbicide use on GM crops is to compete with destructive weed growth. Farmers are resorting to the use of a pre-emergence herbicide followed by a broad-spectrum product or using a broad-spectrum product twice (Pretty, 2001). One farmer reported that because of implementing the routine spray of a broad-spectrum product, millions were saved, and crop yield increased. However, this raises another issue, what composes these broad-spectrum products and how do they impact humans, animals, and the environment? A study reported that because of the switch to using GM crops, their herbicide tolerance increased corresponding with an increase in the strength and quantity of herbicide use (Pretty, 2001). Broad-spectrum herbicides offer a 'complete-weed kill' however, while the crop benefits, other farmland plants, mammals and birds are negatively impacted (Pretty, 2001).

A major effect of GE foods is the development of diseases that have a built-up resistance to antibiotics (Bawa and Anilakumar, 2013). The antibiotic resistant gene can be passed down to future generations and even alter the environment through environmental gene-swapping. The process of genetic modification commonly involves the use of *Agrobacterium tumefaciens,* or an alternate direct gene transfer, by transferring genes with a marker that enables the recovery of the desired phenotype (Gay and Gillespie, 2005). Incorporating antibiotic resistance markers into GM plants creates the possibility for the random transformation and recombination of genetic material. If an antibiotic resistance marker is acquired, it can physiologically cause the GM bacteria to withstand treatment from drugs designed to kill them (Gay and Gillespie, 2005). The breakdown of plant material often resides in soil, where bacteria degrade or digest cellular contents, including DNA. This is one way the antibiotic resistant gene is spread in the environment. Large fragments can persist in the environment long enough for them to be engulfed by other bacteria and transferred to other plants (Gay and Gillespie, 2005). Silos are locations in which crops are stored until maturation (Gay and Gillespie, 2005). Plants are harvested before reaching maturity, kept under anaerobic conditions, and experience lactic fermentation. All of which are done to prevent the growth of bacteria and preserve crops for a period of time. Unfortunately, these are prime conditions for certain bacteria and with many plants of the same species living in close contact, the swapping of genes in bacteria is encouraged (Gay and Gillespie, 2005). Antibiotic resistance gene-swapping can also occur in the gut of humans or other animals. A study measured the amount of plasmid and bacteriophage DNA that would remain in the intestinal tracts of mice (Gay and Gillespie, 2005). Results showed that fragments of DNA remained in the intestines of mice and were resistant to

degradation in the gastrointestinal tract. There was enough genetic material available for transfer to gut bacteria (Gay and Gillespie, 2005).

Another major concern is the adverse effects from GM and allergenicity. When a specific allergen is the known source of causing an allergic reaction, it is easy to test and prevent further encounters (Bawa and Anilakumar, 2013). However, because GM proteins of donor species are present in transgenic plants, it is therefore hard to locate the source of an allergenicity and avoid any potential cross contaminations (Bawa and Anilakumar, 2013). A possible solution is to study the IgE binding sites of GM foods, to determine characteristics of proteins and comparing them to known allergens (Bawa and Anilakumar, 2013). GM foods poses a humanitarian threat because of the inability to distinguish between allergenic contaminates and the challenges with traceability in the modern food supply system.

Unfortunately, there are many issues pertaining to the honesty involved in the labeling of GM foods (Uzogara, 2000). The FDA is responsible for monitoring the safety and wholesomeness of food, with the exception of meat and poultry (Uzogara, 2000). One major issue with GM is the minimal regulatory procedures enacted to ensure safety. Specifically pertaining to allergic reactions, the FDA does not require scientific data and potential allergens contaminated in GM foods to be displayed on labels. The loophole is that if there are potential allergens, companies are only required to simply state “possible contamination of allergens” ultimately, permitting many harmful ingredients to slip through the system (Uzogara, 2000). Proper labeling of foods is beneficial for both the consumer and the company. First, consumers have the ability to trace unintended consequences involved in GM food. Second, with such a significant increase in research opposing GM foods, manufactures would have the opportunity to

publicly emphasize the improved quality of their food, while lack of labeling would negatively skew their brand identity (Uzogara, 2000).

The goal is to set regulatory standards internationally (Pretty, 2001). In Europe, there are strict requirements for the production of GM food and rigorous protocols for post-release monitoring. Currently in the United States, the policy is to establish meticulous assessment procedures prior to release, but then to presume that farmers take part in 'good agricultural practices' (Pretty, 2001). Much of the harm comes from the lack of obedience when following the regulators' criteria. Lack of compliance causes environmental and humanitarian impacts such as the decline of biodiversity (Pretty, 2001). It is necessary to understand how the new agricultural technologies work and their effects on the field, animals, and humans. The Convention on Biological Diversity has been working to assess these effects and form an agreement for countries to adopt. The International Biosafety Protocol is a precautionary principle that could revolutionize the agricultural industry and require a change in the execution of GM foods, for the good of society (Pretty, 2001).

Conclusion

This report scientifically investigated the effects of genetic modification and its impact on the food industry. The concern ultimately lies within the safety of the human population. That said, the balance between supply and demand and the food industry's economic prosperity will remain. Over many years, the knowledge accumulated on genetic modification has grown significantly, as new side effects are emerging. This report investigated how genetic modification works and has evolved over the years. Also, the technological issues that have emerged, such as toxicity, nutritional quality of food, allergens, antibiotic resistance, and environmental concerns were investigated. Lastly, how these concerns effect overall human health and the decline in the

functioning of many body systems since the start of the genetically modified food industry. The underlying theme found in genetic modification is simply, how does something that was intended for good, spoil, or result in harm? I believe that the issue arose, not because of the implementation of genetically modified technology, but rather, the systemic human error, that continues to be a recurring theme throughout history of humanity; the overpowering need for advancement and money. Genetic modification simply put is an industry. An industry that needs to be better controlled through the use of regulatory measures, in order to eliminate health hazards to the human population.

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