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Analysis of the Correlation between Long-term Consumption of Genetically Modified Foods and the Risk of Chronic Diseases

Xiao Yao
Cuixi Academy of Biotechnology, Zhuji, 311800, China
Corresponding author email: 2280551691@qq.com

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Abstract This study explored the association between long-term consumption of genetically modified foods (GM foods) and the risk of chronic disease onset. The study reviews the development history of GM foods and their position in the global food supply, introducing different types of GM foods and common gene editing techniques, as well as assessments about their safety. Based on a systematic analysis of existing research, we explored the relationship between GM foods and chronic diseases. Furthermore, this study discusses multiple factors and uncertainties of disease risk, including genetic and environmental factors. Finally, this study also highlights the challenges and limitations in this field and prospects future research directions, aiming to provide a scientific basis for the research between GM foods and chronic diseases.

Keywords Genetically modified foods; Chronic disease risk; Safety assessment; Gene editing techniques; Environmental factors

In today's globalized food supply chain, GM foods has become a controversial and widely discussed topic. The introduction of GM foods is a technological revolution aimed at increasing crop yield, resisting pests, and improving food quality (Bai and Long, 2018; Kumar et al., 2020). However, this technology has also raised concerns about its potential health and ecological risks (Cui and Shoemaker, 2018).

Over time, GM foods have played an important role in the global food supply. Today, many countries produce and consume genetically modified crops, including corn, soybeans, cotton, rapeseed, etc. These crops and their derived food products have become a major component of the global food market. The popularization of GM foods has changed traditional agricultural models and provided a way to meet the growing global population demand.

However, the controversy related to its widespread application is also becoming increasingly prominent. Some countries and regions have adopted strict regulatory measures for GM foods, requiring clear labeling, and there have also been public opinion movements against GM foods. This controversy highlights concerns about the potential risks of GM foods, including their impact on human health and ecosystems.

The main purpose of this study is to explore the correlation between long-term consumption of GM foods and the risk of chronic disease. Chronic diseases, such as cardiovascular disease, cancer, and metabolic diseases, have become the main factors in global health problems. However, there is no consensus in the scientific community on whether long-term consumption of GM foods is associated with these chronic diseases. Through in-depth research on the relationship between GM foods and chronic diseases, this review aims to provide a comprehensive understanding of this important issue and provide scientific basis for future research, policy formulation, and consumer decision-making.

1 Types of GM foods and Common Gene Editing Techniques

The types of GM foods and common gene editing techniques form the foundation of this field, while also sparking discussions about their safety and ethical issues. By deeply understanding these aspects, this study can better understand the role and risk of GM foods in modern food supply chains.

1.1 Concept and historical development of GM foods

Genetically modified foods, also known as transgenic food or biotechnology food, refers to the introduction of exogenous genes into the genome of an organism through artificial means to endow it with new characteristics or functions, thereby improving its characteristics such as insect resistance, disease resistance, herbicide resistance, increased yield, and extended shelf life (Bawa, and Anilakumar, 2013). This technology has wide applications in agriculture, food production, and medicine. Among them, genetically modified crops in the field of plants dominate the global food supply.

The development history of GM foods can be traced back to the 1990s, when scientists successfully inserted foreign genes into the plant genome for the first time, creating the first batch of genetically modified crops. The early application of this technology mainly focused on major agricultural products such as corn, soybeans, cotton, and tomatoes. By introducing exogenous genes, genetically modified crops have gained a series of beneficial characteristics, such as insect resistance, disease resistance, herbal tolerance, increased yield, and extended shelf life. These characteristics have had a profound impact on agricultural production and food supply chains, driving the modernization and industrialization of global agriculture.

1.2 Common genetically modified agricultural products

Common genetically modified agricultural products have become a major component of global agricultural production, and they have obtained various beneficial characteristics through gene editing technology, which has had a profound impact on modern agriculture and food supply chains. The introduction of these genetically modified agricultural products has improved the yield, quality, and resistance of crops, helped reduce the use of pesticides and fertilizers, and increased the economic benefits of farmers. They also contribute to addressing the challenges of global food security and agricultural sustainability to a certain extent.

Genetically modified corn, which has insect resistance characteristics and typically contains Bt genes, enables it to resist some major pests, thereby reducing the use of pesticides. In addition, some genetically modified corn varieties also have better drought resistance, which is very beneficial for agriculture in arid areas. Genetically modified soybeans are designed to be resistant to the herbicide glyphosate, which allows farmers to more effectively control weeds and increase yields. Some genetically modified soybeans also have insect resistance properties, reducing the threat of pests to crops. Genetically modified cotton has insect resistance properties by containing the Bt gene, reducing the loss of cotton crops from insect damage (Figure 1). The improved fiber quality and strength through gene editing technology make some genetically modified cotton more suitable for textile manufacturing. Genetically modified rapeseed has significant implications for the production of biodiesel and edible oil by increasing its oil content. Similar to soybeans, some genetically modified rapeseed also exhibit resistance to glyphosate.

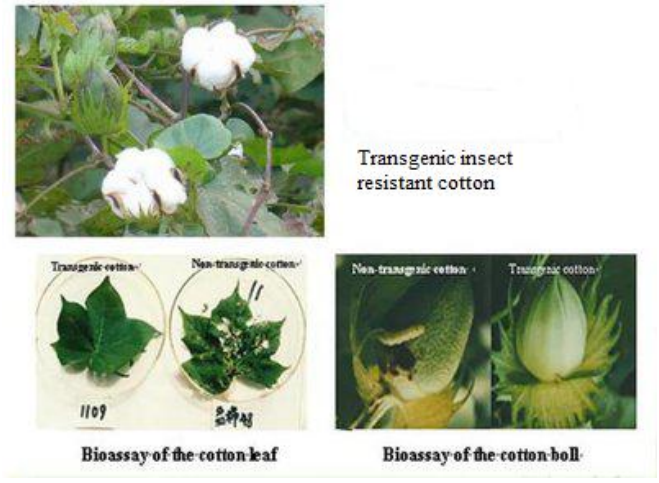

Figure 1 The transgenic cotton contains the Bt gene

1.3 Development and application of gene editing technology

In addition to traditional transgenic technology, gene editing technology has also been widely applied in recent years, with the most famous being CRISPR-Cas9 technology. Its efficient, precise, and customizable features make it easier for scientists to edit the genes of organisms, bringing widespread applications to various fields. In the agricultural field, this technology has been used to improve crops, enabling them to have higher yields, better stress tolerance, and stronger disease resistance. By editing the genes of crops such as rice, wheat, and potatoes, scientists help these plants grow in harsh environments while reducing the demand for pesticides and fertilizers, which helps improve the sustainability of agriculture.

Gene editing technology is also applied to livestock improvement to improve their production performance and health status. By editing the genes of livestock, cows can produce more dairy products, or improve the disease resistance of pigs, reduce the use of drugs in the breeding industry, and thus reduce production costs. In the field of microbial engineering, gene editing technology is widely used in the production of drugs, biofuels, and chemicals. By editing the genes of microorganisms, their production and efficiency can be improved, thereby promoting the development of the biological manufacturing industry.

Gene editing technology also plays a significant role in medical research and treatment (Thompson and Thompson, 2009). Scientists are using this technology to study human genes and diseases, with the potential to develop gene therapy methods to treat some genetic diseases and cancers. However, gene editing technology has also raised a series of ethical and legal issues, such as the ethical controversy surrounding gene editing of human embryos, and how to develop regulatory policies to manage the application of this emerging technology.

1.4 Safety assessment of GM foods

The safety assessment of GM foods is a key step in ensuring that these foods have no adverse effects on human health. These multi-level scientific methods and regulatory reviews ensure a comprehensive assessment of food safety to ensure the legitimate and safe use of GM foods and maintain consumer trust.

Scientists carefully analyze the chemical composition of GM foods, including proteins, fats, carbohydrates, vitamins, and minerals. This helps to determine if there are any significant chemical changes or abnormal components present.

Animal experiments and in vitro studies are used to evaluate potential toxicity and allergic reactions. By introducing GM foods into animal diets and monitoring their physiological conditions, scientists can detect any abnormal biological responses. In vitro research allows researchers to evaluate the effects of food on human cells, which helps identify potential cytotoxicity and changes in gene expression.

In order to comprehensively evaluate the safety of GM foods, human consumption experiments are usually conducted. These experiments include short-term and long-term studies, where volunteers consume foods containing genetically modified ingredients and then monitor physiological and biochemical parameters.

Epidemiological research is an important means of monitoring the association between long-term consumption of GM foods and chronic diseases. By tracking the dietary habits and health status of a large population, researchers can determine whether consuming GM foods is associated with specific health issues.

2 Research on the Correlation between GM foods and Chronic Diseases

The study of the correlation between GM foods and chronic diseases is a complex and challenging field that requires interdisciplinary cooperation and long-term scientific exploration. Although some studies have identified potential health risks, there is currently insufficient evidence to suggest that GM foods pose a serious threat to human health.

2.1 Overview of other studies

Before delving into the correlation between GM foods and chronic diseases, it is necessary to review the existing research reviews (Verma et al., 2011) to understand the current research trends and main findings in the field. For

the past few decades, the scientific community has been exploring the potential impact of GM foods, especially their relationship with chronic diseases. Laboratory research, animal testing, and epidemiological investigations are common research methods used to evaluate whether there is any association between GM foods and chronic diseases.

Some early studies claim that the long-term consumption of GM foods has no adverse effects on human health. An experiment may prove that the intake of genetically modified corn does not lead to significant physiological changes or an increase in chronic diseases. This viewpoint emphasizes the safety of GM foods, particularly in addressing food supply and nutritional issues. There are also other studies that have raised potential health risks. Some animal experiments may reveal that long-term consumption of specific types of genetically modified crops may be associated with liver diseases or immune system abnormalities (Figure 2). This has raised concerns about the potential health effects of GM foods, although these findings have not yet been validated in humans.

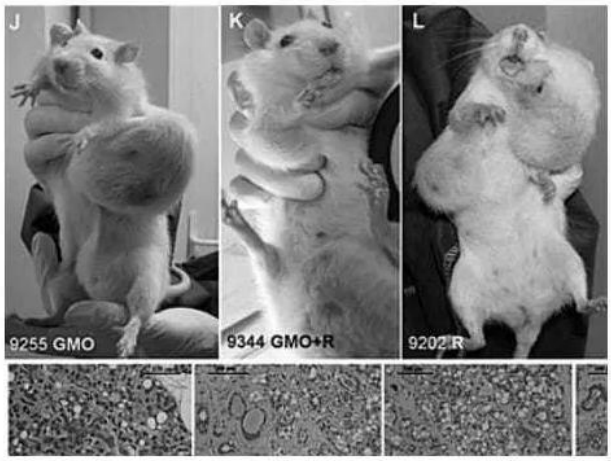

Figure 2 Relationship between GM foods and disease in animal studies (photo credit: *Food and Chemical Toxicology*)

The diversity of research results has sparked widespread controversy and also reflects the complexity of this field. Different research methods, food types, and experimental conditions may lead to different conclusions. Therefore, understanding the review of existing research can provide a background for further research and encourage the scientific community to delve deeper into the relationship between GM foods and chronic diseases.

2.2 Potential impact of GM foods on chronic diseases

The potential impact of GM foods is a complex and highly concerned issue, which depends on specific gene editing and characteristics. It should be noted that the extent of these potential impacts and long-term health effects still require more research to clarify. Because different types of GM foods have different gene editing and characteristics, they may have different impacts on health (Donna and Arvanitoyannis, 2009). In addition, human diet typically includes a variety of foods, including not only GM foods but also traditional foods, making it difficult to attribute the risk of chronic diseases solely to GM foods.

Some genetically modified crops are designed to have insect resistance or glyphosate tolerance, which means that fewer pesticides are required during the planting process. Although this helps reduce environmental pollution and exposure risks for farmers, it also raises concerns about the presence of pesticide residues in food. Long term consumption of food containing pesticide residues may be associated with the risk of chronic diseases. For example, certain pesticides are believed to be related to neurological diseases, cancer, and reproductive system problems. Although regulatory agencies usually have safety restrictions on pesticide residues in food, continuous monitoring and research are still needed to ensure the safety of food.

GM foods may contain new proteins that are not present in traditional foods (Wang et al., 2016). These new proteins may have different effects on the human body, including allergic reactions or immune system abnormalities. For example, a protein in genetically modified soybeans may cause allergic symptoms, although this situation is relatively rare. Allergic reactions may be related to the development of chronic diseases, as

abnormal immune system reactions can lead to inflammation and other health problems.

Some studies have found that GM foods may have an impact on the digestive system. For example, long-term consumption of genetically modified corn may be associated with certain intestinal diseases, such as inflammatory bowel disease. These findings have sparked research interest in the relationship between food and intestinal health, especially its association with chronic intestinal diseases.

2.3 Experimental research on related health issues

In order to gain a deeper understanding of the correlation between GM foods and chronic diseases, scientists conducted a series of experimental studies to simulate the possible effects of long-term consumption of different types of GM foods. These experiments typically include animal model studies and monitoring of physiological and biochemical indicators.

Scientists usually use mouse, rat, or other animal models for experimental research (Pan et al., 2020). These experiments involve dividing animals into experimental and control groups, and then subjecting them to long-term consumption of different doses of GM foods to observe changes in their physiological, metabolic, and immune indicators. For example, an experiment may have mice fed genetically modified corn, while another group of mice fed traditional corn, and then compared their physiological parameters such as body weight, blood sugar levels, and liver function. This experimental design helps to identify potential biological responses and food related health risks.

Another study used a rat model and divided the rats into three groups, each with a diet containing different concentrations of genetically modified corn. The study observed the pancreatic islet function, gastrointestinal inflammation indicators, and immune system responses of these rats. The results showed that a high concentration of genetically modified corn diet may be associated with an increase in some biochemical markers related to gastrointestinal inflammation, which has raised concerns about gastrointestinal health.

These experiments provide preliminary clues, but it should be emphasized that there are differences between animal models and human health. Therefore, the experimental results cannot be directly applied to humans, but they provide valuable guidance for in-depth research and encourage further epidemiological research to evaluate the impact of these potential health risks in humans.

2.4 Long-term consumption of GM foods and the risk of chronic diseases

The long-term consumption of GM foods and the risk of chronic diseases are core issues in this research field, which are of great significance for food safety and public health (Donna, and Arvanitoyannis, 2009). Although no clear conclusions have yet been drawn, future research needs to continue to focus on this issue to ensure food safety and consumer health. Experimental data and long-term epidemiological studies will provide more insights to gain a more comprehensive understanding of this important issue.

The diversity of human diet makes it difficult to attribute the risk of chronic diseases solely to GM foods. People consume various types of food in their daily diet, including traditional agricultural products, GM foods, processed foods, as well as different types of fruits and vegetables. Therefore, it is difficult to rule out the impact of other food factors on health in research. Understanding the association between specific foods and chronic diseases requires consideration of overall dietary patterns, as well as the impact of other lifestyle and genetic factors.

Different types of GM foods may have different gene editing and characteristics, so they may have different impacts on health. For example, insect resistant genetically modified crops and genetically modified crops with high oil content may have different potential impacts on health risks. Therefore, more detailed research is needed on different varieties of GM foods to more accurately evaluate their potential health effects.

Long-term epidemiological research is the key to answering this question. These studies require long-term tracking of the dietary habits and health status of large population groups to obtain reliable conclusions. A long-term epidemiological study tracked tens of thousands of participants for 30 years to assess the relationship

between their genetically modified food consumption and the risk of diabetes. The results showed that, in general, there was no obvious association between GM foods and diabetes. However, some weak associations have been found for certain specific types of GM foods, such as insect resistant genetically modified corn, but further research is needed to confirm their importance. Although such studies require time and resources, they can provide more reliable evidence to clarify the complex relationship between GM foods and chronic diseases.

3 Factors and Uncertainty of Disease Risk

Understanding the long-term consumption of GM foods and the risks of chronic diseases involves multiple factors and uncertainties, including genetic and environmental factors, which collectively affect individual health. Genetic factors play a crucial role in determining an individual's susceptibility to chronic diseases. Everyone has a different genetic background, which may lead to differences in their metabolism or immune response to certain food ingredients. Genetic polymorphism and the overall characteristics of an individual's genome can also affect disease risk. This may result in individual reactions to GM foods varying genetically, increasing uncertainty factors.

Environmental factors are one of the important influencing factors for individual health. Diet and lifestyle play a crucial role in the risk of chronic diseases. Unhealthy diet, lack of exercise and high stress lifestyle may increase the risk of chronic diseases such as diabetes, cardiovascular disease and obesity. In addition, environmental pollutants, socio-economic status, and medical treatment can also have an impact on health. The complex interactions between these factors and their relationship with long-term consumption of GM foods lead to uncertainty in disease risk.

Therefore, answering the correlation between GM foods and the risk of chronic diseases requires comprehensive consideration of multiple factors such as genes, lifestyle, environment, society, and treatment, and conducting in-depth research to obtain more accurate information. This also emphasizes the need for multidisciplinary and long-term research to fully understand the risks of chronic diseases, in order to reveal various aspects of this important issue.

4 Conclusion and Outlook

Although extensive laboratory studies, animal experiments, and epidemiological investigations have been conducted, there is currently no consensus on the association between GM foods and chronic diseases. Some studies have shown that long-term consumption of GM foods may be associated with an increased risk of some chronic diseases, but these associations still remain uncertain. Possible mechanisms include allergic reactions to specific proteins, effects on metabolic pathways, and biological activity of food ingredients.

There are some challenges and limitations in studying the association between GM foods and chronic diseases. The diversity and long-term nature of human diet make it difficult to clearly attribute specific disease risks to GM foods. Although animal models and laboratory research provide valuable clues, they cannot be directly applied to humans. In addition, there are potential biases and methodological challenges in the research, requiring more standardized research designs.

In summary, current research has not provided sufficient evidence to determine a clear association between long-term consumption of GM foods and chronic diseases. Different studies may produce different results, which makes this issue still controversial. However, it should be pointed out that research has emphasized the impact of food diversity, individual genetic differences, and lifestyle factors on the risk of chronic diseases. Therefore, the evaluation of the safety of GM foods cannot be limited to their gene editing or composition, but must also consider the interaction of these factors.

Future research needs to continue to explore the correlation between GM foods and chronic diseases, and address current challenges and limitations. Long term epidemiological research can provide more reliable evidence to answer this question. These studies require long-term tracking of the dietary habits, genetic characteristics, and health status of large population groups in order to gain a more comprehensive understanding of the impact of GM

foods. More detailed research is needed on different types of GM foods to distinguish their potential health impacts. For example, insect resistant genetically modified crops and genetically modified crops with high oil content may have different impacts on health risks. Further study the interaction between individual genes and environmental factors to understand why some individuals may be more at risk for GM foods. This can help identify health recommendations for specific subgroups. Strengthen the supervision of GM foods and ensure that they undergo sufficient safety assessments. At the same time, improve the transparency of research so that the scientific community and the public can better understand the research methods and results.

Overall, the study of the association between GM foods and chronic diseases remains a complex and challenging field. Future research will continue to provide more insights to more accurately evaluate various aspects of this important issue and provide more scientifically based recommendations for food safety and consumer health.

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