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EXPLORING THE ROLE OF GENETICALLY MODIFIED FRUITS IN IMPROVING GLOBAL FOOD SECURITY

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ABSTRACT

With the global population increasing rapidly, agriculture faces the critical challenge of sustainably providing sufficient and nutritious food to meet the ever-growing demand, all while being mindful of environmental health and preservation. Moreover, discussions about population growth always highlight the concern of diminishing arable land. Consequently, the rising demand for food will definitely clash with limited agricultural production, ultimately leading to food insecurity. In this context, traditional crop production methods may not be adequate, making agricultural biotechnology, such as producing genetically modified crops, a viable option to consider. Genetically modified (GM) foods are essential for this effort, as they offer improved yields, disease resistance, and environmental resilience, all of which are crucial to keep pace with global needs. Engineered with traits such as pest resistance, disease tolerance, and climate adaptability, these fruits can significantly boost production efficiency and decrease the need for chemical inputs. Among the subjects for genetic modification are fruits and vegetables, as they are central to a healthy diet due to their rich supply of essential vitamins, nutrients, and dietary fibers, and are crucial for global food security by supporting biodiversity and dietary diversity. Fruits, specifically, provide vital vitamins, minerals, antioxidants, and dietary fibers that enhance metabolic function and detoxification, making them essential for overall health. When genetically modified for beneficial purposes, they can significantly contribute to achieving food security by ensuring access to sufficient, safe, and nutritious food that meets dietary needs and preferences for an active and healthy life.

Keywords: Genetically-Modified (GM) Foods, Genetically-engineered, Food security, Fruits.

1. INTRODUCTION

Global food security has always been a fundamental objective in agriculture. Throughout human history, societies have strived to ensure a stable and sufficient food supply. To achieve this, countless innovations, advancements, and inventions have been developed across different civilizations and eras. This challenge stems from the need to supply an ever-growing human population. As the global population rises, the demand for food increases, putting pressure on agricultural systems to produce more with limited resources [1]. As of 2026, the global population has reached 8.3 billion [2]. Meanwhile, the FAO baseline scenario predicts that by 2050, the available arable land per person will decrease to approximately 0.18 hectares, down from the current 0.242 hectares [3].

Therefore, genetically modifying food is of great significance, as GM foods offer substantial benefits in addressing global hunger and malnutrition. These foods have the potential to enhance agricultural productivity by growing more rapidly than traditionally cultivated crops, which can lead to a greater food supply. Additionally, by increasing yields and reducing the reliance on synthetic pesticides and herbicides, GM foods contribute to environmental protection and preservation. This dual advantage of enhancing food security while mitigating environmental impact highlights the critical role of genetic modification in sustainable agriculture [4]. By emphasizing foods, dietary practices such as including fruits and vegetables, alongside legumes, nuts, and whole grains, are central to a healthy diet [5]. A diet rich in a variety of fruits and vegetables, abundant in essential nutrients, phytonutrients, and dietary fibers, is crucial for maintaining good health [6]. Studies suggest that to promote human health and achieve a sustainable food supply with limited environmental impact—particularly regarding water usage and chemical inputs—a daily intake of 300–600 g is ideal, with 200–600 g coming from vegetables and 100–300 g from fruits [7–9]. Even so, global fruit consumption remains significantly below these recommendations, with the supply of vegetables notably surpassing that of fruits [10]. Additionally, it is estimated that nearly a third of the fruits and vegetables produced worldwide never make it to consumers, being lost during the stages of production, storage, and processing [11].

Despite the growing body of literature on genetically modified crops and their contributions to global food security, research and commercialization efforts have largely focused on cereals, oilseeds, and vegetable crops, with comparatively limited attention given to fruit species. This review aims to address this knowledge gap by: (1) synthesizing the current status and distribution of genetically modified traits in fruit crops relative to major staple crops; (2) critically evaluating the roles of GM fruit traits—particularly disease resistance, delayed ripening, and quality preservation—in enhancing food security and reducing postharvest losses; (3) examining the environmental sustainability implications of GM fruits, including reduced pesticide use and improved resource-use efficiency; and (4) identifying key scientific, regulatory, and socio-economic gaps that must be addressed to enable the broader integration of genetically modified fruits into sustainable and climate-resilient food production systems.

2. LINKING GENETICALLY MODIFIED FRUITS TO GLOBAL FOOD SECURITY

GM fruits are an important tool in addressing global food security by improving stress tolerance, nutritional value, resistance to pests and diseases, and postharvest longevity. Each of these elements contributes in a unique, but often synergistic, way to strengthening food systems. Below is a short discussion of these major contributions.

Global Food Security

Global food security is not a temporary objective that can be achieved and then set aside to sustain itself; instead, it is a fundamental goal of agriculture that must be continuously monitored and addressed, especially in light of a growing population and limited resources. Since the establishment of communities and societies, this issue has been of paramount concern, as demonstrated by ongoing efforts to define and address global food security, which continues to evolve over time.

The concept of food security has evolved significantly since its initial definition by the World Food Summit in 1974, which focused on the consistent availability of adequate food supplies, specifically stating it as "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices". However, availability alone proved insufficient, as issues of access soon became evident. In response, the FAO updated the definition in 1983 to include both physical and economic access to food.

Over time, the definition has been further refined to reflect changing global conditions, culminating in the widely accepted view that food security exists when all people, at all times, have access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life [12–14]. Still, the FAO Committee on World Food Security has further refined and combined various elements to define food and nutrition security. According to this definition, “Food and nutrition security exists when all people at all times have physical, social and economic access to food, which is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life” [15].

Global food security is influenced by various factors, including population growth, environmental changes, and resource competition, all of which will have a significant impact on our ability to sustain food production. Increasing food production alone will not be sufficient to meet society's needs; factors such as access to food, affordability of foodstuffs, and other critical food system activities like production, storage, processing, and packaging are equally important [16]. In response to these challenges, a balanced approach that combines self-sufficiency with the importation of food has been suggested as the most effective strategy for ensuring food security [17].

Meanwhile, fruits and vegetables play a crucial role in enhancing food security and nutrition by contributing to dietary diversity and food biodiversity, ensuring a wide range of nutrients essential for health and supporting balanced diets across populations [10]. They offer sustainable options that can be cultivated even in challenging environments, helping secure food supplies in the face of climate change, and fruit tree portfolios address seasonal availability by providing a steady source of nutrition year-round, reducing periods of food scarcity. Additionally, home gardens promote food production diversity, empowering communities to grow a variety of crops that contribute to both food security and improved nutrition [18].

Genetically Modified Food

To ensure global food security, advancing agricultural productivity through new research, biotechnology, and innovation is crucial for increasing crop yields. Agricultural biotechnology plays an essential role in this endeavor [19, 20]. Cutting-edge innovations like transgenic crops, insect-resistant varieties, herbicide-tolerant strains, and viral-resistant plants are key to enhancing global yields. These advancements, which can be achieved through the process of genetic modification, if embraced responsibly, can drive sustainable agricultural production and meet the growing demands of our world.

Genetic modification is a biological technique that induces alterations in the genetic composition of various living organisms. The World Health Organization (WHO) defines genetically modified organisms (GMOs) as "organisms (i.e., plants, animals, or microorganisms) in which the genetic material (DNA) has been altered in a manner that does not occur naturally through mating and/or natural recombination" [5]. Genetically modified organisms are also termed as genetically engineered or transgenic organisms [21-22].

It was in 1944 that scientists made a pivotal discovery that DNA could be transferred between organisms, a breakthrough that significantly advanced our understanding of genetics [23]. The creation of the first genetically modified (GM) plant occurred in 1983, featuring an antibiotic-resistant tobacco variety. China pioneered the commercialization of transgenic crops in the early 1990s with the release of virus-resistant tobacco. In 1994, the FDA approved the 'Flavour Saver' tomato for sale in the USA, marking it as the first genetically engineered food granted a license for human consumption. This transgenic tomato was designed to delay ripening after harvest. By 1995, only a few transgenic crops had obtained marketing approval. Among the GM foods on the market are cotton, soybeans, canola, potatoes, eggplant, strawberries, corn, tomatoes, lettuce, cantaloupe, carrots, and others [4]. Furthermore, insect-resistant fruits such as apples, virus-resistant cantaloupes and cucumbers, and herbicide-tolerant crops like corn, tomatoes, potatoes, and soybeans have all been successfully cultivated as well [22].

As reported and deliberated, genetically engineered foods have higher nutrient levels, including increased minerals and vitamins, compared to traditionally grown foods, and they are often noted for their improved taste. Another advantage of genetically engineered foods is their extended shelf life, which reduces the risk of spoilage and enhances their appeal to consumers. They can be utilized to grow plants faster, increase crop yields, and reduce crop losses by making plants more resilient to pests, weeds, herbicides, viruses, worms, insects, salinity, pH variations, temperature extremes, frost, drought, and adverse weather conditions [1, 22, 24-26].

Conversely, while genetically modified foods present numerous advantages, they also raise several significant concerns. As highlighted by numerous articles, one of the major concerns surrounding genetically modified foods is the potential adverse effects on human health, such as the risk of fostering antibiotic-resistant diseases and the uncertainty regarding the long-term health impacts due to the relatively recent introduction of these foods. Health risks associated with GM foods include potential toxins, allergens, and genetic hazards. There are ongoing controversies regarding the safety of GM foods, the necessity and methodology of their labeling, and their role in addressing global hunger. Environmental concerns include the unintentional transfer of genes to wild plants, the possible creation of new viruses or toxins, and threats to crop genetic diversity. Additionally, issues related to the patenting of GM seeds may limit access, while religious, cultural, and ethical objections, as well as concerns from animal rights groups and organic farmers, further complicate the debate. Despite these concerns, the risks of GM foods must be weighed against their potential benefits [4, 22, 26].

GM Trait Adoption in Fruit Crops Relative to Major Staples

The global adoption of genetically modified crops has been overwhelmingly concentrated in major staple and commodity crops such as maize, soybean, canola, rice, wheat, sugar beet, and sugarcane. These crops exhibit a broad range of introduced traits, including herbicide tolerance, insect resistance, drought stress tolerance, fertility restoration, and metabolic modifications affecting oil, starch, or protein composition. In contrast, the representation of fruit crops within the GM landscape remains limited, both in terms of the number of species commercialized and the diversity of traits deployed (see Table 1) [27].

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Table 1. Approved genetically modified foods and their key traits from International Service for the Acquisition of Agri-Biotech Applications (ISAAA)

Genetically modified food	GM traits
Apple *Malus* × *domestica* Borkh.	Antibiotic resistance, non-browning phenotype
Argentine Canola *Brassica napus* L.	Modified oil/fatty acid, antibiotic resistance, glufosinate herbicide tolerance, fertility restoration, male sterility, oxynil herbicide tolerance, glyphosate herbicide tolerance
Bean *Phaseolus vulgaris* L.	Viral disease resistance
Chicory *Cichorium intybus* L.	Glufosinate herbicide tolerance, Male sterility, Antibiotic resistance
Cowpea *Vigna unguiculata* (L.) Walp	Lepidopteran insect resistance
Eggplant *Solanum melongena* L.	Lepidopteran insect resistance, antibiotic resistance
Flax *Linum usitatissimum* L.	Sulfonylurea herbicide tolerance, Antibiotic resistance, Nopaline synthesis
Maize *Zea mays* L.	Male sterility, fertility restoration, visual marker, modified alpha amylase, mannose metabolism, glufosinate herbicide tolerance, Lepidopteran insect resistance, glyphosate herbicide tolerance, coleopteran insect resistance, multiple insect resistance, sulfonylurea herbicide tolerance, antibiotic resistance, 2, 4-D herbicide tolerance, drought stress tolerance
Melon *Cucumis melo* L.	Delayed ripening/senescence, antibiotic resistance
Papaya *Carica papaya* L.	Viral disease resistance, antibiotic resistance visual marker
Pineapple *Ananas comosus* (L.) Merr.	Increased lycopene content (pink flesh), delayed ripening, altered fruit coloration, elevated β-carotene
Plum *Prunus domestica* L.	Viral disease resistance, antibiotic resistance visual marker
Polish canola *Brassica rapa* L.	Glufosinate herbicide tolerance, glyphosate herbicide tolerance
Potato *Solanum tuberosum* L.	Coleopteran insect resistance, antibiotic resistance, modified starch/carbohydrate, reduced acrylamide potential, black spot bruise tolerance, viral disease resistance
Rice *Oryza sativa* L.	Anti-allergy, antibiotic resistance, Lepidopteran insect resistance, Lepidopteran insect resistance, glufosinate herbicide tolerance
Safflower	Modified oil/fatty acid, antibiotic resistance, Glufosinate

Carthamus tinctorius L.	herbicide tolerance , 2,4-D herbicide tolerance
Soybean *Glycine max* (L.) Merr.	Modified oil/fatty acid, antibiotic resistance, visual marker, glufosinate herbicide tolerance, sulfonylurea herbicide tolerance, glyphosate herbicide tolerance, 2, 4-D herbicide tolerance, isoxaflutole herbicide tolerance, drought stress tolerance, Lepidopteran insect resistance, dicamba herbicide tolerance, mesotrione herbicide tolerance
Squash *Cucurbita pepo* L.	Viral disease resistance, antibiotic resistance
Sugar Beet *Beta vulgaris* L.	Glyphosate herbicide tolerance, Visual marker, Antibiotic resistance, Glufosinate herbicide tolerance, Dicamba herbicide tolerance
Sugarcane *Saccharum* sp.	Drought stress tolerance, antibiotic resistance, Lepidopteran insect resistance, Glyphosate herbicide tolerance
Sweet pepper *Capsicum annuum* L.	Viral disease resistance
Tomato *Solanum lycopersicum* L.	Delayed ripening/senescence, antibiotic resistance, Lepidopteran insect resistance, delayed fruit softening, viral disease resistance
Wheat *Triticum aestivum* L.	Glyphosate herbicide tolerance, Drought stress tolerance

To date, only a small number of fruit crops—including papaya, apple, pineapple, melon, plum, tomato, eggplant, and sweet pepper—have been genetically modified and approved for cultivation. Among these, genetic modification has primarily targeted critical biotic constraints and postharvest quality traits, rather than the agronomic traits commonly engineered in staple crops. One of the most prominent examples is genetically modified papaya resistant to papaya ringspot virus (PRSV), which was developed in response to a severe industry-wide crisis in Hawaii during the early 1990s. The introduction of PRSV-resistant papaya led to a substantial recovery in productivity and effectively prevented the collapse of the Hawaiian papaya industry. At present, approximately 80% of papayas grown in Hawaii are genetically modified, reflecting the absence of effective conventional or organic alternatives for controlling the disease [4].

Other commercially approved GM fruits remain few and geographically restricted. The Rosé pineapple, developed by Del Monte Fresh Produce Company, is currently the only genetically modified pineapple variety available. This cultivar exhibits delayed ripening, altered fruit coloration, and elevated levels of lycopene and β-carotene, traits aimed at enhancing fruit quality and nutritional value rather than field-level stress tolerance. The Rosé pineapple has been approved for cultivation in the United States since 2016 and in Canada since 2021. Similarly, genetically modified apples developed by Okanagan Specialty Fruits Incorporated—including Arctic™, Arctic™ Golden Delicious, and Arctic™ Fuji—have been engineered to suppress enzymatic browning, thereby reducing postharvest losses and improving consumer appeal. These apple varieties have received regulatory approval in the United States and Canada between 2015 and 2019, with commercial cultivation already underway [28].

Overall, the current distribution of genetically modified traits highlights a clear disparity between fruit crops and major staple crops. While staple crops are characterized by extensive trait stacking and large-scale adoption, GM fruits remain species-specific and problem-driven, with a narrow focus on disease resistance and postharvest quality. This imbalance reflects biological complexity, longer breeding timelines, regulatory hurdles, and heightened consumer sensitivity surrounding fruit crops, and underscores the significant untapped potential of genetic modification to enhance productivity, reduce losses, and strengthen the contribution of fruits to global food security.

GM and Food production

Genetic modification significantly benefits farming and food production by boosting agricultural productivity through advancements in chemistry, biotechnology, and crop science [29]. These innovations not only increase the efficiency of fertilizer use but also improve overall crop production and expand the global food supply by developing environmentally friendly crops. Genetic modification offers farmers greater flexibility, particularly in pest management, by creating crops that are resistant to specific pests and diseases. Additionally, herbicide-tolerant crops facilitate conservation tillage practices, which help preserve topsoil and protect water quality by reducing soil erosion and runoff. These benefits collectively contribute to more sustainable and efficient agricultural practices, supporting both environmental conservation and food security

Role of Genetically Modified Fruit in Food Security

Vegetables and fruits are crucial for improving diet quality, nutrition, and economic well-being. They provide essential nutrients such as Vitamins A and C, iron, calcium, carbohydrates, and proteins. In fact, some vegetables offer higher protein content compared to rice and legumes on a dry matter basis. Thus, including a diverse range of vegetables and fruits can address nutrient deficiencies and contribute to food security at the household level [30].

Drawing attention to fruits, they play an important role in human nutrition and health. They are a rich source of vitamins, minerals, folic acid, dietary fibers, antioxidants, and thiamine. As fruits are rich in antioxidants and function is to modify metabolic activation and detoxification. So, by this, they will improve the functioning of the body. Fruits also contain a unique set of nutrients that are essential for proper body functioning [31].

Focusing on some fruits that have been genetically modified, such as apples, papayas, and pineapples: Apples, offer a range of health benefits. They are rich in antioxidants like flavonoids and contain fiber, potassium, vitamin K, some B vitamins, and iron. These nutrients help lower the risk of diabetes and asthma, support heart health, manage blood pressure, improve intestinal health, and enhance bone density. Apples also contain pectin, a prebiotic fiber that aids digestion and metabolic health. Regular consumption of apples can contribute to overall well-being and reduce the need for medical visits. Papaya is a valuable fruit for disease prevention and overall health. It is a rich source of folate, vitamin A, and vitamin C. Additionally, it contains papain, an enzyme that aids digestion. Papaya also helps protect the skin from damage. Pineapple contains an enzyme called bromelain, which helps alleviate coughs and colds, and may also inhibit cancer cell growth. Rich in vitamins and manganese, pineapple supports heart health, improves bone strength, reduces cancer risk, and can help manage asthma symptoms [31-34].

Fruit production is a vital component of food and nutrition security. Fruits are crucial for both food and nutrition security, often ranking third in importance after cereals and vegetables in many countries. Beyond enhancing nutritional status, fruit production also fosters income generation and job creation. Rising incomes, population growth, and urbanization are driving

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increased local demand for fruits. Additionally, planting fruit trees supports environmental improvement through afforestation and conservation efforts. The growing awareness of balanced diets and changing dietary habits is further accelerating the demand for fruits [35].

Maintaining fruit as well as vegetable biodiversity is essential for future generations. Genetically modified fruits are playing a key role in this effort by enhancing genetic diversity and creating new crop varieties. As global fruit and vegetable consumption increases and technology advances, GM fruits help tackle the challenges of a growing population and environmental changes, supporting long-term food security and agricultural sustainability [36].

A study explored the role of fruit and vegetable consumption in enhancing food security in Limpopo province, South Africa [37]. Although the study did not exclusively focus on fruits, it found that the intake of fruits and vegetables significantly improved household food security. The research concludes that prioritizing and promoting the production and consumption of these foods could be a crucial approach to mitigating the country's high levels of food insecurity. Similarly, surveys conducted in Uganda reveal that increasing fruit and vegetable production enhances food security and positively impacts anemia levels, particularly for women of childbearing age [38]. However, cultivating fruits and vegetables inherently involves risks such as crop failure due to drought, adverse weather conditions, pests, and diseases [30]. Hence, effectively managing these challenges requires both specialized knowledge and access to advanced inputs, including drought-tolerant and disease-resistant plant varieties.

Modern biotechnology, including genetic modification techniques, is proposed as a means to lessen environmental impact by enhancing food quality and boosting productivity. Developing high-yield, disease-resistant, and climate-resilient crop varieties is essential for food security. Traditional plant breeding methods are slow and labor-intensive, whereas genetically modified crops offer a more precise and efficient solution by incorporating desired traits from various sources. GM crops have been shown to reduce the need for chemical inputs, increase yield, and provide economic benefits. Indeed, GM crops have the potential to ensure food security, but societal acceptance remains a significant challenge, as many farmers are concerned that growing GM crops might deter consumers from buying them despite extensive research confirming their safety [28].

Genetically Modified Fruits and Environmental Sustainability

The environmental benefits of genetically engineered crops are diverse. These crops offer enhanced protection against insect damage, which reduces the need for chemical insecticides, thereby minimizing environmental pollution and preserving beneficial insect populations. Herbicide-tolerant crops enable more efficient and targeted weed control, leading to fewer herbicide applications and less chemical runoff. Furthermore, improvements in crop yields and efficiency contribute to reduced land use, helping to conserve natural habitats and biodiversity. Genetic engineering also facilitates the conservation of resources by lowering the need for labor, fuel, fertilizers, and water, promoting more sustainable farming practices. They also play a crucial role in preserving water quality by reducing runoff of fertilizers and pesticides into water bodies. Additionally, these crops are designed to resist specific plant diseases, reducing the need for chemical treatments and enhancing overall crop health and yield [22,39]. Moreover, genetic modification can enhance bioremediation by developing plants capable of removing toxic waste from the environment [40]. Bio-engineered plants, such as mustard greens, alfalfa, river reeds, poplar trees, and special weeds, are utilized to address pollutants from industrial, agricultural, and petroleum sources, either by converting toxins into harmless compounds or by absorbing them.

3. KNOWLEDGE GAPS AND FUTURE RESEARCH DIRECTIONS

Despite the fact genetically modified fruits have demonstrated clear benefits—such as disease resistance, improved postharvest quality, and enhanced nutritional content—there remains a profound lack of comprehensive, cultivar-specific evidence across diverse fruit species. Unlike staple crops, fruit crops present unique physiological and developmental complexities, including perennial growth, long juvenile phases, fleshy tissues, and intricate reproductive systems. These features limit the direct transferability of findings from model species or annual crops, making it critical to investigate the species- and cultivar-specific impacts of genetic modification on physiology, metabolism, and yield.

Significant scientific gaps exist in understanding the molecular, biochemical, and ecological mechanisms by which introduced genes interact with fruit development and environmental stress responses. Key areas of investigation include: 1) the long-term effects of GM traits on plant growth, fruit quality, and stress resilience under variable field conditions; 2) potential off-target or unintended metabolic and ecological consequences; and 3) interactions with pests, pollinators, and soil microbiomes. Current research predominantly evaluates individual traits in isolation, neglecting multi-trait or stacked trait interactions, which may influence both productivity and environmental outcomes.

In addition to scientific uncertainties, substantial regulatory and socio-economic gaps constrain the wider adoption of GM fruits. Complex, inconsistent regulatory frameworks, high approval costs, and variable public acceptance hinder commercialization, even when scientific evidence supports safety and efficacy. Ethical considerations—including equitable access, consumer transparency, and human health—remain central to public trust and the responsible deployment of these technologies.

Future research must adopt integrated, multidisciplinary approaches that combine molecular biology, horticultural practices, environmental modeling, and social sciences. Priority actions include: 1) elucidating gene function and stress response pathways in specific fruit cultivars; 2) validating GM fruit performance across diverse agro-ecological zones and cropping systems; and 3) developing frameworks to address socio-economic, ethical, and regulatory challenges. By systematically addressing these gaps, genetically modified fruits can be more effectively integrated into sustainable and climate-resilient food production systems, helping to secure global food supplies while minimizing environmental and societal risks.

4. CONCLUSION

The struggle to eradicate world hunger will persist as long as global food insecurity exists. Despite substantial human efforts and resource investments aimed at addressing this persistent issue, complete resolution has yet to be achieved, although significant progress has been made. One of the notable steps toward food security is the incorporation of biotechnology in agriculture, particularly through the genetic modification of crops that are consumed as food. Genetic engineering, through the development of GM crops, plays a crucial role in modern agriculture by providing traits such as disease resistance, drought tolerance, and improved nutrition. GM technology has the potential to significantly boost food production and enhance global food security, offering a promising solution. Despite some limitations, the benefits of GM crops make them a valuable tool for advancing food security and sustainable agriculture. Since the global population cannot be controlled but can be predicted, we should focus on methods to ensure food production keeps pace with population growth, despite the limitations of arable land and other resources required for food production.

In light to this, fruits and vegetables are vital for global food security and nutrition due to their rich micronutrient content [10]. However, many fruits are highly perishable, with short storage lives and a need for rapid disposal after harvest. Hence, utilizing biotechnology offers a strategic solution to these challenges. Genetic modification can extend the shelf life of these foods, reducing spoilage and could also enhance their appeal to consumers. With it, increased crop yields, reduced losses, and improved plant resilience and standing to adverse weather conditions could be attained.

Although food security depends on factors such as sustainability, availability, access, and utilization beyond mere production, it is evident that adopting a new approach is crucial for efficiently and equitably feeding the global population. In fact, agriculture is multifaceted, and achieving success requires us to embrace its diversity. That said, GM foods are not a complete solution to ending global food insecurity, and the quest to solve it is much more complicated and cannot just be resolved by focusing solely on increasing food quantity or quality. As a matter of fact, according to FAO's definition, achieving food security requires meeting four key components: availability, accessibility, acceptability, and adequacy. Nonetheless, genetically modified foods have diverse potential applications and, in the near future, may play a crucial role in achieving these essential elements to secure global food security.

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Author Contributions

Eidenwin V. Canoy conceived and designed the review, conducted the literature search, synthesized interdisciplinary evidence on genetically modified fruits and food security, drafted the manuscript, prepared tables, and ensured overall clarity and coherence.

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Data availability

Not applicable

Declarations

Competing Interests

The author declares no competing interests.

Ethics, and Consent to Participate

Not applicable.

Consent to Publish

I, the sole author, have read and approved the manuscript and consent to its publication.

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