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ROLE OF BIOTECHNOLOGY IN FOOD SECURITY: A REVIEW

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SUMMARY

One of the most serious issues confronting the global food system is the wastage of approximately one-third of food at various points throughout the supply chain due to environmental and economic factors. Declines in production and food quality deterioration are concerns due to less awareness of the farming community and end users about the advanced technologies. Therefore, scientists face to develop cutting-edge technology to solve these problems and feed the bulging population to prevent starvation. Genetic engineering (GE) techniques can aid in several contexts to boost crop yields and quality. Biotechnology, genetic modification, and recombinant (r) deoxyribonucleic acid (DNA) technologies are significantly beneficial in pursuing chief progress in food production and supply. This latest literature review illustrates the recent advances in GE, their sources, current trends, and future. GE foods from animals, microbes, and crop plants have altered DNA and introduced modified genetic characteristics. Genetically modified organisms (GMOs) are vital parts of the industrial food system, and most packaged foods contain GMO ingredients that received engineering for resistance to pesticides and herbicides. Several issues raise red flags concerning GMOs, including safety, effects on the environment, and ineffective usage of pesticides. Many people are anxious about GMOs; however, most do not understand the problems.

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Keywords: biotechnology and genetic engineering, food security, less crop production, food quality, environmental factors, advanced technologies, people's awareness

Key findings: Globally, scientists are trying to manage food waste in a better way to lessen poverty. The presented review shed light on advanced breeding techniques like using GMOs, biotechnology, genetic modification, and recombinant (r) deoxyribonucleic acid (DNA) to improve crop yield sufficient to feed the community and prevent starvation.

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INTRODUCTION

Agriculture is vital in providing basic needs, including food, clothing, and shelter for humans. According to recent studies, the community living in absolute poverty decreases by 0.6% and 1.2% for every percentage point increase in agricultural output (Afonso and Miller, 2021). A prediction also states that by 2050, the global population can reach 9.7 billion, requiring an increase in food production of almost 70%. It is necessary to enhance crop yields to cope with this immense requirement. Plant yield also has impacts from a wide range of factors (Figure 1). Increasing crop yield requires farmers to also need support in terms of finances, as well as advanced production technologies. For example, in Bangladesh, the farmers took advantage of heavily discounted chemical fertilizers and pesticides (Umetsu, 2022). Moreover, the leading causes of crops' low yield are late planting, improper plant spacings and planting methods, shallow sowing, pest and disease management, insufficient fertilizer uses, delayed harvesting, and adopting low-yielding cultivars (Jiang *et al.,* 2022; Gondal *et al.,* 2023).

Everyone has an inherent right to have sufficient food and nutrition daily. Food insecurity exists when the food supply lessens due to a lack of resources providing food consistently for their nutritional needs. However, it is regrettable to mention that many people globally still struggle with hunger. Worldwide, about 2.37 billion people have limited food to meet their caloric needs, making them undernourished (Figure 2) (FAO, 2023). The global community has also committed to eradicating hunger, food insecurity, and malnutrition in general by 2030. The World Food Programme (WFP) asserts that low-income-owned communities have disproportionate influences from macroeconomic variables like unemployment and increasing food costs, leading to food insecurity. For food insecurity reduction, it is much more necessary to develop new high-yielding crop cultivars with the help of genetic engineering and biotechnology to get more yields and develop food processing and preservation techniques.

Preventing future famines and fulfilling the food needs of the growing population entails innovative technologies and methodologies to address these problems (Shaikh *et al.,* 2022). Biotechnology has paved the way to alter DNA to develop new and compelling traits in various living organisms, including crop plants, bacteria, fungi, and animals. Some microorganisms' employment has occurred in manufacturing enzymes for food processing, and the technology usage has been extensive to increase herbicide and insect resistance. Improving food production and availability may take the aid of recombinant deoxyribonucleic acid (DNA), genetic modification (GM), genetic engineering (GE), and biotechnology (by enhancing the nutritional content of specific foods). GM foods are derivatives of organisms with altered DNA resulting from human intervention, such as, introducing a foreign gene (Sharma *et al.,* 2022). Most genetically modified foods come from plants, but soon, we may expect to see GM microbes and animals.

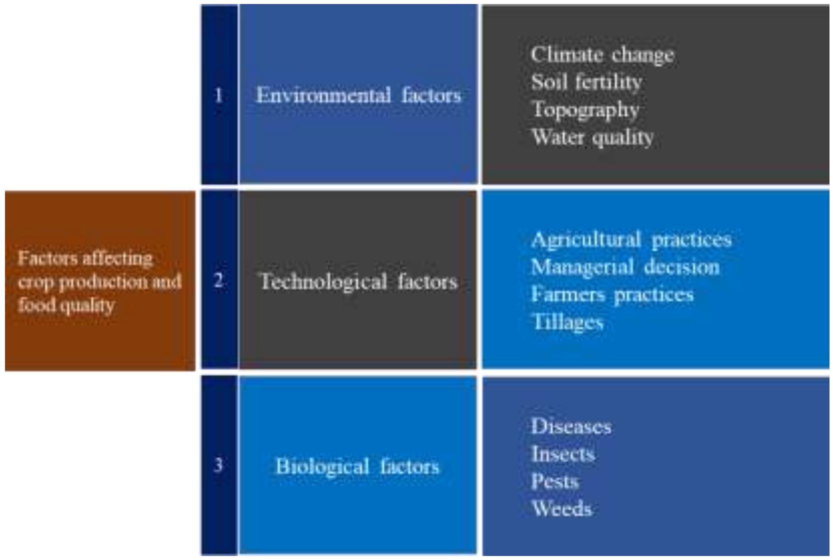

Figure 1. Factors that affect crop yield and food quality.

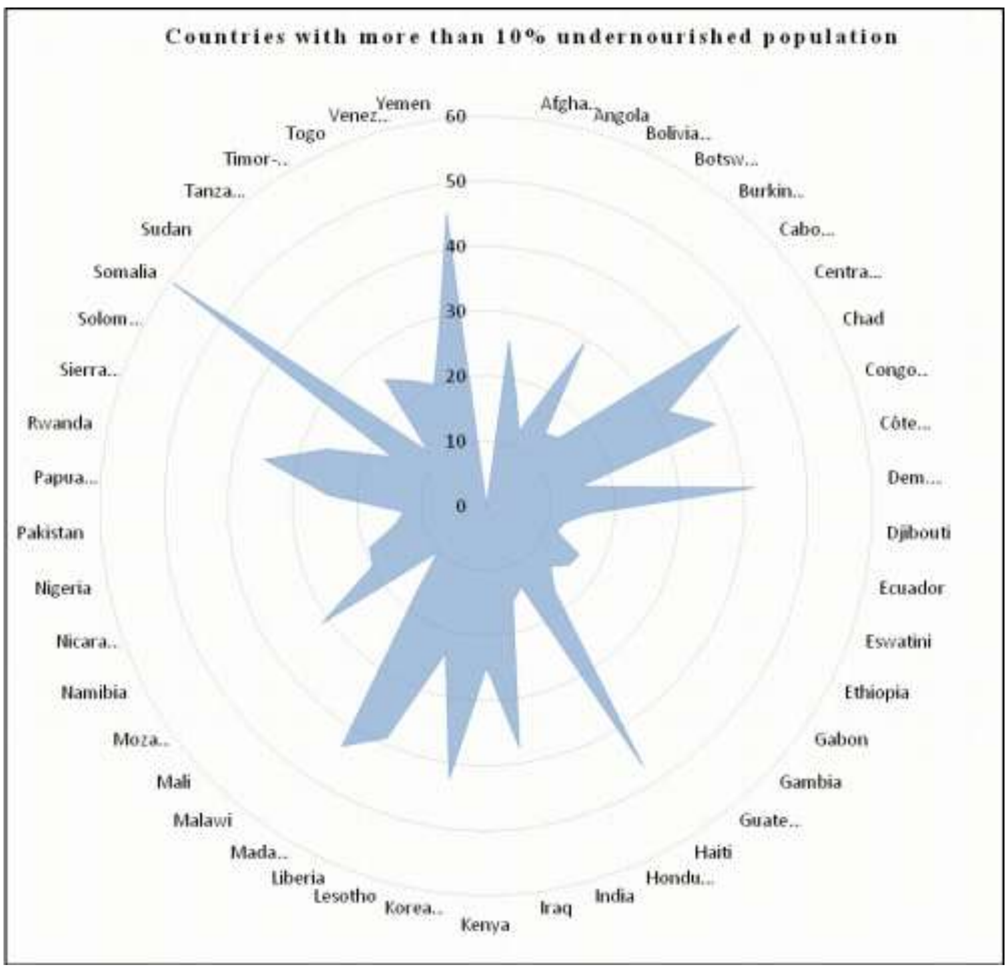

Figure 2. Countries with more than 10% undernourished population from 2018 to 2020.

Enzymes are protein molecules that speed up crucial metabolic processes and are available in all organisms that can digest their food. Every day, humans eat them as whole and processed meals. There is evidence that enzymes' inadvertent utilization in food production and processing has existed for thousands of years, most notably in forming dough (Paul and Joshi, 2022). During the development of enzymes, materials largely came from plant and animal sources, making them prohibitively costly for food processors. Commercial synthesis of enzymes utilizes microorganisms like bacteria and fungi adapting to a cultivar or processing conditions. One prominent use of genetically modified microorganisms (GMMs) is the manufacture of calf chymosin for use in cheese manufacturing. Today's most engineered GM crops resist blight and herbicides for enhanced yields (Garland and Curry, 2022).

The increased yields and consistency in genetically modified crops might contribute to lower food costs. In the future, altering the food's nutritious content, allergenic potential, and the food production systems' efficiency may occur with genetic engineering. Combating malnutrition among those living with a limited budget, for instance, researchers in underdeveloped countries attempt to improve the nutritional value of staple foods like bananas, rice, cassava, and sweet potatoes. The genetically modified foods in the global market are safe via rigorous scientific analysis. By developing GM foods, some key safety measures come to mind. Controversies and misinformation capture the fields of GE, biotechnology, and allied disciplines. The information in this article has an assemblage of credible and authoritative sources to provide a concise overview of the theme at hand.

Biotechnology

Biotechnology, GE, and GMOs are the terms used to describe the application of genetic modification methods and technologies for developing and improving the production of foods and their ingredients. Biotechnology categorizes any technological procedure employing biological systems, living organisms, and components to create commodities. A school of thought holds that biotechnology and GE are bad for wildlife, humans, and the planet. Some also worry about the long-term effects of GMOs on human daily life and the environment's safety; others argue that the benefits outweigh the risks, particularly on food safety, farmer income, the health of the planet, and sustainability in food supply.

With its positive responses, the crop production trend has increased through bioengineering (Figure 3). Furthermore, the National Academies of Sciences, Engineering, and Medicine have run evaluations on this issue for decades, and two new analyses have also been published in the last few years (NASEM, 2016). This fact sheet's creation offered a high-level overview of biotechnology and genetic engineering relating to the food chain, using information from reliable and fact-based sources. Saving lives via nutritional augmentation of foods, biotechnology, and genetic modification methods are means to fulfill the world's rising food supply needs more efficiently, inexpensively, and environmentally safe (FDA, 2016).

History

Biology and GE around the time that people started seed storage for later use in conventional selective breeding (around 10,000 years ago), they also started experimenting with GM (Table 1). However, modifying genes has given way to more sophisticated molecular and cellular techniques (IFT, 2000). According to academies, voicing biosafety concerns after the first publication of rDNA technology in the 1970s rose, prompting the National Institutes of Health to create biosafety principles for safe research techniques and standards.

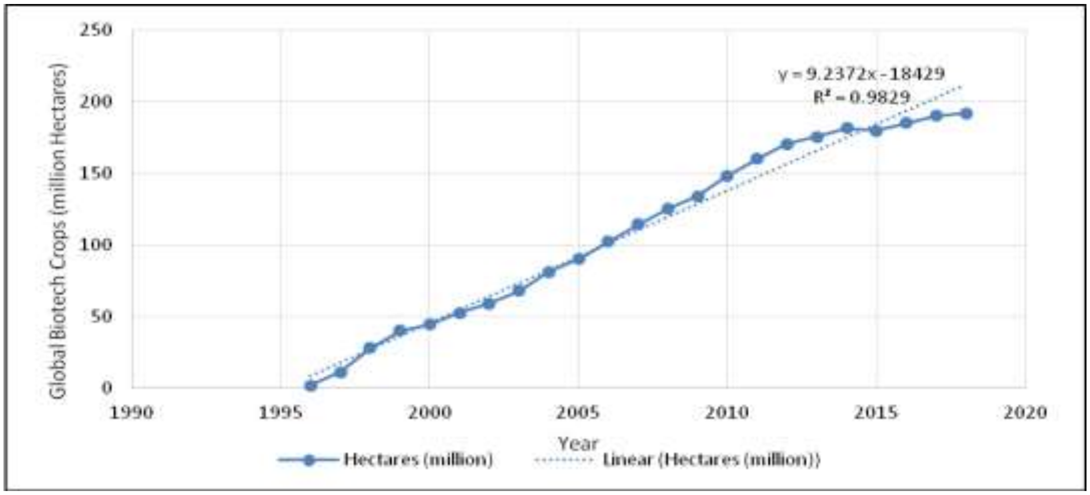

Figure 3. Global biotechnological crops in million hectares from 1990 to 2018.

Table 1. The developments in genetic engineering from 1866 to 2020.

No.	Scientist/organization	Year	Crop used	Description
1	Gregor Mendel	1866	Peas	Identified the basic procedure of genetics and bred two kinds of peas
2	-	1922	Corn	Hybrid corn is developed and commercially sold
3	-	1940	-	Starting of random mutations in an organism's genome using radiation or chemicals
4	James Watson, Rosalind Franklin, Francis Crick	1953	-	Identified the DNA structure
5	Herbert Boyer and Stanley Cohen	1973	-	Using bacterial DNA insertion for genetic engineering
6	FDA	1982	-	Human insulin, a genetically engineered treatment for diabetes, has been approved by the FDA as the first GMO product for general consumption.
7	FDA, EPA, and USDA	1986	-	The federal government creates a coordinated biotechnology regulatory framework.
8	FDA	1992	-	GMO foods must meet the same safety criteria as regular foods.
9		1994	Tomato	The first GMO fruit made through genetic engineering goes on sale after federal studies verify it's safe.
10		1990s	Potatoes, summer squash, papayas, canola soybeans	First GMO products available to consumers
11	WHO and FAO	2003	-	International GMO safety guidelines and regulations
12		2005	Alfalfa and sugar beets	America-sold crops
13	FDA	2015	-	FDA permits first genetically modified animal for consumption, a salmon.
14	Congress	2016	-	Congress passes a law requiring labelling for some genetically altered goods, using the term "bioengineered."
15	-	2017:	Apples	U.S.-sold
	FDA	2019:		First meal from a genome-edited plant undergoes consultation
16	-	2020	Pineapple	U.S.-sold
17		2020	-	GalSafe pig application granted

Traditional selection and hybridization, existing for generations, are unequal with the use of genetic engineering in crop plants. Choosing organisms with a desired property and selecting and breeding the offspring with the highest frequency of traits is more typical of conventional breeding than rapid evolution. For developing disease-resistant tomatoes, the one logical strategy is to cultivate several plants but only save the seeds from the ones that show the highest resistance. After a few generations, a population will be far more robust than its progenitor. The traditional intraspecific cross-breeding, and among the closely related species, maintain DNA and gene sequences and result in desirable and undesirable characteristics. However, GE makes it possible to take out a single gene from one organism's genome and transfer it to another.

Crops and food developed by biotechnology

In 2016, the National Academies looked at the development of GE in crop plants and the history of legislation about various foods and their ingredients that have included these techniques. The rDNA methods pioneered in the 1970s ushered in the era of GE. Improvements in plant tissue culture and other related areas were also taken into account while developing plant-based applications. In the 1990s, the first plant commercially produced in the United States utilizing rDNA technology was a tomato with delayed softening and ripening features. Herbicide-tolerant soybean and canola, insect-resistant potato and maize, and virus-resistant squash were some rDNA-derived crops developed in the following years. In 1999, the enzyme chymosin, needed in the cheese-making process, showed manufacturing from a genetically engineered microbe, offering a non-animal and bacterial/fungal source (EOP, 2017). As a result of this development, these techniques might benefit in developing new enzymes of food-grade quality for use in food manufacturing and processing.

Future of biotechnological crops

The more recent development is the introduction of a seal on packaging to denote non-GMO foods, which also divided the business community over whether or not to support the widespread adoption and commercialization of genetic engineering advances in the food chain and the science behind these developments has stood up to extensive academic peer review and the rigors of the scientific method (FAO, 2020). However, misunderstandings often arose regarding the science behind the inventions that corporations might use. The number of nations using biotechnology rose from five in 1996 to 30 in 2015 (ISAAA, 2016) (With 19 developing and seven industrial countries planting "biotech" crops in 2016). In 2016, biotech crops' acceptance and sowing in 26 countries ensued (12 in the Americas, eight in Asia, four in Europe, and two in Africa). In 2016, the United States grew the most biotech crops of any country, accounting for 39% of the total. Following was Brazil at 27%, Argentina (13%), Canada (6%), India (6%), Paraguay (2%), Pakistan (2%), China (2%), South Africa (1%), and Uruguay at 1% (ISAAA, 2016). The same year, eight of the top 10 countries planting biotech crops were also among the world's least developed places. In addition, a report also stated that biotechnology-derived crops had increased the farmer's income, slowed biodiversity loss, kept some land from being plowed and farmed, reduced environmental impact, and contributed to the solution of various issues related to sustainability, climate change, poverty, and hunger (ISAAA, 2016).

Concept of small versus large-scale farming and monoculture

Genetic engineering with a scale-neutral nature can apply to small and large farms. However, mitigating the adverse effects of monoculture by extensive planting of one type of crop can develop a GE trait in numerous crop cultivars (Hines and Travis, 2016).

Scientific support for biotechnology

Biotechnology and genetic engineering claim to have solid scientific support. In a recent open letter, Nobel laureates emphasized their support for biotechnology innovation and condemned the concerted hostility to the sector. One such example is Golden Rice, a kind of rice that underwent genetic engineering to include beta-carotene that converts to vitamin A upon digestion in the body. Millions of people in Southeast Asia and Africa suffer from malnutrition, and this GM rice has come to symbolize the hope that GM crops might alleviate the problem. A letter signed by 123 Nobel laureates in fields as diverse as chemistry, economics, literature, medicine, peace, and physics argued that transgenic crops and foods are safe and even safer than those that might result from other modes of production (FAO, 2015; EOP, 2017). For humans and animals, no single example occurred when their ingestion was harmful. They have demonstrated time and time again to have positive impacts on biodiversity and the environment.

Genetic engineering

The cells are the building blocks of life, which hold DNA molecules that preserve the blueprints for our inherited traits. Genes are the instructions for how an organism should develop phenotypically, as well as how long it will live. Only 1% of the DNA sequence comprises genes, which also manage protein synthesis at specific times (Vogel and Marcotte, 2012). The GE refers to using synthetic means to directly modify the genetic material to alter the hereditary characteristics of a cell or the whole organism. The said procedure may involve the exchange of specific features or genes among the organisms of the same or other species. Other forms of genetic engineering include the targeted destruction of genes (known as gene silencing), the addition of whole new genes, and the intentional insertion of mutation. Choosing organisms with a desired property and then selecting and breeding the offspring with the maximum frequency of that trait is more typical of conventional breeding than of rapid evolution.

Genetic engineering role in crop production

Conventional plant breeding has focused primarily on increasing plant output in absolute terms rather than reducing the yield gap. Genetically engineered developments, such as, hybrid maize or semi-dwarf wheat and rice, have historically raised yields dramatically. However, in the current era, the average annual increase in harvest from breeding is only 1%–2% in commodity crops like maize, soybeans, and wheat. Future genetic engineering methods to increase plant productivity include enhancing nutrient-use efficiency, introducing nitrogen fixation, and engineering the primary metabolism, specifically by augmenting photosynthesis's efficiency (Kartina *et al*., 2021; Ismail *et al*., 2023).

Nutrient use efficiency

The ratio of a crop's final output to the amount of nutrients used (like those found in fertilizer) applied to grow the crop is known as the plant's nutrient utilization efficiency (NUE). NUE has several factors affecting it, such as, root system density, root cells' efficiency in absorbing nutrients, and nutrient delivery from the roots to the shoots. It will likely take multiple factor-specific genes to modify any of these components that boost productivity. Using genetic engineering to alter a root system's size and shape, for instance, will likely require programming of the numerous genes involved in the development, while increasing the roots' nutrient uptake efficiency may necessitate modifying the concentrations of membrane transporter-proteins.

Since growing concerns over the exhaustion of the world's mineable phosphate supply persist, how to best utilize the element has become central to enhancing plant science's understanding. However, there are high- and low-affinity phosphate transporters in plant roots, and genetic engineering could serve to modify them for better results (Ozyigit *et al.,* 2021) since phosphate sensing and uptake have intricate regulations tied to root growth (Scheible and Rojas-Triana, 2015). Strategies that use genetic engineering to improve plants' phosphorus-use efficiency are evolving as scientists learn more about the regulators of phosphate sensing, uptake, and response (Wang *et al.,* 2013). Enhancing phosphorus-use efficiency came up with a proposal to modify the phosphorus distribution within the plants, which would necessitate the manipulation of numerous genes (Salvi *et al.,* 2022). Finally, many have demonstrated that plant phosphate-use efficiency improvement can result in designing plants to produce phosphatase enzymes that can liberate phosphate from the soil's organic components (Wang *et al.,* 2009).

Nitrogen fixation

Nitrogen is a vital nutrient, and its deficiency frequently stunts plant growth and development. Atmospheric nitrogen transformation and fixation can occur with nitrogen-fixing bacteria, making it available in a form that could benefit living organisms. Leguminous crops like soybeans and common beans (*Phaseolus vulgaris*) are two prime examples that do not need nitrogen fertilizer and other organic amendments due to symbiotic connections developed with nitrogen-fixing bacteria (Otaiku *et al.,* 2022). Despite legumes' superior nitrogen-use efficiency compared with cereals, legumes grown with a supplementary nitrogen fertilizer to ensure constant yields are often economically advantageous because the fertilizer cost is usually not prohibitive (Kamanga *et al.,* 2010).

Biological nitrogen fixation favorably influences the environment since it does not require large amounts of natural gas and fossil fuel to produce nitrogen fertilizer. Two approaches assist plants in fixing sufficient nitrogen to maintain high yields. Optionally, introducing genes encoding all the nitrogen-fixing proteins could be applicable. The biological nitrogen fixation in crop plants requires the introduction with modification of several genes because the nitrogen fixation system is a bacterial metabolic pathway. Designing a sub-cellular compartment with low oxygen content is essential to maintain the nitrogen-fixing activity. Another approach is to enhance the plant-bacterial nitrogen-fixation relationship in legume species where it naturally exists and generate the genetic networks required for nitrogen-fixing symbiosis in plants that do not usually have this interaction.

These strategies were on the agenda at a Gates Foundation meeting in 2011 (Beatty and Good, 2011), resulting in the Gates Foundation funding fundamental research with the aim of engineering cereals' nitrogen fixation. The Gates Foundation has also supported both approaches for engineering the cereals with the ability to fix nitrogen. The first alters grains so that nodules like those seen in legumes and habitats for nitrogen-fixing bacteria can form (Rogers and Oldroyd, 2014). Synthetic engineering of nitrogenases tries to insert the necessary genes into plastids and mitochondria to fix atmospheric nitrogen. Synthetic biology will be a requirement to engineer the pathways affecting cell biology and plant metabolism to develop methods for engineering nitrogen fixation in cereals (Rogers and Oldroyd, 2014).

Photosynthetic efficiency

Another example of modifying metabolism to increase productivity is enhancing photosynthesis, which could accelerate plant development and increase grain yield (Bräutigam *et al.,* 2014). To a lesser extent, it is a fact that the enzyme that launches the process of fixing carbon dioxide into sugar (RuBisCo) can also react with oxygen in a side reaction that wastes energy, hindering photosynthesis. Exposure of RuBisCo to carbon dioxide and oxygen also determines the strength of the oxygen side reaction. Some

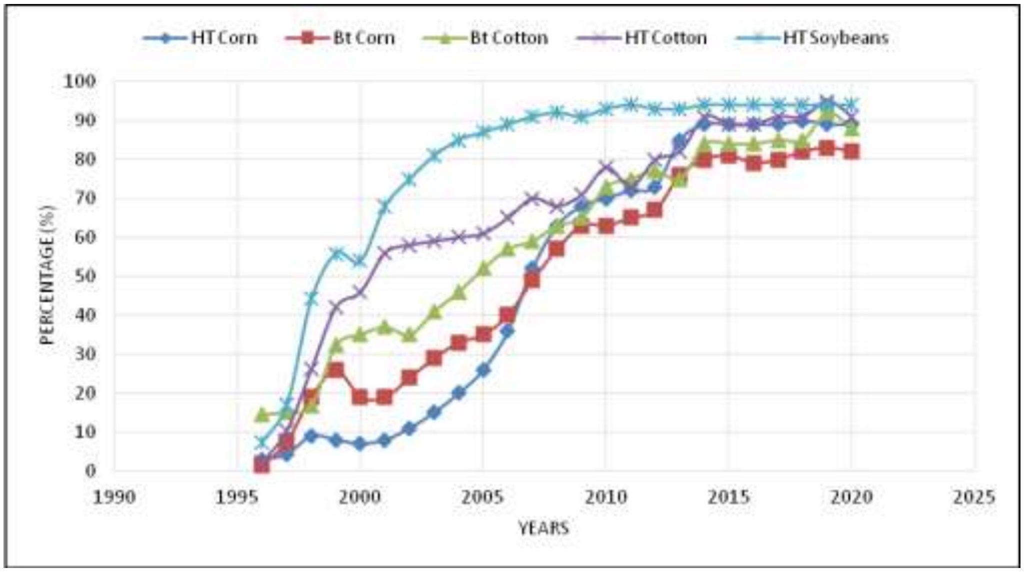

Figure 4. Adoption of genetically engineered crops in the USA from 1996-2020.

plants have developed the potential to restrict RuBisCo and carbon fixation to cells that sequester carbon dioxide via cycling four-carbon compounds like malate (this type of metabolism refers to C4). Corn has a C4 metabolism (Boyer, 1970), and incorporating C4 metabolism into crops like rice that do not have it could boost their yields (Whitney *et al.,* 2011). However, to engineer rice's carbon-fixation metabolism, numerous genes would need manipulation, including those that regulate leaf development and differentiation and those that encode the enzymes of C4 metabolism (Raines, 2006). The International Rice Research Institute (IRRI, Philippines) has begun a multiyear project to develop methods for successfully growing C4 rice.

Genetic engineering role in food quality

Vitamins, essential amino acids and fatty acids, minerals, and trace elements are just a few of at least 50 nutrients considerably necessary for human survival. Staple food crops are limited suppliers of some primary nutrients; therefore, current agriculture cannot adequately meet those needs, especially in underdeveloped nations. However, implementing genetic engineering in crop production can successfully fill this gap (Figure 4).

Selecting for increased crop yield and, in the case of fruits and vegetables, the improved flavor and ease of processing has become the norm in plant breeding. Unfortunately, in a few staple crops, the several phytonutrients that make up the vast majority of the food consumed by humans have been depleted throughout the roughly 10,000 years of cultivation (Robinson, 2013). Despite the caveat that one must account for differences in sampling methods, choosing cultivars for analysis, analytical methods, and the growing environment continued for a comprehensive examination of the compositional variations of nutrients of 43 garden crops from 1950 to 1999. Davis *et al.* (2004) suggested a loss of six nutrients (protein, calcium, phosphorus, iron, riboflavin, and ascorbic acid). However, germplasm collection no longer includes the genes for high phytonutrients; genetic engineering may be the sole viable option for reviving the phytonutrient levels.

Flavonoids, antioxidant phenomena

Among the most abundant plant pigment types, anthocyanins can be found in various fruits and flowers, giving them distinctive red and purple colors. Several possible health benefits have also interlinked with their antioxidant activity (Yousuf *et al.,* 2015). Flavonoid molecules (anthocyanidins) fused with sugar molecules and other chemical groups to produce anthocyanins. The anthocyanidins also serve as building blocks for the more complex condensed tannins. Since anthocyanins already exist in plants, traditional breeding can enhance their concentration in fruits and vegetative tissues if there is enough natural variation. To boost anthocyanin concentrations, introduce anthocyanins into fruits that often lack them, and design related flavonoids like flavonols in fruit tissues, breeders are turning to using genetic-engineering tools and the isolation of mutants (Dixon *et al.,* 2012).

Despite the presence of anthocyanin pigments in the vegetative tissues of tomato plants, the red color of tomato skin and flesh is primarily due to carotenoids. The fruit lacks the helpful anthocyanin antioxidants despite having modest amounts of flavonoids in the peel in chalcone glycosides (conjugated precursors of flavonols and anthocyanins). The presence of anthocyanins is unlikely to account for the purple coloring of the skin of some heirloom tomato types. Tomatoes containing anthocyanins only in their skin resulted from conventional breeding techniques. Genetic engineering creates purple tomatoes high in anthocyanin and have anthocyanin throughout the flesh.

Chymosin by genetic engineering

Chymosin causes milk to curdle and is an essential enzyme in producing cheese. Historically, chymosin extraction came from the digestive systems of young calves. With increased cheese production and a decrease in killing calves, it became difficult to source adequate raw material for the manufacturing of chymosin at stable costs, prompting the hunt for alternative clotting agents. Thanks to advances in biotechnology, chymosin manufacturing can now be in microbes, decreasing the need for calf stomachs. The extracted chymosin gene from calf cells undergo splicing into bacteria, fungi, and yeasts. Cultures of these genetically modified microorganisms (GMMs) have permission to manufacture chymosin under strict control. After being isolated and refined, the chymosin needs to curdle the milk for cheese making, a byproduct of the cheese-making process. Presently, 80% of all cheese made in the United States uses chymosin generated by GMM. By isolating and purifying chymosin, scientists can guarantee that contaminants, such as, GMM cell debris, have been removed (Velkov, 1996).

Generate seeds and chemical dependence

Corporate involvement significantly affects how quickly technology is developing on a larger scale. In 1980, the USA Supreme Court ruled that researchers could patent a genetically modified microbe that can digest oil spills. This ruling, which held that copyright and ownership over life itself are possible, provided a business incentive to produce GMOs for profit. Monsanto, the largest manufacturer of GMOs and a current Bayer subsidiary, has a long history as a chemical producer. Agent Orange, a very toxic defoliant employed in the Vietnam War, had this company producing it, among many others. After World War II, the business began manufacturing agricultural chemicals like Roundup, the most extensively used glyphosate herbicide, then began experimenting with genetically altering seeds to resist the chemical so that spraying the pesticides would not cause fear of crop destruction. Roundup Ready seed's first introduction came in 1996, and two years later, the company split its chemical business off to concentrate on biotechnology (Bravo, 2014). By the end of 2017, Monsanto had made USD 9.5 billion from the sale of genetically modified (GM) seeds of maize, soybeans, and cotton (Statista, 2018).

Clustered regularly interspaced short palindromic repeats (CRISPR)

Genetic engineering appears to have a bright future, and with the help of CRISPR technology, researchers can extract and essentially "cut and paste" precise DNA regions. As a result, the process is more accurate, effective, and economical, enabling many more scientists to conduct research using this method. Using site-specific nucleases (SSNs) is prevalent in genome editing because their engineering may bind and cleave a specific nucleic acid sequence, creating double-stranded breaks (DSBs). SSNs consist of four types: meganucleases, zinc-finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), and Cas proteins (Pickar and Gersbach, 2019). These SSNs offer enormous potential for plant breeding and enable multiple ways for modulating host genome structure and function, such as, gene knock-out, knock-in, stacking, targeted mutagenesis, and translation modulation. The SSNs also provide considerable economic benefits with reduced time compared with traditional plant breeding (Chen, 2019).

Notably, the CRISPR/Cas system has emerged as the foremost, game-changing SSN, and its efficacy for plant genome editing was reputable in 2013 (Nekrasov, 2013). However, its implementation in crop plants has grown faster than other new plant breeding technologies (NPBTs). CRISPR research has also introduced various influential agricultural traits, such as, heat, cold, and herbicide tolerance; viral, bacterial, and fungal resistance; and increased grain size and weight into a wide range of economically valuable crops, including rice (*Oryza sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum*), tobacco (*Nicotiana tabacum*), cotton (Gossypium spp.), soybean (*Glycine max*), and brassicas (Nekrasov, 2013).

Engineering of polyunsaturated fatty acids and vitamins

Golden Rice, modified to have high concentrations of provitamin A beta-carotene, and canola, modified to contain high concentrations of polyunsaturated fatty acids, are the two most well-known instances of increasing their nutritional values through GE. Plants naturally containing the nutrients in question and have a highly variable genetic pool concerning the trait can benefit from conventional breeding advancements to improve their nutritional composition (Goldman, 2014). However, when germplasm lacks the genes required to supply the feature, employing genetic engineering has created new cultivars. It has also been more challenging to engineer healthful polyunsaturated fatty acids (PUFAs) with profiles similar to those found in fish oils than provitamin A, which has often necessitated the introduction of multiple genes from different species. Up to 20% of the seed oil of GE *Camelina sativa* contains eicosapentaenoic acid and docosahexaenoic acid, respectively. Moreover, in trials giving salmon a diet containing no fish oil, oil from the GE plants proved to be an effective substitute (Detric, 2018).

Assessing measures

Given the social, legal, political, and cultural differences between countries and the controversies surrounding them, regulations also may vary widely. In the United States, a federal oversight exists to guarantee the safety of biotechnology products and the protection of health and the environment, as described in the 2017 revision of the U.S. Coordinated Framework for the Regulation of Biotechnology, initially established in 1986. Reviewing GE crops is more arduous than testing conventionally bred crops, and GE crops may undergo more scrutiny than conventional crops.

Comparing genetically modified products to their traditional food, appraising intended and unforeseen effects, and assessing impacts are all necessary steps in gauging food safety and environmental issues. Information on detecting new risks, the impact on nutritional and other composition, toxicity, and allergenicity are all part of a comprehensive risk assessment, including a safety assessment. The possibility of gene transfer to closely related species and other environmental impacts on non-target organisms are also under scrutiny.

Insect and weed resistance showed developing in some regions, necessitating integrated pest management measures to ensure the long-term viability of crops engineered for resistance to these pests. In addition, they discovered that gene flow from a GE crop to a wild-related plant species occurred, but this transfer did not lead to any unfavorable environmental effects.

Prospects

There are various perspectives to consider when evaluating genetically modified foods and not only health and environmental issues. Dr. Jorgen Schlundt, Director of WHO's Food Safety Department, has remarked, "We can avoid creating a genetic split between those nations which approve GM crops and those which do not if we encourage our Member States to do this on a national basis." Every nation has unique social and economic norms, and its citizens have developed their unique traditions and beliefs around food with its history. All these can impact people's perceptions of genetically modified (GM) foods, and addressing these issues will determine whether or not GM foods are ultimately acceptable or rejectable, along with any potential health benefits and risks associated with them. WHO collaborates with other UN agencies like the FAO and the United Nations Environment Programme (UNEP) to aid countries in thoroughly evaluating the potential impacts of introducing a new genetically modified food. By assisting nations in studying how they can manage and capitalize on the introduction of GM products for the benefit of their people, Dr. Schlundt argues, "We can hope to obtain the health and nutritional gains of GM foods."

CONCLUSIONS

Lack of technology and less awareness of modern technologies led the farming community to get blamed for declining productivity and deteriorating food quality. The methods and equipment of GE can be helpful in a crop cultivar to improve the yield and quality. Biotechnology, genetic modification, and GE and recombinant (r) deoxyribonucleic acid (DNA) may be exceptionally beneficial for significantly upgrading food production and supply. GE causes new modified genetic traits in animals, microorganisms, and crop plants, and then used to produce food. Most processed foods today come with genetically modified ingredients to repel chemicals killing insects and plants. Concerns about the safety of GMOs, the environmental issues of GMO products, and the increased but ineffective use of pesticides have all been in focus. However, many people's fears are unfounded concerning the widespread of GMOs. Consequently, this review can clarify the knowledge about GMOs among the general public.

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