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Review

Consumer Social and Psychological Factors Influencing the Use of Genetically Modified Foods—A Review

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Abstract: Due to rapid globalization in the world, the understanding of cultural differences, such as beliefs, values, ways of thinking, and perceptions about new technologies in food processing have also increased. Since the 1990s, when genetically modified (GM) foods were introduced into the food supply, they have provoked many debates. In this review, it was identified and discussed how social and psychological factors influence public attitudes to GM foods and the perceptions of consumers in using GM foods. According to this review, GM foods are deemed unnatural and artificial, thus affecting the overall acceptance of their application. Due to the concerns about their effects on the environment and human health, people expect an assessment of the known or possible dangers, as well as the preventative management of the risks. Providing adequate information about GM foods via a compulsory labeling policy may serve as an appropriate way to increase public awareness and acceptance of GM foods.

Keywords: genetically modified foods; public attitudes; motivation; perceptions; social trust; labeling

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1. Introduction

Food is perhaps the most crucial consumer commodity, as it is required for survival. Food aids in the constant renewal of our bodies and gives us the energy we need to live. Moreover, food can provide exquisite hedonistic pleasures and has strong cultural implications associated with refinement and fashion, particularly in developed countries and social networks [1]. In the 21st century, biotechnology has been used as an eco-techno-political technology. Many countries have devised technical ways to boost their output in various industries. Biotechnologists can use genetic engineering to insert genetic material

from completely other species into the genome of a plant or animal to produce specific features in genetically modified organisms (GMOs) [2,3]. The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) of the United Nations define GMOs as follows: "Organisms (i.e., plants, animals, or microbes), and products thereof, whose genetic material (DNA) has been altered in a way that does not occur normally through hybridization (mating) and/or natural recombination" [4]. Accordingly, foods made from GMOs are referred to as "GM foods" [5]. There are three basic issues that encourage humans to rely on GM foods, i.e., increase in population, decreasing available land for agriculture, and traditional breeding conflict.

Increase in population. The current world population is estimated to be at 7.35 billion people. In 2030, the global population is expected to reach 8.5 billion people, rising to 9.7 billion in 2050. One of the leading factors for undernourishment around the world is population growth. In 2020, it was projected that up to 811 million people went hungry, and hunger will not be eradicated by 2030 [6]. As a result, eliminating hunger should be a top priority for policymakers.

Decreasing available land for agriculture. According to the FAO, by 2050, the finite portion of arable land used for food production per person will decline from 0.242 ha to 0.18 ha. This issue combines the problems of the rise in population and subsequent food insecurity. However, it appears that our ability to cultivate new land is inadequate. The alternative is the higher yield per acre, which requires more agricultural inputs, such as fertilizer, water, and pesticides, as well as genetic enhancement. Several complicating factors contribute to this scenario: (1) increased demand for biofuel and feedstock production; (2) accelerated urban development; (3) land deforestation, salinization, and deterioration; (4) shifting land use from staple foods to pasture, due to socioeconomic factors; (5) climate change; and (6) water resource limitation. As a result, agricultural technology that may boost productivity, such as GMOs, is seen as a possible solution.

Traditional breeding conflict. Traditional breeding involves crossing one parental line with another in the expectation of exhibiting a desirable trait. Breeders choose the optimal offspring and backcross it to one of its parents in order to select the desired trait while removing irrelevant or unwanted features. The method generally takes a number of years before the actual expression of the needed characteristic can be verified and subsequently improved to commercially relevant levels through traditional breeding [7]. In addition to the naturally long generation times, the availability of genetic variation limits the growth of traditional breeding. An available gene pool displaying the desired qualities and sexual compatibility of organisms with those traits are prerequisites to breeding methods. In fact, genetic variability has been reduced in recent years (most likely because of prior efforts at optimization), so we now operate in a limited improvement space. Although modern approaches can expand this region by using chemicals or radiation to create additional mutational diversities, these are unsophisticated instruments that produce better features only by chance and a little bit of luck. Indeed, the non-selectivity of these approaches will almost certainly lengthen the breeding cycle [8]. Taking these facts into consideration, the development of biotechnology significantly reduces the time in producing new strains. It also provides us with alternative ways for achieving global food security through the production of GM foods. Plants and animals' genomes can now be modified to make them more tolerant to abiotic and biotic stresses, or to increase their production of different nutrients, enzymes, or vitamins.

Since GMOs play a significant role in addressing contemporary issues, particularly those pertaining to global food security, they have several other advantages, many producers are incorporating GMO systems into their productions, and many have spread throughout the worldwide market [9]. However, from the consumer's perspective, they are typically always interested in knowing about the food they are about to purchase and consume, including its origin, production process, and any additional components. Due to the fact that GMO products are still relatively new to the market, consumers may be more hesitant to purchase them as well. Furthermore, several studies have shown that many

Asian (i.e., Japan and Taiwan) and European consumers have difficulties embracing GM products [10]. This is due to consumer concerns about the unknown effects of GM foods on human health, as well as religious and ethical issues regarding the probable consumption of animal genes found in GM foods. With the high rate of rejection owing to these concerns, there has been a significant demand for labeling GM products in the EU and countries, such as Japan and Taiwan, since some of the consumers also still believe that GM products are a solution to global food safety issues and have many other advantages [10]. As a consequence, issues associated with consumer acceptability of GM products are gradually becoming a topic of global discussion, both in the industrial and academic sectors.

This review aims to delve further into the acceptability of GM foods on the worldwide market to better understand the social and psychological aspects that impact consumers' consumption of GM foods. As a result, it is anticipated that this study will aid government, decision-makers, and relevant companies in formulating the most effective approach to promote and entice consumers to place more faith in GMO products and be more eager to purchase them.

2. Genetically Modified Foods: An Overview

Humans began domesticating 10,000 years ago through selective breeding. Farmers and scientists began crossbreeding plants in the 1700s. Researchers develop more precise and controllable genetic engineering methods in the 1980s to make plants with desirable features. There has been a strong discussion regarding the applications of gene technology since the late 1980s when the first GMOs were developed for the manufacturing of medical items. GM foods were initially commercially sold in 1994 as a failed Flavr Savr delayed-ripening tomato, upgraded for increased flavor and longer shelf-life; unfortunately, the product quickly proved to be a financial disaster, due to high production costs.

In 1996, GM corn and soybean varieties were approved and were followed by sugar beet and papaya variants. These first-generation crops were designed specifically for farmers who needed higher yields, improved pest and disease resistance, and the ability to apply herbicides and insecticides (Figure 1) [11]. With advancements in biotechnology, crops with novel features, such as a longer shelf life, greater nutrient content, and drought resistance are now partially attributable [12,13]. One of the most significant developments is the ability to utilize genetic engineering to delete genes linked to allergies, such as the gene that creates allergenic protein in a certain crop. The introduction of genes into crops, such as rice and wheat, can improve their nutritional value, such as golden rice. Beta-carotene, a precursor of vitamin A, is abundant in golden rice [14,15]. Genetic changes can be utilized to create healthier foods by removing trans fats and caffeine, for example. For the betterment of society, the agricultural output must be increased to address poverty and food insecurity. Plants with desired features can be produced quickly and cheaply via genetic engineering [16]. The scheme to maximize the product's property usually includes when and where the transferred gene is expressed. In summation, GM crops, therefore, can be categorized based on their traits, i.e., genetic traits and commercial traits (Table 1) [17].

Based on the data maintained by the International Service for the Acquisition of Agri-biotech Applications [17], currently, there are at least 32 approved GM crops consisting of 24 crops intended for foods or consumable products (e.g., vegetable oils), while the others are non-food crops, such as alfalfa, cotton, and ornamental flowers. The total area used to cultivate GM crops in 2019 was approximately 190.4 million hectares, with the US as the largest GM crop producing country, followed by Brazil and Argentina (Table 2) [17]. Nowadays, GM ingredients are found in about 75% of processed foods manufactured in the United States (US) and India. Crackers, breakfast cereals, and cooking oils are among these foods [1,2]. Indeed, the introduction of GM crops has created new possibilities for enhancing agricultural production and feeding the world.

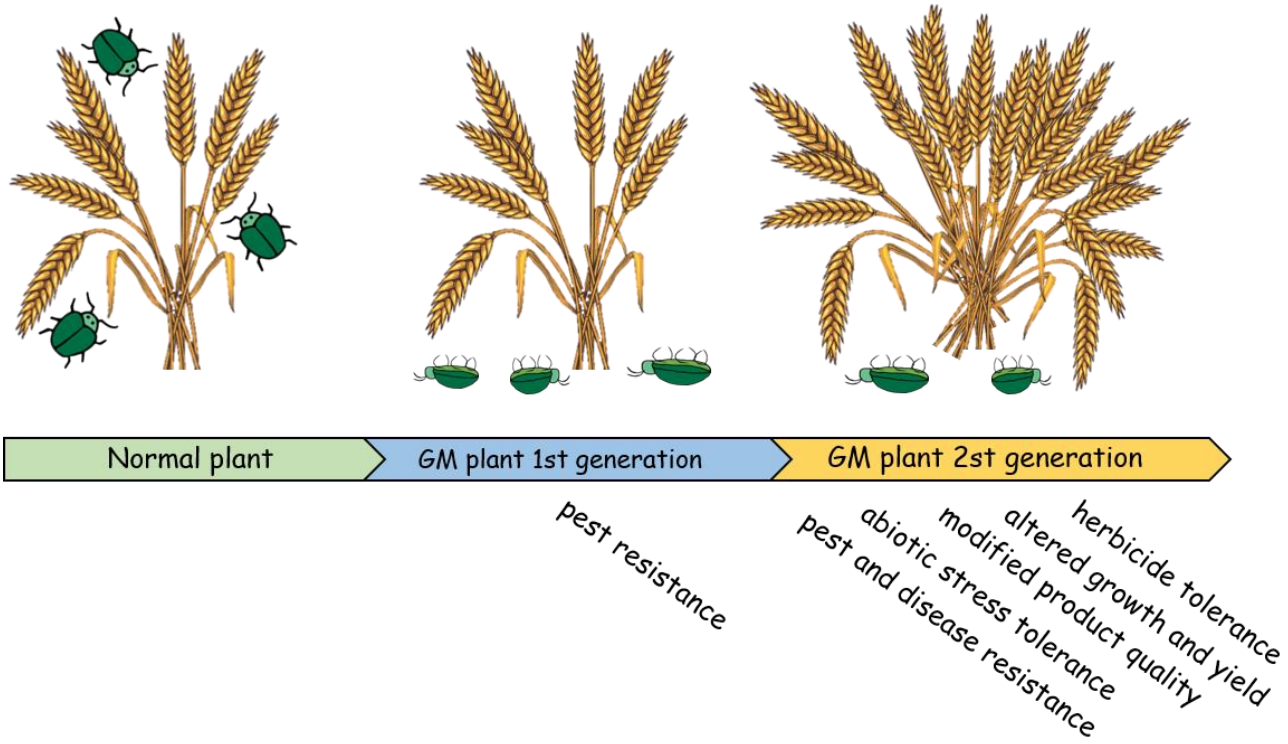

Figure 1. The main advantages of the GM plants of the first and second generations.

Table 1. List of genetically modified food-crops, based on their genetic and commercial traits (data are retrieved from [17]).

Crops	Genetic Traits	Commercial Traits
Apple	antibiotic resistance; non-browning	modified product quality
Argentine canola	antibiotic resistance; fertility restoration; herbicide tolerance (dicamba, glufosinate, glyphosate, imazamox, and oxynil); male sterility; modified oil/fatty acid; phytase reduction	herbicide tolerance; modified product quality; pollination control system
Bean	viral disease resistance	disease resistance
Chicory	antibiotic resistance; glufosinate herbicide resistance; male sterility	herbicide tolerance; pollination control system
Corn	antibiotic resistance; drought stress tolerance; enhanced photosynthesis/yield; fertility restoration; herbicide tolerance (2,4-D, dicamba, glufosinate, glyphosate, and sulfonylurea); increased ear biomass; insect resistance (coleopteran and lepidopteran); male sterility; mannose metabolism; modified alpha amylase; modified amino acid; phytase reduction	abiotic stress tolerance; altered growth/yield; herbicide tolerance; insect resistance; modified product quality; pollination control system
Cowpea	insect resistance (lepidopteran)	insect resistance
Eggplant	antibiotic resistance; insect resistance (lepidopteran)	insect resistance
Flax	antibiotic resistance; nopaline synthesis; sulfonylurea herbicide tolerance	herbicide tolerance
Melon	antibiotic resistance; delayed ripening	modified product quality
Papaya	antibiotic resistance; viral disease resistance	disease resistance
Pineapple	delayed ripening; modified fruit color	modified product quality
Plum	antibiotic resistance; viral disease resistance	disease resistance

Table 1. *Cont.*

Crops	Genetic Traits	Commercial Traits
Polish canola	herbicide resistance (glufosinate and glyphosate)	herbicide tolerance
Potato	antibiotic resistance; late blight disease resistance; glyphosate herbicide resistance; lowered free asparagine; lowered reducing sugars; modified starch; reduced black spots; viral disease resistance	disease resistance; herbicide tolerance; insect resistance; modified product quality
Rice	anti-allergy; antibiotic resistance; enhance provitamin A content; glufosinate herbicide resistance; insect resistance (lepidopteran)	herbicide tolerance; insect resistance; modified product quality
Safflower	antibiotic resistance; modified oil/fatty acid	modified product quality
Soybean	antibiotic resistance; drought stress tolerance; enhance photosynthesis/yield; herbicide tolerance (2,4-D, dicamba, glufosinate, glyphosate, isoxaflutole, mesotrione, and sulfonylurea); insect resistance (lepidopteran); modified oil/fatty acid	abiotic stress tolerance; altered growth/yield; herbicide tolerance; insect resistance; modified product quality
Squash	antibiotic resistance; viral disease resistance	disease resistance
Sugar beet	antibiotic resistance; herbicide resistance (glufosinate and glyphosate)	herbicide tolerance
Sugarcane	antibiotic resistance; drought stress tolerance; insect resistance (lepidopteran)	abiotic stress tolerance; insect resistance
Sweet pepper	viral disease resistance	disease resistance
Tobacco	antibiotic resistance; nicotine reduction; oxynil herbicide tolerance	herbicide tolerance; modified product quality
Tomato	antibiotic resistance; delayed fruit softening; delayed ripening; insect resistance (lepidopteran); viral disease resistance	disease resistance; insect resistance; modified product quality
Wheat	glyphosate herbicide resistance	herbicide tolerance

Table 2. Area used for the cultivation of genetically modified crops worldwide in 2019 (data are retrieved from [17]).

Country	Crops	Cultivation Area (Million Hectares)
USA	alfalfa *, apple, Argentine canola, chicory, corn, cotton *, creeping bentgrass *, flax, melon, papaya, petunia *, pineapple, plum, potato, rice, rose, soybean, squash, sugar beet, sugarcane, tobacco, tomato, wheat	71.5
Brazil	bean, cotton*, corn, eucalyptus *, soybean, sugarcane	52.8
Argentina	alfalfa *, corn, cotton *, potato, soybean	24
Canada	alfalfa *, apple, Argentine canola, corn, cotton*, flax, papaya, pineapple, Polish canola, potato, rice, soybean, squash, sugar beet, sugarcane, tomato	12.5
India	cotton *, soybean	11.9
Paraguay	corn, cotton *, soybean	4.1
China	Argentine canola, corn, cotton *, papaya, petunia *, poplar *, rice, soybean, sugar beet, sweet pepper, tomato	3.2
South Africa	Argentine canola, corn, cotton *, rice, soybean	2.7
Pakistan	corn, cotton *	2.5
Bolivia	Soybean	1.4

Table 2. *Cont.*

Country	Crops	Cultivation Area (Million Hectares)
Uruguay	corn, soybean	1.2
Philippines	alfalfa *, Argentine canola, carnation *, corn, cotton *, eggplant, potato, rice, soybean, sugar beet	0.9
Australia	alfalfa *, Argentine canola, carnation *, corn, cotton *, potato, rice, rose, safflower, soybean, sugar beet, wheat	0.6
Myanmar	cotton *	0.3
Sudan	cotton *	0.2
Mexico	alfalfa *, Argentine canola, corn, cotton *, potato, rice, soybean, sugar beet, tomato	0.2
Spain	n.a.	0.1
Colombia	carnation *, corn, cotton *, flax, rice, rose, soybean, sugar beet, wheat	0.1
Vietnam	corn, soybean	0.1
Honduras	corn, rice	<0.1
Chile	canola, corn, soybean	<0.1
Malawi	n.a.	<0.1
Portugal	n.a.	<0.1
Indonesia	corn, potato, soybean, sugarcane	<0.1
Bangladesh	Eggplant	<0.1
Nigeria	corn, cotton *, cowpea, soybean	<0.1
Eswatini	cotton *	<0.1
Ethiopia	cotton *	<0.1
Costa Rica	corn, cotton *, soybean	<0.1
	Total	c.a. 190.4

* = non-food crops.

3. Methodology

The systematic review was conducted according to recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [18,19]. The review covered scientific articles on consumer social and psychological factors affecting the use of genetically modified foods. Keywords were chosen in order to search articles in the following reputable and authoritative research databases, including Science Direct, Springer, Web of Science, PubMed, and Taylor and Francis. In addition, we also seek articles in a common platform, such as ResearchGate and Google Scholar. The appropriate literature was found using quotation marks and Boolean moderators (i.e., "AND" and "OR"). In each database, the following keywords were used "consumer social factors" OR "consumer psychological factors" OR "consumer behaviour" AND "genetically modified foods." The initial selection of the articles was based on criteria, as follows: (1) articles published after they were peer-reviewed; (2) articles reporting on consumer behavior towards GM foods; and (3) articles written consistently in English. We then looked through the reference list of the selected articles in case there were missing and potentially relevant articles during the establishment of the dataset.

In the beginning, there were 913 articles identified through database searching. Duplicate articles were omitted. The articles were initially screened by reading the titles and abstracts, and articles that were not in agreement with the topic to be studied were excluded, such as articles that did not discuss consumer behaviour towards GM foods. Then, the resulting 85 eligible articles were carefully read and further screened by considering the

inclusion criteria. The criteria for inclusion were the article exclusively reported consumer social and/or psychological factors influencing the use of GM foods. In the end, 47 articles were selected. The diagram flow of the article selection can be seen in Figure 2.

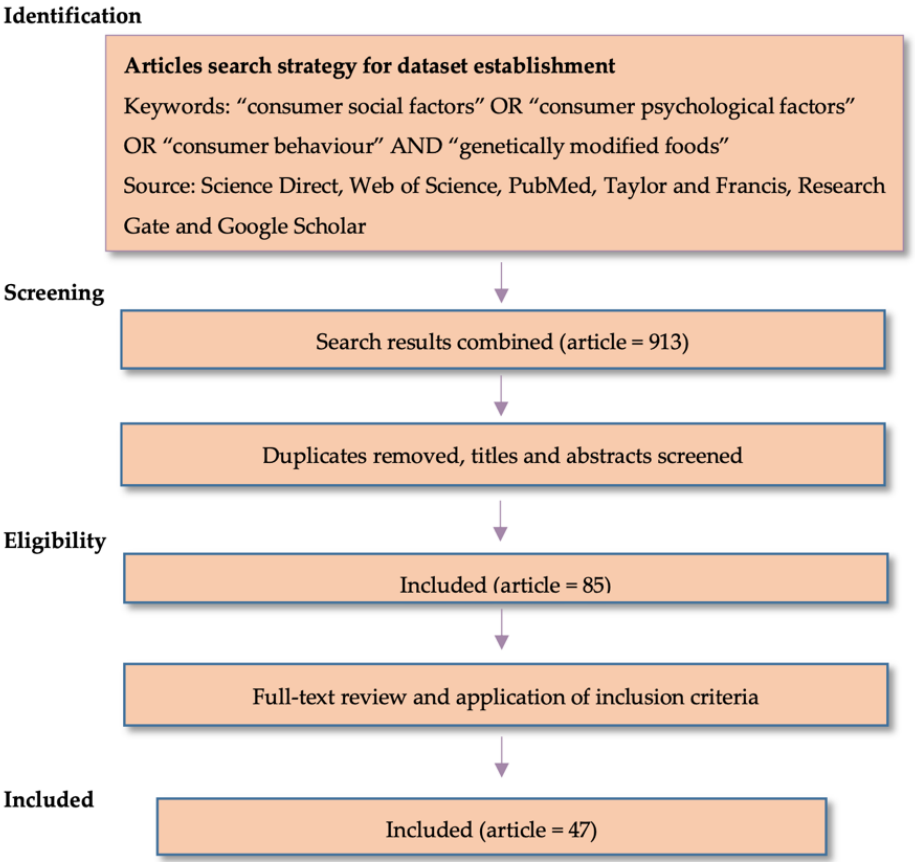

Figure 2. Diagram flow of the article selection.

4. Consumer Social Factors for Genetically Modified Foods

In addition to enhancing food production, technological advancements have also aided in boosting the nutritional value of food and accommodating consumer preferences for variety [20]. Moreover, since genetic modifications have such a significant impact on food production, it is vital for food companies, policymakers, and regulators to understand how the public reacts to this technology, particularly in developing nations where demand is strong. Therefore, the worldwide acceptability of genetically modified (GM) foods is still paradoxical since many are seen as unnatural and artificial, based on public behaviour, beliefs, perspectives, as well as attitudes. As a result, a more detailed analysis of consumer social factors for genetically modified foods is required, such as public risk perceptions of, attitudes to, and acceptance of GM foods, as well as public demand for information on GM foods.

4.1. Public Risk Perception of Genetically Modified Foods

There is a lot of debate concerning GM foods all across the globe, including whether they are safe to consume and if they should be labeled individually for their products [21,22]. As a consequence, consumers will not feel comfortable consuming foods with negative features, especially in democratic societies where consumers have a variety of food options to choose from [23,24]. Therefore, it is inevitable that the public's perception of the risk associated with GM foods would affect consumers' attitudes and behaviours toward food choices [15].

In addition, there are other factors that contribute to the public's perception of the risk posed by GM foods, such as the ideas that production procedures or agricultural practices may have a detrimental environmental impact, as well as thoughts that there is ambiguity about unexpected animal or human health impacts. Ethical problems are also significant (for example, whether a technology constitutes "tampering with nature" or whether unintended consequences are unforeseeable and so unknown to science). Some technologies are referred to as "transformative" because they have the potential to change the way society is organized [25]. Concerns regarding the impact of technology on societal and social structures and relationships may drive societal responses to the deployment of technology advancements. As a result, much work has gone into gaining a better understanding of people's opinions regarding new biosciences. Hence, understanding public views about GM foods have received special attention [25], and there are research reports stating that GMO methods are safe and provide no cause for concern, even safer than conventional agricultural methods. Despite the fact that the public perception of GM foods in the global community is still unfavourable, people increasingly realize that GM products are also advantageous.

4.2. Public Internal Structure of Attitudes to Genetically Modified Foods

Consumer attitudes will substantially influence the long-term function of genetic alteration and its uses in society. This is especially true in the agro-food sector, where consumer opposition to genetically modified foods has already affected commercialization. Numerous studies explore why so many people have unfavorable attitudes regarding GM products and comprehend the fundamental concerns of consumers; thus, a regulatory framework that satisfies consumer demands should be implemented [15]. In research, surveys give a limited grasp of the community's concerns and perspectives. However, qualitative research gives a far deeper understanding of the issues and views of individuals. One issue with qualitative, in-depth research, such as the ones described above, is that they are frequently based on tiny samples, which can restrict their generalizability. Moreover, some large-scale studies have attempted to quantify the relative impact of the perceived risk, perceived usefulness/benefit, and moral acceptability of GM foods on people's overall acceptance of the technology [26].

Furthermore, the general public's opinion about the rejection and acceptance of GM food is also linked to numerous aspects, such as GM food products in the first and second generations [5]. In the first generation of genetically modified organisms, researchers extract genes from plant species and transfer them to agricultural plants to build resistance to insect pests. Regarding second-generation GM foods, researchers are using current genetic engineering in food production, for instance, to increase the protein content, extend the shelf life, or change the taste. From the application of GM technology, user satisfaction and general moral acceptance of its application determine the guidance and assistance of society in both generations of GM food. In the model, moral acceptability was slightly stronger, and the impact of the perceived risk was relatively low, whereas other factors were held constant [5].

Additionally, the degree of interconnection among consumers' perceptions of dangers and benefits associated with GM foods was explored in a survey involving representative samples of German, Danish, UK, and Italian consumers [15]. The co-variation between all of these impressions should be low if consumers rated these risks and rewards independently before forming an overall assessment. Moreover, if people rated the dangers and rewards, based on their prior beliefs regarding gene technology, there should be a lot of overlap. Indeed, familiar perceived-risk dimension and a similar underlying perceived-benefit dimension could statistically accurately reflect the dangers and benefits. The actual structure of the attitude of consumers toward GM foods was discovered to suggest that people form attitudes toward the risk level and usability of the technology first and then infer how risky or helpful they find a specific consequence related to a specific implementation of the technology from these attitudes [15].

4.3. Public Acceptance of Applications of Genetically Modified Foods

Consumer opinions about genetically modified foods are diverse and intertwined with the consumer's understanding of science, lifestyle, and public perception [27]. Moreover, many scientists and business people believe that if a particularly appealing benefit can be produced in GM foods, thus, societal acceptance will follow as well. Problematically, how the public understands risk and benefit may differ significantly from how professionals characterize the same concerns. Furthermore, when it comes to thoughts and attitudes, the public is not uniform [27]. Varied countries and cultures have different views of risk and profit associated with hazards, as do persons within countries, and members at different times and in different scenarios. In the domain of "preventative nutrition treatment", where innovative foods with potential health benefits will be produced and commercialized, the food industry would need to determine what kinds of GM food will be acceptable and useful to customers. Failure to do so is likely to jeopardize the commercialization of certain items, especially because consumer judgments about what comprises a benefit are willing to leave to market judgments [27].

People, for example, do not always eat nutritious foods, despite significant efforts to produce health education campaigns [28]. As a result, there is no reason why consumers will automatically accept innovative meals with health benefits, regardless of whether or not the technological approach employed to manufacture them is questionable. Barriers to making healthy eating decisions are associated with demographic characteristics to some extent. Wealthier, more educated women, for example, are usually more health conscientious, and hence may be more encouraged to process complex nutrition and health messages [28]. Food sensory qualities are expected to be as significant as functioning or health-related considerations in evaluating whether customers appreciate novel meals developed by genetic manipulation, with preferences for certain sensory properties being subject to inter-individual variation once again. As a result, providing benefits for consumers associated with specific meals is unlikely to result in the widespread adoption of GM foods; rather, some customers will be enthusiastic about certain items, while others will prefer other food options. Of course, in this case, food choice presupposes the development and implementation of efficient labeling measures [28].

In conclusion, several innovations have experienced challenges and impediments throughout history before gaining social acceptance. In addition, there is a constant gap between expert understanding and public perception of scientific topics. In general, the results of the natural sciences represent the truth, however cultures and attitudes may differ due to the impact of religion and/or political parties. Thus, divergent views on GMO, GMO technology, and GMO food must be recognized. Government leadership is required to develop a transparent framework for assessing this technology for commercial usage, while protecting the public's ability to vote via the labeling of GM foods. This will empower the people to make their own decisions on genetically modified foods. With the government's implementation of a GMO-related policy, it is intended that the public would become more aware of and knowledgeable about GM products. Many nations, such as nations in the European Union, Australia, Brazil, China, Japan, and Russia, have established measures to label GM goods and offer customers with greater knowledge of the significance and advantages of GM products; thus, many nations have begun to embrace GM products and are ready to purchase and consume them [21].

4.4. Public Demand for Information about Genetically Modified Foods

A module on consumer perceptions toward policy concerns involving GM foods was included by the European Commission. Consumers were asked whether they agreed that GM crops "should only be tried to introduce if it is proven scientifically that they are harmless" in one of the questions (on a three-point scale with feedback categories ranging from "inclined to disagree" over "don't know" to "inclined to agree"). The result shows that 86% of the almost 16,000 European customers who took part in the survey agreed. When questioned whether they desired to "learn more about this type of cuisine before

eating it," 86% said yes [29]. When questioned if they desired "the right to choose," >95% of those polled, said yes.

Furthermore, labeling is the main source of information about a food product for many consumers. This suggests that most European customers would want to have information on GM foods available and that a vast number wants to be able to make an informed decision, mandating GM foods labeling. Furthermore, before a GM food is approved for commercialization in the European community, people expect an assessment of known or possible dangers, as well as preventative management of these risks [29]. In essence, consumers are apprehensive and have a strong demand for GM product labeling because they want more information to guarantee that GM products are safe to consume.

5. Consumer Psychological Factors for Genetically Modified Foods

The introduction of genetically modified organisms (GMOs) has sparked much debate in many nations, which has had an effect on the public acceptability of diverse GM foods worldwide. Hence, the GM foods development has been a matter of huge interest and worldwide public controversy. As a consequence, the development of this new technology has caused several issues in the food business and among consumers, including the emergence of a feeling of uncertainty and risks. However, understanding the benefits and side effects is less for these potential food industry innovations [30].

The perception and behaviour of the public toward trending technologies are considered an important factor for the determination of consumer encouragement for emerging technologies in the future. It is found from various studies that consumers show positive behaviours for using gene technology in the medical field [31], rather than in food production [32]. It is found from studies that although outcomes of technical risk assessments are more bothering for the public, they are also worried about the uncertainty to these outcomes. Development in technology also increases the fear of unnaturalness if a delay occurs in possible harmful effects. Furthermore, most people do not have much knowledge of gene technology; this lack of knowledge increases the risk perception and decreases acceptance [33]. Prior research has shown that consumer opinions toward organic foods are highly favorable, whereas sentiments against genetically modified foods (GMF) are extremely unfavorable. The diversity of consumer attitudes towards genetically modified foods around the world is also influenced by several factors, such as consumer perceptions, knowledge, social trust, health expectations and naturalness, and also consumers' perspectives toward genetically modified food labeling.

5.1. Perception Factors for Consuming Genetically Modified Foods

Consumers are typically curious about the food they eat, including its source, processing method, and substances that may be added to the food product [34]. As a result, as new concepts arise in food production systems, consumers may become more apprehensive about purchasing newly developed foods, such as GM products. Furthermore, consumer perceptions of the risks of eating GM products have a crucial role in the psychological reaction to GM products [35]. This is due to the fact that consumer knowledge about GM goods, social beliefs, health expectations, and the naturalness of GM foods, as well as inadequate labeling, may shape and affect consumer perceptions of GM products [36–38]. Consumers that are more concerned about the negative effects show a negative attitude, whereas consumers who have high levels of information exhibit a positive attitude toward GM foods. Thus, information provided to consumers may influence the attitude of consumers toward GM foods [39,40].

Risk and safety, which is associated with GM foods, must be tested scientifically on a large scale. Despite this, several GM foods are available for consumers currently in supermarkets around the globe. As GM foods are available extensively, all necessary information for these foods should be readily available to consumers. It is found from the published research that consumers from the EU and US have more positive views for non-GM food products [41]. Furthermore, it is said that all foods must have proper labelling,

thus products which have GMOs or products that are derived from GMOs are able to be traced at any production stage and market chain [42]. The compulsory labelling of GM foods in the US is found to lower the level of consumer opposition [43]. In short, labelling has a significant influence in establishing the public perceptions of new products, such as GM products. Labelling may aid consumers in gaining additional information about newly introduced products on the market. Through labelling, consumers may also discern whether a product is safe for consumption, which influences their purchasing decisions.

5.1.1. Consumers' Knowledge toward Genetically Modified Foods

Consumers' knowledge of GM foods plays an important role in acceptance [20,44]. In general, the knowledge of consumers about GM technology is very limited. Furthermore, most consumers have very little knowledge about gene technology in food processing. A lack of information and controversies causes risks in the consumption of GM foods [45]. Good knowledge can reduce the uncertainties regarding the production of GM foods and can help consumers to make purchase decisions by being fully informed [46,47]. It influences the information of consumers which eventually urges them to buy GM foods. Similarly, consumers with a positive attitude toward GM food have high purchase intentions [48].

Knowledge is either subjective knowledge, which is the perception of people and how much knowledge they have, or objective knowledge, which is what people know. It is found from studies that subjective knowledge is obviously linked with general attitudes [20]. In general, the knowledge of consumers for GM foods is relatively low, according to survey studies. It was found by conducting a survey by the Food Policy Institute that information to US consumers about GM foods was only fair, about 48% have knowledge that in supermarkets, GM foods are available, whereas only 31% believe that they have consumed GM foods [9].

In the US, about 43% of consumers know that supermarkets are selling GM foods, 54% have less or no knowledge about GM foods, and 25% have never heard about GM foods [49]. In Latvia, 50% of consumers believe that foreign genes are not present in normal tomatoes but are present in GM tomatoes, 62% believe that GM food genes can be transmitted to human's generative cells and to future generations. Additionally, 40.9% of Latvian consumers believe that by eating GM tomatoes, a person's genes can be changed, and 95.5% know that both non-GM foods and GM foods can cause allergy and toxicity [50]. In Turkey, 32.4%of nursing students were able to identify cotton, soy, and corn as widely cultivated GM crops, whereas 58.4% identified zucchini, tomatoes, and peppers wrongly as widely cultivated GM crops, 77% Turkish students think that production of GM foods causes risks for all living things [51]. In Poland, 64.1% of students believe that GM foods' media reports are not trustworthy; 81.4% either have very less knowledge about GM foods or do not know at all, whereas 16.8% have much knowledge about GM foods [52]. About 28% Italians and 33.3% Japanese know very little about GM foods on average. US, Italian and Japanese consumers rate GM free as the 17th, 5th, and 7th most important character [53] (Table 3).

Moreover, after the COVID-19 pandemic, there has been an upsurge in the number of persons who are malnourished [54]. In addition, the economic situation has not yet completely recovered, which, along with the negative political situation between nations, has led to inflation in many nations and an increase in the price of basic foodstuffs [54]. Moreover, since the economic situation has not changed, it has become difficult for consumers to buy essential food products. Consequently, these economic, social, and psychological factors drive consumers to shift to more affordable food products. In contrast, GMO food items are the best choice for consumers in the aftermath of the COVID-19 pandemic and the economic crisis, since they are less expensive [55]. Of the response to the rise in GMO products on the market, the U.S. government has begun importing GMO technology from other nations, in order to combat food insecurity and boost consumer demand [56].

Table 3. Consumers' knowledge of genetically modified foods.

Population	Sample Size	Main Findings	Reference
South Korean	N = 1000	South Korean consumers may be helped to prevent food safety issues through the dissemination of valuable information.	[20]
		Consumers who have had more negative information exposed are more inclined to overestimate their actual knowledge.	
		The group with the lowest perceived risks among consumers was the one that underestimated its factual knowledge. In contrast, consumers who overestimated their knowledge had the greatest perceived risks.	
		Higher levels of education, income, and food involvement, as well as more exposure to negative information regarding genetically modified foods, prompted consumers to overestimate their real level of knowledge.	
		Less-educated and higher-income consumers were more inclined to overestimate their knowledge.	
Chinese consumers (Shandong Province)	N = 573	Higher risk perception among consumers will result in a reduced buying intent, although the perceived benefit has a negative correlation with the desire to buy.	[39]
		People who perceive higher risks and benefits associated with GM foods have a greater desire for knowledge and a propensity to absorb information in a systematic manner.	
		Systematic processing is a good indicator of intentions to look for information.	
		People's judgments about the purchase of genetically modified foods may depend on their professional knowledge and information, and the majority of them may lack the ability to digest such information in a systematic manner.	
		Most people depend on government decisions to choose whether or not to buy GM foods.	
Chinese consumers (Anhui province)	N = 504	The majority of consumers base their choice to purchase GM foods on their level of information, whereas those with less knowledge and experience may rely on expert or government advice.	[57]
		Urgent action is required to give consumers better and more intelligible information on genetically modified foods and to avoid the spread of negative, biased information in the mass media, since the majority of consumers have received undesirable information about GM foods.	
		The government plays a significant role in the acceptability of genetically modified foods because consumers think they can always rely on the information they supply.	
		Consumers favour GM technology because they feel it may minimize pesticides and boost the growth of the society.	
Brazilian consumers (Limeira, São Paulo)	224	Price and quality are highly connected and are crucial considerations when purchasing GM foods.	[47]
		Consumers' lack of information regarding genetically modified foods may lead them to purchase depending on the advice of experts.	

Table 3. *Cont.*

Population	Sample Size	Main Findings	Reference
US and Chinese consumers	US = 1340 Chinese = 1065	Following the COVID-19 pandemic, the prevalence of malnutrition has risen.	[54]
		Consumers shift their food purchasing habits and switch to GMO products as they are cheaper and because the government does not support their economic choices.	
		To combat food insecurity and enhance consumer demand, the US government has begun importing GMO technology from several nations.	
US consumers	N = 1148	Forty-three percent have knowledge of GM foods sold in supermarkets.	[49]
		Twenty-six percent believe that they have probably eaten a GM food.	
		Fifty-four percent know very little about GM foods.	
		Twenty-five percent have never heard of GM foods.	
	n = 491	Fifty-nine percent have knowledge that GM soybeans are sold in supermarkets.	
		Fifty-six percent mistakenly believe that GM tomatoes are sold in supermarkets.	
		Fifty-five percent mistakenly believe that GM wheat is sold in supermarkets.	
		Fifty percent mistakenly believe that GM chicken is sold in supermarkets.	
Latvian consumers	(not reported)	Fifty percent believe that normal tomatoes do not have foreign genes, but GM tomatoes do.	[50]
		Of those surveyed, 68.2% believe that genes of GM foods can transmit into the generative cells of humans and can also be passed down to future generations.	
		Of those surveyed, 40.9% believe that due to eating a GM tomato, the gene of a person can change.	
		Ninety percent have The knowledge that by inserting the gene of a fish, the taste of tomato will not be fishy.	
		Of those surveyed, 95.5% have the knowledge that non-GM foods and GM foods can be a reason for allergy or can cause toxicity.	
		Of those surveyed, 22.7% have a knowledge rate of 06 out of 10.	
		Of those surveyed, 77.3% have a knowledge rate of 05 out of 10 or even less.	

Table 3. *Cont.*

Population	Sample Size	Main Findings	Reference
Turkish nursing students	N = 346	Of those surveyed, 32.4% identified cotton, soy, and corn as widely cultivated GM crops.	[51]
		Of those surveyed, 58.4% wrongly identified zucchini, tomatoes, and peppers as widely cultivated GM crops.	
		Of those surveyed, 5.5% wrongly identified eggplant, potatoes, and wheat as widely cultivated GM crops.	
		Seventy-seven percent believe that GM food production causes risks for all living objects.	
		Of those surveyed, 72.8% believe that the consumption of GM foods can be dangerous.	
		Of those surveyed, 82.9% feel that information of GM foods is not given properly to society.	
		Of those surveyed, 16.8% believe that they have enough knowledge about GM foods themselves.	
Polish students	N = 500	Of those surveyed, 57.4% think that studies on GM food effects on human health are reliable.	[52]
		Of those surveyed, 64.1% say that GM foods related reports by the media are not trustworthy.	
		Of those surveyed, 59.9% have negative thoughts about GM crops in the system of food production.	
		Of those surveyed, 81.4% report that either, "I have very little knowledge about it" or "unlikely that I know".	
		Of those surveyed, 16.8% say that they know a lot about GM foods.	
US, Italian and Japanese food shoppers	N = 550 US consumers, 200 Italian consumers and 128 Japanese consumers	Of those surveyed, 40.9% of US consumers have knowledge on an average level or on a high level, about GM foods.	[53]
		Twenty-eight percent of Italian consumers have knowledge on an average level or on a high level, about GM foods.	
		Of those surveyed, 33.3% of Japanese consumers have knowledge on an average level or on a high level, about GM foods.	
		US consumers rate "GMO-free" as the 17th most important character. Italian consumers rate "GMO-free" as the 5th most important character. Japanese consumers rate "GMO-free" as the 7th most important character.	

GM = genetically modified; GMO = genetically modified organism; N = total sample; n = question-specific sample.

Regarding a comprehensive review of consumers' knowledge of GM foods in different nations, it may be stated that the adoption or rejection of GM products is also heavily influenced by the economic, pandemic period, social, psychological, and consumer knowledge factors. Further, it was noted that if a country's economic status is not in good shape, the purchasing power of its individuals would be affected as well, forcing them to move to cheaper food products. In addition, a pandemic, such as COVID-19, is related with the deterioration of a country's economy, since practically all industrial sectors are rendered inoperable, resulting in a decline in the state income and inflation. Accordingly, consumers are unable to work to earn money to satisfy their daily necessities, such as food, and are compelled to switch to less expensive food products. In conclusion, economic causes and the pandemic period necessitated the formation of social and psychological factors that encouraged customers to buy GMO food products, since they were less expensive. As a

result, consumer demand for GMO food products is growing in the post-pandemic era, reaching 8.5% in 2021 [58].

Further, the GMO acceptance factor is also caused by the level of the knowledge about GMO food products, such as the less consumers know about GM products, the less they accept them. This is due to the fact that consumers with low knowledge of GM products have limited information and typically only focus on the negative information, such as the information saying that consuming GM products can replace a human's genes and that GM foods can also transmit into the generative cells of humans and can be passed down to future generations [37,59]. In the meantime, if consumers have adequate and greater knowledge about GM products, the level of acceptability of the products will increase, as they will already be aware of the different advantages of GM products. Therefore, it is advised that the government and companies involved in GM products advertise and educate consumers about GM products [37,57,60]. Thus, as consumer understanding rises, so will their acceptance of genetically modified foods. Consumers may acquire information on GM foods through various sources and platforms, i.e., the internet, television, radio, newspaper, magazine, scientific papers, or from person to person (Table 4).

Table 4. Sources of genetically modified foods knowledge.

Population	Sample Size	Main Findings	References
Chinese consumers (Anhui province)	N = 504	Social media is where most people find out about GM foods.	[57]
		The government is also responsible for giving information about GM foods.	
Chinese consumers (Beijing)	N = 1460	Fifty-five percent of Chinese consumers reject genetically modified foods, and over 60% do not accept the information offered by GM experts.	[37]
		Forty-two percent of Chinese consumers rely on government-supplied information on genetically modified foods.	
		Approximately 35% of people accept the misconceptions about GM technologies spread by the media.	
		Trust in the GM scientists and the government have a large positive influence on the consumer acceptance of GM foods, but trust in non-GM scientists or persons and belief in disinformation have a significant negative effect.	
		Chinese customers heard about the safety of genetically modified foods through the internet or WeChat.	
		Consumers who heard about GM technology through the internet or WeChat are less inclined to purchase GM foods than those who heard about it from other sources.	
Russian, Czech, and Ukrainians	Russia = 113 Czech Republic = 217 Ukraine = 52	Knowledge of the role of individual reference views in the attitude development might help enhance the understanding of consumer acceptance of products that are often connected with health or other issues, such as GM foods.	[60]
		The closest individuals, such as parents and relatives, also have a role in delivering knowledge about GM foods and have a substantial influence on the purchase of GM foods.	
		Parents in Russia and the Czech Republic play a larger role in giving information about GM food and have a bigger impact on their purchasing decisions than parents in Ukraine.	

Table 4. *Cont.*

Population	Sample Size	Main Findings	References
Japanese (Osaka)	N = 250	In order to enhance the acceptance and confidence in GM foods it is vital to expand understanding and the beneficial function of communication science.	[61]
		Science communication is the primary factor that may affect the market success and desire to buy genetically modified foods.	
US (Midwestern state)	N = 931	The majority of consumers know about GM foods through the media, and media coverage may influence the association between knowledge and unfavourable sentiments about GM foods.	[59]
		Consumers often hear about genetically modified foods from the media.	
Latvian consumers	n.a.	Of those surveyed, 77.3% obtained the information regarding GM foods from internet.	[50]
		Of those surveyed, 63.6% obtained the information regarding GM foods from the television.	
		Of those surveyed, 54.5% obtained the information regarding GM foods from people they know (relatives and friends).	
		Of those surveyed, 36.4% obtained the information regarding GM foods from the radio.	
		Of those surveyed, 22.7% obtained the information regarding GM foods from newspapers and magazines.	
		Of those surveyed, 13.6% obtained the information regarding GM foods from scientific papers.	
Turkish nursing students	N = 346	Of those surveyed, 74.3% obtained the information regarding GM foods from the television or radio.	[51]
		Of those surveyed, 27.7% obtained the information regarding GM foods from newspapers.	
		Of those surveyed, 22.3% obtained the information regarding GM foods from a friend.	
		Of those surveyed, 21.7% obtained the information regarding GM foods from the internet.	
		Of those surveyed, 9.2% obtained the information regarding GM foods from a questionnaire, alone.	
Chinese consumers	n.a.	Of those surveyed, 69.3% obtained the information regarding GM foods from the internet.	[21]
		Of those surveyed, 45.3% obtained the information regarding GM foods from the television.	
		Of those surveyed, 27.8% obtained the information regarding GM foods from books and periodicals.	
		Of those surveyed, 22.8% obtained the information regarding GM foods from communication from relatives and friends.	
		Of those surveyed, 22.4% obtained the information regarding GM foods from learning at school.	
		Of those surveyed, 9.6% obtained the information regarding GM foods from public lectures.	

GM = genetically modified; n.a. not available.

Given the variety of sources of information about genetically modified foods, it is believed that some would offer misleading info on GM products, which would negatively impact the worldwide acceptability of GM goods. In China, Cui and Shoemaker [21] found

that consumers obtained GM food knowledge mostly through the internet. However, the authors suggested that information posted on the internet was often inaccurate. Therefore, it is advised that the government or businesses involved in GM foods give the public trustworthy information so that everyone has the same knowledge of GM products. This may also assist in eliminating fake news about GM goods since reputable sources from the government or linked sectors are accessible.

5.1.2. Social Trust

GMFs provide substantial scientific advancements in current agriculture in addition to tremendous societal and economic advantages. However, as with many previous new food technologies throughout history, GMF's new technology has been a cause of fear, uncertainty, controversy, and low acceptability since its introduction to the marketplace [56]. The controversy surrounding GM products stems from a lack of consumer trust in GM products. Additionally, trust is the most influential aspect on the public's acceptance of new technologies and products, such as GM products [62]. People with a limited understanding of technology, particularly new technologies such as GMOs, often depend on social trust to identify the merits and drawbacks of their products. Thus, the community's social trust is well-developed and based on the scientific study by professionals. Consequently, a social trust may also be utilized to guide consumers in the purchase, consumption, and implementation of new technology such as GMOs.

5.1.3. Health Expectations and Naturalness

The elements that humans consume, both natural and artificial, have a significant impact on their health [58]. Therefore, individuals are increasingly worried about the products they consume. In addition, the introduction of new GM products to the market has sparked strong public debate, scientific discussion, and media attention over their safety for human consumption. Although there is no agreement on the prospective impacts of GMOs, the truth remains that their effects on health are harmful and very unpredictable, particularly given the trend of globalization. Hence, concerns toward health can also affect the acceptance of people for GM foods [63]. Studies show that people who have more concerns for health think negatively about GM foods, as compared to the people who do not have many health concerns [64]. Some consumers are afraid that the consumption of GM foods can lower the well-being of a person and that these food products are not trustworthy, due to their assumed long-term health and environmental effects. Naturalness is another factor affecting the acceptance rate of GM foods. Consumers perceive modification in genetics as unnatural.

5.1.4. Consumer's Perspectives towards Genetically Modified Food Labelling

In recent decades, the quality and safety of food items have increasingly affected consumer purchasing decisions [34]. Thus, in this constantly shifting new context, food labelling is crucial to the food system and marketing strategy. Moreover, labels provide consumers with a variety of information about food properties, allowing them to make buying decisions, based on specific food attributes associated with a certain product [35,65]. Therefore, in this scenario, the food label is the only credible source of information accessible to consumers and capable of influencing their decisions.

According to prior studies, around 60–70% of processed food products in North America have at least a few ingredients that are from genetic modifications. Therefore, consumers do not have awareness for the consumption of these foods. Nevertheless, labelling should have been required, and this has been controlled by U.S. regulation [35,66]. As a result, many U.S. consumers object to unlabelled products because they believe they are unsafe for consumption and distribution on the market. Moreover, a survey which was conducted in Canada also suggests that around 88% of consumers demand labelling of GM foods [35,66]. A survey on biotechnology organized by the European Commission revealed

that the public supports the medical biotechnology and industrial biotechnology broadly, whereas it opposes strongly to agricultural biotechnology.

Thus, it can be concluded that there are still pros and cons to GM products. Most consumers are willing to accept GM products provided they are labelled with concise and clear information regarding their genetic modification [35,67]. As a consequence, people are becoming more aware about GM foods and are more willing to purchase them. In addition, it can be seen that there are still some rejections of modern biotechnology in agriculture, since a great number of individuals still believe the created products are unsafe for human consumption.

6. Conclusions

This research attempted to determine what factors, particularly social and psychological aspects, might impact the consumption of GM foods. In addition, this research revealed that GM foods are deemed unnatural and artificial, based on public behaviour, beliefs, views, and attitudes. Furthermore, people's motives and views of current technology are still seen to be crucial variables in determining the consumer motivation for developing technologies in the future. Furthermore, in this research, it was also revealed that consumers demonstrated a good behaviour to utilize gene technology in the medical industry rather than in food production. However, throughout time, the public has also grown to embrace technical innovations that are centred on food products, such as GM foods. In this study, it was also found that consumers have started to accept and are willing to buy and consume GM products since these products also have numerous benefits. In addition, given the current circumstances, particularly after the COVID-19 pandemic and the political issues that have caused the economy in a country to weaken, resulting in a decrease in consumer purchasing power and inflation that has led to rising food prices, many consumers around the world suffer and find it challenging to purchase food [67]. Accordingly, GMO food is an option for consumers since it may be purchased at a lower cost [54]. As affordability is one of the most significant aspects for consumers when purchasing food products, this also makes the prospect of GMO products more appealing in the future. Hence, it is anticipated that the findings of this work will serve as a hint to policymakers, governments, and related industries to concentrate more on GMO food products, in order to fulfil the public demand for food as prices rise, and that regulations governing food consumption and sales will be improved for the growth of this sector.

In addition, a number of prior studies (Tables 3 and 4) have shown that the acceptability of GMO food products is also influenced by an individual's level of knowledge of GMO food. This is the reason why Americans are more accepting of GMO food products than certain European (Poland, Italy, and Latvia) and Asian nations (Turkey and Japan). Comparatively, between 43% and 59% of U.S. consumers are aware of GMO food products, but in Europe and Asia, fewer than 40% of consumers are aware of GMO food products. Hereinafter, this study concludes that social and psychological factors, such as the perceived risks, environmental implications, attitudes regarding GM food labelling, the perceived distinctions between GM and non-GM foods, and advantages of GM food, affect consumer acceptance of GM foods. As viewed by the study, the perceived high risk associated with GM foods is the greatest impediment to the consumer adoption of such foods, which underlines the need to educate and provide more information to consumers about GM foods in a more scientifically objective way. In addition, the findings demonstrate the necessity of labelling GM foods, indicating the need to give consumers more information regarding GM foods, in order to build consumer trust.

This review also determined that the reason consumers do not want to purchase GM foods is because they have received too much information and are unable to determine what is reliable. As a result of these difficulties, people have a growing reluctance to purchase GM foods, as the information they receive from the media is mostly misleading. Following that, many consumers from various countries, including Japan, China, and Brazil, rely on the information provided by government and experts, in order to decide

whether or not to purchase GM foods. Next, it has been found that parents and close family members have a substantial impact on the acceptability of GM foods.

With the finding of this work, it is anticipated that the government, policymakers, and associated businesses will be able to develop GM products that are in accordance with market demands and consumer needs, as a result of several concerns, such as the pandemic period and the economic crisis. Furthermore, by reviewing the opinions, attitudes, and perceptions of consumers about GM foods shows that if they know a lot about GM foods, they are more likely to accept and be willing to buy GM foods. However, it is also found that consumers who believe they are highly aware of GM foods also become redundant and have high levels of anxiety because they are overwhelmed with information and are unable to filter it. It was also discovered that there is a need for aid in giving information from researchers, experts, and the government to filter the information extensively circulated in the media so that consumers only acquire the right information and are ready to accept and purchase GM foods. In addition, it is hoped that from the founding of this research, it will provide the government and related industry parties with an overview of the future development of the GM food industry, so that they can make better-informed decisions about whether or not to invest in the development and use of GM technology for their industry. With the proper approach, the government and allied sectors may control the production of GM foods depending on public demand and consumption trends.

Consequently, this study may also contribute to future GM products and agricultural biotechnology development. As it turns out, the government and experts need to work together to give direct information to the public about GM foods so that they do not obtain incorrect information via the media, which may boost consumers' purchasing intentions to buy GM foods. In addition to the level of knowledge, the source of information is a significant factor in the level of acceptance of GM foods. Therefore, additional research focusing on the media and how to provide the correct information to consumers is required to support the growth of the GM foods industry. Further study may be required also to determine the best methods for the government and experts to convey accurate information about GM foods to consumers so that they obtain information from reliable sources. Hereinafter, governments must investigate the viability of establishing online portals that provide general consumers with information about GM food, in simple terms. The government should also investigate the potential of creating an online site that provides general consumers with information regarding GM foods in plain terms that the public can readily understand.

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