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EDITED BY
Raul Avila-Sosa,
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REVIEWED BY
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Independent Researcher, Scansano, Italy
Fabiola Avelino Flores,
Benemérita Autonomous University of Puebla, Mexico

*CORRESPONDENCE
Randy Kwaku Amponsah
✉ ramponsah17@gmail.com

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Understanding the societal dilemma of genetically modified food consumption: a stimulus-organism-response investigation

Xu Hui[1], Randy Kwaku Amponsah[1]*, Samuel Antwi[2], Patrick Kweku Gbolonyo[3], Moses Agyemang Ameyaw[4], Geoffrey Bentum-Micah[5] and Edward Oppong Adjei[6]

[1]School of Economics and Management, Yangtze University, Jingzhou, Hubei, China, [2]School of Management and E-Business, Zhejiang Gongshang University, Hangzhou, Zhejiang, China, [3]Department of Mathematics, Wilfrid Laurier University, Waterloo, ON, Canada, [4]School of Business, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, [5]College of Teacher Education, Zhejiang Normal University, Jinhua, Zhejiang, China, [6]School of Public Administration, Zhenjiang Gongshang University, Hangzhou, Zhejiang, China

Consumer worries about their health and the environment are drawing attention to the usage of genetically modified food on a global scale. The study aims to provide fresh insight into how consumers view GM foods and how they plan to respond to them. Data were collected from Chinese consumers, who are at the advanced stage of GM food, and Ghanaians, who are at the early stage of GM food. The data were analyzed using Smart PLS, R-Studio, and SPSS. Based on a valid response from nine hundred and seventy-six (976) respondents across the two countries, the results demonstrate the dynamics of GM acceptance among consumers and provide valuable insights for policymakers and businesses in the GM foods industry. Our research adds up to the relatively fewer studies which have addressed GM food consumption likelihood from consumers across different stage of GM food readiness.

KEYWORDS

genetically modified food, health consciousness, environmental consciousness, perceived benefits, perceived risk, consumption likelihood, buying frequency

Introduction

One of our basic human needs is food since we must eat to survive. Long-standing practices include improving plants and animals for food production and utilizing various conservation methods (Chekol, 2021). According to Hansmann et al. (2020), food production and consumption impact environmental and human health. Genetically modified (GM) food has gained public attention recently due to increased consumer awareness of the need for food safety and environmental protection worldwide. The rising public interest in genetically modified food can be attributed to the need to sustain the environment while preserving our health.

According to research, GM foods are environmentally friendly and aid in lowering greenhouse gas emissions. Globally, farmers use fewer resources to grow GM crops, such as fewer pesticide applications and the fuel needed to run tractors to till the land. The time fuel-dependent farm equipment is used decreases due to these agricultural practices. Brookes and

Barfoot (2020) report that 920 million liters less gasoline was used in 2018 due to these practices.

The cumulative fuel savings from GM agriculture amount to about 12,799 liters of fuel and 34,172 million kg of carbon dioxide. According to Brookes and Barfoot (2020), this fuel savings is equivalent to removing 22.65 million cars from the road for an entire year. According to Smyth (2020), GM crops have significantly helped achieve the UN Sustainable Development Goals, especially Goals 1 and 2 (reducing hunger). GM crops can resist insects, tolerate drought and flooding, and slow climate change. While higher household incomes have reduced poverty as a result of higher household yields, higher yields have also improved food security for households (Smyth, 2020).

According to reports, biofortified, including GM, foods include more minerals and vitamins than traditionally farmed foods (Bawa and Anilakumar, 2013; Hefferon, 2015; Smyth, 2020) although exposure studies did not yet address the upper limit issue (EFSA, 2024), and a reduced amount of used chemicals then potentially less harmful to human health and the environment." Despite these greater benefits of GMO foods, some concerns have been raised that GM foods can cause harm to the human body. Thus, consuming these meals is thought to increase the risk of developing antibiotics-resistant illnesses (Bawa and Anilakumar, 2013). Chekol (2021) opined that GM food's potential health consequences are toxicity, allergenicity, and genetic hazards. Bawa and Anilakumar (2013) again added that since GM foods are relatively new, nothing is known about how they will affect people in the long run. Customers could be wary of its usage because the health repercussions are unknown. Despite this, there is no proof consuming food that has been genetically modified is harmful (The Royal Society, 2016; National Academies, 2022).

Knowledge of consumer behavior surrounding the consumption of GM food will have significance for researchers and business managers to create better judgments and policies as GM awareness and the market grow fast. Therefore, it is crucial to comprehend customer views and behavioral intentions about GM food. Additionally, according to Grimmer and Miles (2017), customer attitudes and understanding of environmental issues may impact their decision to buy food. To achieve this, people concerned about the environment and their health will favor products that promote both.

Given that research on consumer behavior of genetically modified food has received less research attention and the public debate associated with GMO food, this study utilized the Stimulus-Organism-Response (SOR) paradigm as a theoretical framework to investigate Ghanaian and Chinese consumers' motivations for GM food from the health and environmental context. Because there is a dearth of information on this topic and China and Ghana are at various phases of producing genetically modified foods, the researchers chose to conduct a cross-over study in these two nations. Examples of GM food in China are sweet peppers, tomatoes, potatoes, cowpeas, and rice. Tao and Shudong (2003) report that China was the first country to grow GM crops commercially, starting with virus-resistant tobacco plants in 1988.

LI (2012) added that the Chinese government actively encourages biotechnology in food and agriculture to address the country's serious food security problems. Ghana introduced the Biosafety Act to introduce GMOs legally and ultimately allow farmers to use GM foods in crop production (Borgen Magazine, 2018). The government also imports some GM foods. Again, both countries are at different stages of genetically modified food production. China is regarded as the pioneer in genetically modified food as they were the first country to plant GM crops commercially, whereas Ghana is relatively new to GM production.

Stimulus-organism-response framework

The S-O-R framework (Mehrabian and Russell, 1974) is widely used by researchers and scholars to analyze human behavior. Three stages make up this process: stimuli, organism, and response. According to Eroglu et al. (2003), the stimulus refers to social contexts or environmental cues that may elicit or stimulate a person's psychological or behavioral responses or changes. This study examines GM foods, which are frequently viewed as dangerous and unhealthy by some consumers (Jurkiewicz et al., 2014; Wunderlich and Gatto, 2015; National Academies of Sciences, Engineering, and Medicine, 2016). As a result, customers will be wary about eating GMO food. The current study uses environmental consciousness in addition to health consciousness to measure stimuli.

According to Jurkiewicz et al. (2014), the organism is the internal decision-making process that occurs between a stimulus and a reaction. Prior experiences, knowledge, beliefs, attitudes, predispositions, intentions, values, cognitive networks, schema, scripts, motives, the person's personality, and feelings were all described by Jacoby (2002) as belonging to the organism component. It is claimed that internal processes that mediate the impact of the stimulus on the reaction are responsible for both the perceived advantages and disadvantages of consuming GM food. Response describes the intentions, choices, or behavioral modifications from the stimuli and "organism" elements. In the context of this research, a response is defined as the consumption likelihood of GMO food by Chinese and Ghanaian consumers. Consequently, the consumption likelihood of GMO food is proposed as a response.

Constructs definition and study hypotheses

Health consciousness of GMO food consumption

Kar and Somani (2019) define consciousness as the experience of realizing and comprehending something. According to Pu et al. (2020), such a thing is more akin to human ideas, feelings, and memories. It can also develop and transmit relevant information and alter continuously in response to human requirements, allowing us to act independently (Marchetti, 2018). The measure of a person's readiness to take proactive steps to safeguard their health and identify with it is called health consciousness. According to Becker et al. (1977), it's the degree to which a person is likely to engage in healthy behaviors. Research has indicated that health-conscious customers exhibit a great deal of worry about their overall health (Kraft and Goodell, 1993; Newsom et al., 2005; Chen and Lin, 2018). The researchers claim that these customers strongly desire to engage in healthy activities to preserve or enhance their health and quality of life and stave off illness. In the context of this research, health consciousness is a consumer's behavior and attitude toward consuming genetically modified foods.

The notion of self-consciousness holds that self-awareness can predict attitude and behavior consistency, including health

consciousness and health-related behaviors (Gould, 1990). Health-consciousness and health-promoting behaviors are consistent. Health-conscious individuals typically have a better understanding of health, are aware of personal health issues, and take proactive steps to maintain their health (Piko and Keresztes, 2006). Genes from other plants or animals have been used to alter the DNA of GM foods, making them different from non-G and/or organic food. People may be concerned about how eating certain foods could affect their health because of the alleged negative consequences of food produced using synthetic and chemical methods that are common in contemporary agriculture practices (Qasim et al., 2019; Ranjbar Shamsi et al., 2020). Nonetheless, it is well known that genetically modified foods are more nutrient-dense, have a more excellent supply of food at a lower cost and longer shelf life, grow faster in both plants and animals and are resistant to disease and drought, requiring less water and fertilizer from the environment (Raman, 2020; Barrell, 2022). Despite the advantages of genetically modified food, studies have revealed that consumers thought it would be somewhat harmful to their health (Oselinsky et al., 2021).

The impact of GM food on human health has been studied and discussed in public; however, the results seem to be mixed. According to studies from the World Health Organization (2014), genetically modified foods sold internationally have passed safety evaluations and are not anticipated to pose a risk to public health. Furthermore, the general public's intake of these foods has not been linked to any adverse health impacts in the nations where they have been authorized. They further opined there had been no evidence of allergic reactions to GM foods sold in stores. Nonetheless, according to the Food and Drug Administration (2022), several allergens can be present in GM foods, including some proteins found in milk, eggs, wheat, fish, tree nuts, peanuts, soybeans, and shellfish.

Thus, this study anticipates that consumers' perceptions of the benefits and risks of eating genetically modified food will be significantly influenced by their level of health consciousness. Consequently, we suggest that:

> *H1a*: Health consciousness has a significant effect on the perceived benefits of GM foods.
>
> *H1b*: Health consciousness has a significant effect on the perceived risks of GM foods.

Environmental consciousness of GMO food consumption

Environmental issues have drawn much attention from researchers and other stakeholders over the past decades (Wang et al., 2020). Schlegelmilch et al. (1996) describe environmental consciousness as a driving force stemming from an individual's knowledge of the adverse environmental effects of people's irresponsible behavior (which includes businesses, goods, or brands). Mishal et al. (2017) see the concept as psychological factors determining consumers' propensity toward pro-environmental behaviors. Consumers who prioritize the environment over other considerations act morally and think about how their daily purchases may affect the environment and the community in which they live (Pino et al., 2012). Environmental consciousness in this study refers to how worried consumers are about environmental issues associated with their purchase.

According to Kwak et al. (2020), consumers and researchers hold mixed views of the environmental impact of genetically modified foods. They went on to say that the European Union mandates buffer zones and isolation distances in the production of GM and non-GM crops out of concern that gene flow could happen between related crops. According to some studies, genetically modified foods have adverse effects on the environment, including soil erosion and depletion, the transgenic nature of GM crops, cross-pollination, and van Acker et al. (2007) and Mathur et. al. (2017). However, other studies contend that GM food may provide an environmentally sustainable source by reducing reliance on non-renewable energy sources (Qaim, 2009; Godfray et al., 2010). Research has additionally demonstrated that genetically modified crops may lower greenhouse gas emissions worldwide by eliminating the requirement for plowing when crops are planted (Maghari and Ardekani, 2011; Barrows et al., 2014). According to van Acker et al. (2007), these crops also make no-till and conservation tillage techniques easier to implement, which lower soil erosion and preserve soil moisture. Research on green consumer behavior has demonstrated that consumer behavioral intentions are positively impacted by environmental concerns (Sinnappan and Rahman, 2011; Wahid et al., 2011; Huang et al., 2014). Drawing from this, we expect that environmental consciousness will affect consumers' perceived risks and benefits of consuming GMO food. Consequently, we suggest:

> *H2a*: Environmental consciousness has a significant effect on perceived risk of GM foods.
>
> *H2b*: Environmental consciousness has a significant effect on perceived benefits of GM foods.

Perceived risks and benefits of GMO food consumption

Every purchase decision a consumer makes exposes them to risk in the quest for varied advantages (Kim et al., 2008). Beliefs in the favorable consequences of actions taken in reaction to an actual or perceived threat are commonly referred to as perceived benefits. Leung (2013) sees perceived benefits as a perception of a positive consequence caused by a specific action. A customer's perceived risk is regarded as uncertainty about the outcome of a purchase decision. According to Lee (2020), perceived risk represents unfavorable actions or reasons, while Elhoushy et al. (2020) opined that perceived benefits represent favorable reasons or actions. Consumers weigh the risks and benefits before deciding on an action.

As a result, customers will balance the advantages and disadvantages of eating GMO food. There are advantages and disadvantages to eating food (Ashwell, 1991). The degree of perceived danger and reward influenced by the euphoria associated with the gain and the fury associated with the hazard determines how much food is consumed (Ashwell, 1991). Studies have indicated that customers are better able to make an informed choice when they know the advantages and/or disadvantages of any given good or service (Gupta and Arora, 2017; Boyetey and Antwi, 2021). Therefore, we argue that the likelihood of consumers consuming genetically modified food is highly dependent on their perceptions of its dangers

and benefits. Accordingly, we posit that the perceived health and other benefits of GM food and consumer worries about the consumption of GM food are likely to influence their consumption likelihood. Hence, we propose:

> *H3*: Perceived benefit has a significant influence on consumers' willingness to consume GM foods.
>
> *H4*: Perceived Risk has a significant influence on consumers' willingness to consume GM foods.

Differential effects of consciousness on consumer perception

Although consumer behavior toward GM foods is primarily driven by health and environmental concerns, the degree or stage of GM food consumption can impact this decision. Based on studies, China is the world's pioneer in commercial GM crop cultivation, having begun with virus-resistant tobacco plants in 1998 (Tao and Shudong, 2003). According to Maina (2022), genetically modified crops have been promoted as a practical way to feed China's enormous population while reducing their dependency on large agricultural exporters. Conversely, Ghana passed the Biosafety Act in 2011 to introduce GM foods to the country legally, ultimately allowing farmers to use GMOs in their crop production process (Borgen Magazine, 2018). Given China's pioneers in GM food, the popularity of GM foods in their market, and the consumers' level of education on GM foods, we expect Chinese consumers to have a higher knowledge of GM food than Ghanaian consumers.

> *H5a-b*: Health Consciousness will have a stronger positive effect on (a) Perceived Benefits (b) Perceived Risks for consumers who have a Low Buying Frequency of GM foods than consumers High Buying Frequency.
>
> *H6a-b*: Environmental Consciousness will have a stronger positive effect on (a) Perceived Benefits (b) Perceived Risks for consumers who have a Low Buying Frequency of GM foods than consumers with High Buying Frequency.

Differential effects of consumer perception on consumption likelihood

Before consumers buy GM food, they evaluate its benefits and potential risks. To bolster this, Ashwell (1991) argued that eating has advantages and disadvantages. The positive aspect is regarded as the benefits, and the negative aspect is viewed as the risks associated with consuming food. Consumer knowledge about GM food can be a significant driver for their consumption. It calculates how well consumers know and understand food that has undergone genetic modification. We expect that consumers are more likely to buy GM food if they perceive it to be beneficial to their health and the environment. We posit that consumers are less likely to buy GM food if they perceive it to be risky to their health and the environment. This decision will be based on their level of knowledge about the food. Based on the literature reviewed, GM foods have been in the Chinese market more than the Ghanaian market, hence, the Chinese consumers are more knowledgeable and experienced with GM foods than Ghanaian consumers. Thus, we hypothesize:

> *H7*: Perceived Benefits, compared to Perceived Risks of GM food will have a stronger positive effect on Consumption Likelihood for consumers with High Buying Frequency than for consumers with Low Buying Frequency.
>
> *H8*: Perceived Risks, compared to Perceived Benefits of GM food will have a stronger positive effect on Consumption Likelihood for consumers with Low Buying Frequency than for consumers with High Buying Frequency.

Control variables

We included age and gender (Ashraf et al., 2014), individualism–collectivism, and uncertainty avoidance (Sharma, 2010) as control variables. Since research has shown that culture can influence consumer behavior, applying collectivism–individualism and uncertainty avoidance is justified (Takieddine and Sun, 2015; Zhang et al., 2018). Given that age and gender have been demonstrated to impact technology uptake and use significantly, we included them as control variables (Venkatesh et al., 2012). This is because research and development in the agriculture sector led to the acceptance of technologies that resulted in the production of genetically modified food (Figure 1).

Methodology

Survey design

A questionnaire was employed to gather data for the study. The items used to test the proposed constructs were developed by adapting pre-validated scales, where available. The five Health Consciousness measuring questions were taken from Espinosa and Kadić-Maglajlić (2018). An example of the item includes "I am alert to changes in my health." Environmental consciousness was measured using five items (Maloney and Ward, 1973; Iyer et al., 2016). An example is, "I always purchase products that are less harmful to the environment." Next, Perceived Benefits were assessed using five items (Westaby, 2005; Tan et al., 2022).

An example is "Genetically Modified Foods are good for my health." Moreover, the Perceived risk was assessed using a five-item scale (Westaby, 2005). An example is "The quality and safety of Genetically Modified Foods nowadays concern me." Also, the consumption likelihood of GMO foods was measured with a five-item scale (Shaharudin et al., 2010; Gbolonyo et al., 2022). An example is, "I am happy to consume Genetically Modified Foods." The items utilized the 7-point Likert scale to solicit the respondents' responses on a scale of one to seven, wherein a score of one indicated strongly disagree, and seven indicated strongly agree.

The validity and reliability of these scales were tested in the context of the present study, as reported later in the analysis. Buying frequency was measured by the frequency of purchase of Genetically Modified Food items wherein buyers with high frequency were identified as consumers

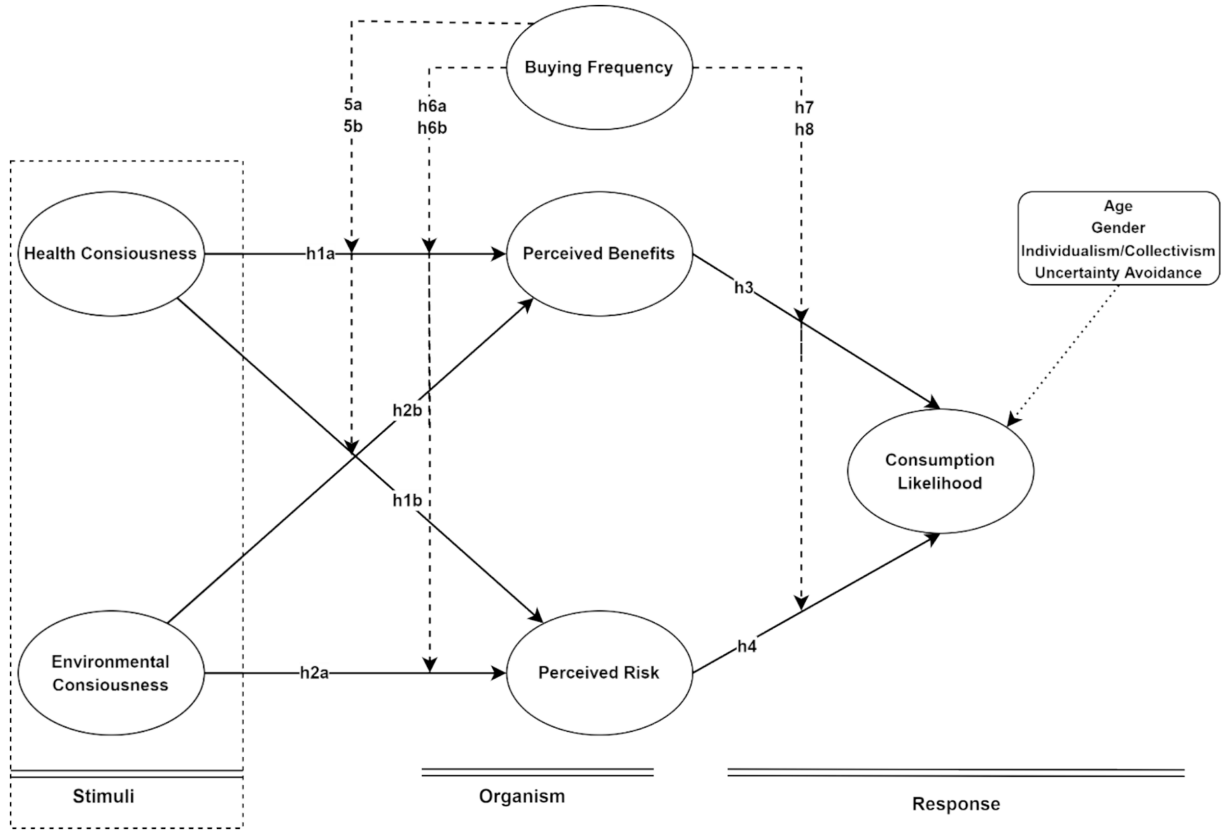

FIGURE 1
Concept model.

who engaged in more frequent purchases (10 or more times per month), while respondents with low frequency were identified as consumers who engaged in less frequent purchases (below 10) of GMO foods. The responses related to respondents who selected Not At All (in a month) were deleted from the study as they barely or do not consume GMO food. A total of thirty-eight (38) responses related to Ghanaian consumers were deleted. All the Chinese respondents had consumed GMO foods.

Data collection procedures

To meet the research objectives, we gathered data from Ghana and China. Google Forms (for data gathered from Ghana) and Microsoft Forms (for data collected from China) were used to distribute the questionnaires as online web surveys. The questionnaire was translated into Mandarin, the most common language in China, to overcome linguistic differences in a country where English is not predominantly spoken. The English-language questionnaire was first translated into Chinese Mandarin and then back-translated into English to avoid potential translation biases (Brislin, 1980).

Since English is the primary language of instruction in Ghana, the survey was administered in English to the country's respondents. Before distributing the survey for our data collection, we sought input on the clarity and content of the questionnaire from three academicians or experts in marketing and agriculture with experience in food marketing and genetically modified food. Minor adjustments were made to the survey instruments in response to the input we received. We obtained a valid response from nine hundred and seventy-six (976) GMO consumers from the two countries; Ghana (353) and China (623).

Data processing and analysis

The data obtained for the study were first processed for data cleaning using Microsoft Excel 2021. The analysis was conducted using Smart PLS version 4, SPSS version 26 and R-Studio. Detailing of results and methods is captured in the next section.

Respondents demographic information

Table 1 summarizes the dynamics of the average Ghanaian and Chinese GMO population from a valid sample size of 353 (Ghanaian consumers) and 623 (Chinese consumers).

From the table, females dominated the Ghanaian respondents, while males dominated the Chinese respondents. On the education level, most of the respondents from Ghana and China had tertiary education. Regarding the cultural dimensions, the table further reveals that both Chinese and Ghanaian consumers are collectivists, confirming Hofstede's cultural dimensions theory (Hofstede Insights, 2023). The measurement model for the constructs is described in

TABLE 1 Background information of respondents (Ghana and China).

Variables	Items	Ghana ($N = 353$)	China ($N = 623$)
		Freq. (%)	Freq. (%)
Gender	Male	167 (47.3)	283 (54.6)
	Female	186 (52.7)	283 (45.4)
Age	Below 18 years	30 (8.5)	33 (5.3)
	18–25 years	126 (35.7)	216 (34.7)
	26–30 years	96 (27.2)	210 (33.7)
	31–40 years	58 (16.4)	101 (16.2)
	Over 40 years	43 (12.2)	63 (10.1)
Educational level	High school graduate	22 (6.2)	56 (9.0)
	Tertiary education	213 (60.3)	454 (72.9)
	Tech/vocational training	118 (33.4)	113 (18.1)
Buying freq. (monthly)	1–4	119 (33.7)	46 (7.4)
	5–9	212 (60.1)	70 (11.2)
	10 and above	22 (6.2)	507 (81.4)
Cultural dimensions	Individualism	109 (30.9)	122 (19.6)
	Collectivism	244 (69.1)	501 (80.4)
Uncertainty avoidance	High uncertainty avoidance	234 (66.3)	545 (87.5)
	Low uncertainty avoidance	119 (33.7)	78 (12.5)
Total		353 (100)	623 (100)

TABLE 2 Validity assessment model for the overall structural model (Ghana and China).

Latent constructs	Cronbach's alpha (CA)	Composite reliability (CR)	Average variance extracted (AVE)
Health consciousness	0.899	0.926	0.713
Environmental consciousness	0.891	0.920	0.698
Perceived benefits	0.883	0.915	0.682
Perceived risk	0.890	0.920	0.696
Willingness to consume	0.890	0.920	0.696

Table 2. Cronbach's alpha is a convenient test for determining a composite score's reliability. Cronbach alpha is generally considered good if it is 0.70 or higher; 0.80 or higher is considered better. However, readings beyond 0.95 may also suggest that the constructs being utilized are redundant (Ringle et al., 2020).

It is recommended that the composite reliability of a construct is at least 0.70. High composite reliability indicates that all your items constantly measure the same construct. The results above show that all the composite reliability for the constructs exceeded the threshold. For the Average Variance Extracted (AVE), they were all above 0.5. Overall, the measurement model was concluded as appropriate for the analysis (Hair et al., 2019).

Upon closer inspection, Table 3 demonstrates the evaluation of discriminant validity through the use of HTMT, suggested by Henseler et al. (2015), to gauge the degree of correlation between variables. According to Henseler et al. (2015), discriminant validity is present when the HTMT value is less than 0.9. The study results show HTMT values below the threshold, indicating the presence of excellent discriminant validity.

TABLE 3 Heterotrait-Monotrait ratio (HTMT).

Constructs	HTC	ETC	PB	PR	WGC
HTC					
ETC	0.844				
PB	0.870	0.851			
PR	0.834	0.860	0.844		
WGC	0.860	0.830	0.849	0.841	

Test of the baseline structural model

First, we assessed the overall model that comprised data from all the two countries ($n = 976$) via PLS in R. We evaluated the two nation-specific structural models. To assess whether or not the path coefficients differ substantially from zero for both the national-specific and overall models, we used a maximum likelihood robust (MLR) estimate approach to generate the Wald

TABLE 4 Path coefficients results of the structural model (overall and two countries).

Constructs	Overall model *N* (976)		Ghana *N* (353)		China *N* (623)	
	(β)	z-value	(β)	z-value	(β)	z-value
DV: Perceived benefits	R^2 (0.723)		R^2 (0.622)		R^2 (0.712)	
Health consciousness	0.285***	9.611	0.247***	6.581	0.316***	7.498
Environmental consciousness	0.563***	18.429	0.604***	15.229	0.525***	12.349
DV: Perceived risk	R^2 (0.798)		R^2 (0.596)		R^2 (0.831)	
Health consciousness	0.323***	12.539	0.042***	8.849	0.278***	8.907
Environmental consciousness	0.583***	21.992	0.044***	12.017	0.596***	18.913
DV: Willingness to consume	R^2 (0.880)		R^2 (0.761)		R^2 (0.948)	
Perceived benefits	0.484***	22.095	0.152***	3.160	0.649***	38.112
Perceived risk	0.067***	2.649	0.088**	2.057	−0.021	−0.372
Health consciousness	0.391***	17.114	0.707***	17.309	0.172***	8.505
Environmental consciousness	0.066**	2.320	0.022	0.395	0.205***	8.245
Age	−0.003	0.802	−0.0001	−0.006	0.005	0.533
Gender	0.026	1.188	0.061	1.515	0.028	1.512
Cultural dimensions	0.014	0.523	0.050	1.090	−0.043	−1.298
Uncertainty avoidance	0.030	1.054	0.019	0.426	−0.037	−0.927

***p-value < 0.01, **p-value < 0.05.
DV, dependent variable.
R^2, R-Square (variance explained).

statistics (z-values), as indicated in Table 4. For the summary of the hypotheses testing, refer to Table 5. According to the results from Table 4, health consciousness had a statistically significant, positive effect on perceived benefits and perceived risk for the overall model and Ghana and China. This suggests that higher health consciousness is associated with higher perceived benefits and perceived risk of consumption. Environmental consciousness had a statistically significant, positive effect on perceived benefits and perceived risk, respectively, for the overall and country-specific models. This suggests that higher environmental consciousness is associated with higher perceived benefits and perceived risk of consumption, respectively.

Perceived benefits had a statistically significant, positive effect on willingness to consume for the overall model and the country-specific models, indicating that higher perceived benefits are associated with higher willingness to consume. Perceived risk had a statistically significant, positive effect on willingness to consume for the overall model and Ghana. Health consciousness had a statistically significant, positive effect on willingness to consume for the overall model and the country-specific (Ghana and China) model, suggesting that higher health consciousness is associated with higher willingness to consume. Environmental consciousness had a statistically significant, positive effect on willingness to consume for the overall model and China. Regarding the control variables, age, gender, cultural dimensions, and uncertainty avoidance had no statistically significant effect on willingness to consume.

Furthermore, we evaluated the variance explained (R^2) in the dependent constructs in the structural model, as shown in Table 4.

TABLE 5 Summary of hypotheses testing.

Hypotheses	Remarks
DV: Perceived benefits	
H1a: Health consciousness → Benefits	Supported (Both Countries)
H2a: Environmental consciousness → Benefits	Supported (Both Countries)
DV: Perceived risk	
H1b: Health consciousness → Risk	Supported (Both Countries)
H2b: Environmental consciousness → Risk	Supported (Both Countries)
DV: Willingness to consume	
H3: Perceived benefits → Willingness to consume	Supported (Both Countries)
H4: Perceived risk → Willingness to consume	Supported (Ghana)

We found that the variance explained in the dependent constructs in the model differs across countries. Thus, for perceived benefits, the r-squared (R^2) values are 62.2 and 71.2% for Ghana and China, respectively. For perceived risk, the R^2 values are 59.6 and 83.1% for Ghana and China, respectively. Finally, the R^2 values for willingness to consume are 76.1 and 94.8% for Ghana and China, respectively.

Multigroup analysis of country-specific differences

Table 6 presents the multigroup comparison results between individuals with high and low buying frequency. The path

TABLE 6 Multi group comparison (low buying frequency vs. high buying frequency).

Constructs	Low → High	
	(β)	z-value
Health consciousness → Perceived benefits	0.286***	8.331
Environmental consciousness → Perceived benefits	0.568***	16.107
Health consciousness → Perceived risk	0.314***	8.581
Environmental consciousness → Perceived risk	0.590***	15.117
Perceived benefits → Willingness to consume	0.584***	21.964
Perceived risk →Willingness to consume	0.035	1.101

***p-value < 0.01.
Dependent variables = Perceived Benefits, Perceived Risk, and Willingness to consume.

TABLE 7 Effect sizes (Cohen's F^2) for benefit, risk, and willingness to consume.

Antecedent	Ghana (N = 353)			China (N = 623)		
	Benefits	Risk	Consume	Benefits	Risk	Consume
Health	0.138*	0.225**		0.082*	0.123*	
Environmental	0.495***	0.286**		0.243**	0.622***	
Benefits			0.091*			2.847***
Risk			0.194**			0.187**

From 0.02 to 0.14* = small/weak effect size, 0.15 to 0.34** = medium effect size, 0.35*** and above = large effect size.

TABLE 8 Goodness of fit indices of the structural model.

Fit indices	CFI	TLI	SRMR	χ^2/d.f. (p-value)	RMSEA
Baseline model	0.922	0.877	0.030	0.045	0.100
Constraint model	0.955	0.915	0.025	0.005	0.040
Threshold value	≥0.900	≥0.900	< 0.05	p-value <0.05	< 0.06
Remarks on constraint model	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory

CFI, Comparative fit index; TLI, Tucker-Lewis index; SRMR, Standardized root mean square residual; RMSEA, Root mean square error of approximation.

coefficients and z-values are reported for the relationships between different constructs. According to the results in Table 6 (and Table 7 for the effect size), the effects of health (environmental) consciousness on perceived benefits and risk are positive and significantly different for individuals with low (vs. high) buying frequency countries, thus supporting H5a-b and H6a-b. Correspondingly, as we hypothesized, the effects of perceived benefits on willingness to consume genetically modified foods were positive and significantly different for individuals with high (*vs* low) buying frequency countries, thus supporting H7.

Again, the resultant effect of perceived risk on the willingness to consume genetically modified foods was insignificantly different for individuals with low (*vs* high) buying frequency countries, thus not supporting H8.

Table 8 shows the goodness-of-fit indices for the structural model's baseline and constraint models. The constraint model shows improved fit indices compared to the baseline model, indicating a better fit to the data. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values for the constraint model exceed the threshold of 0.900, indicating a satisfactory fit.

The Standardized Root Mean Square Residual (SRMR) values are below 0.05 for both models, indicating a good fit in the discrepancy between observed and predicted covariance matrices. The χ2/d.f. p-values are less than 0.05 for both models, suggesting a reasonable match between the models and the data. The Root Mean Square Error of Approximation (RMSEA) values for both models fall below the threshold of 0.06, indicating an acceptable fit. In summary, the constraint model demonstrates a better fit to the data based on the improved goodness-of-fit indices, supporting the effectiveness of the modifications made in enhancing the model's overall fit.

Discussion and implications

The results of this study shed light on the dynamics of GM food acceptance among Ghanaian and Chinese consumers, providing valuable insights for policymakers and businesses in the GM foods industry. The measurement model's reliability and validity have been established, confirming the consistency and accuracy of the constructs used. This finding is crucial for ensuring that the measurement items capture consumers' perceptions and attitudes toward GM foods in both countries. The high composite reliability and AVE values signify that the constructs are reliable and distinct, demonstrating that the measurement model is suitable for the analysis. The structural

model highlights the important connections between the various variables, highlighting how consumers' attitudes toward and willingness to eat genetically modified organisms are shaped by their health and environmental concerns. Higher levels of health consciousness are associated with increased perceived benefits and perceived risks, while higher environmental consciousness also leads to higher perceived benefits and perceived risks. These findings indicate that consumers who are more health-conscious and environmentally aware are more likely to perceive both the benefits and potential risks associated with GM food consumption.

Moreover, the study demonstrates that perceived benefits positively influence consumers' willingness to consume GM foods in both Ghana and China. This shows that emphasizing the benefits of genetically modified foods, such as higher agricultural yields and better nutritional content, may encourage customers to adopt these products. Nonetheless, the relationship between perceived risks and willingness to consume GM foods does not significantly differ between individuals with low and high buying frequency. This implies that consumers' frequency of purchasing GM foods does not significantly impact their perceived risks, highlighting the need for targeted communication strategies to address consumer concerns and dispel misinformation about GM foods. The multigroup comparison results provide further valuable insights, indicating that the effects of health and environmental consciousness on perceived benefits and perceived risks are significantly different between individuals with low and high buying frequency. This suggests that consumers' buying frequency can influence how health and environmental consciousness affect their perceptions of GM foods. Therefore, marketers and policymakers should tailor their communication and promotional strategies based on consumers' buying frequency to maximize their impact and address specific concerns.

The study's conclusions significantly affect Chinese and Ghanaian marketers and policymakers. Policymakers can use these insights to develop targeted public awareness campaigns about GM foods, emphasizing these products' health and environmental benefits to enhance consumer acceptance. Additionally, by understanding how health and environmental consciousness affect customer views, marketers may create persuasive campaigns that speak to the values and beliefs of their target audience. By addressing consumer concerns, debunking misconceptions, and promoting the benefits of GMOs, policymakers and marketers can facilitate a more positive perception of GMOs and increase their adoption in both countries.

Conclusion

Our research provides a comprehensive understanding of Genetically Modified Food (GMO) consumption in two countries at different stages of GM food consumption. We offer a better understanding of why and when key drivers of health and environmental consciousness, perceived risks, and benefits may play a role in the consumption likelihood of GM foods. While considering the findings of our study, researchers should keep in mind some limitations associated with the studies. First, we used a closed-ended questionnaire to solicit data from the respondents, which may be affected by the possibility of not obtaining detailed information and respondents providing answers they may not be thinking. As such, future studies should use an open-ended questionnaire and/or an interview so that the respondent can provide detailed responses that cover all possible answers. Also, since food consumption is linked to culture, economy, and geography, future studies on GM food consumption behavior should include qualitative research to capture the related nuances in detail. Moreover, future studies should investigate the nutritional properties and planetary diets of GM food against non-GM foods. Second, although this is cross-country research, we focused on only two countries (China and Ghana). Therefore, we recommend that future studies expand the geographical locations to include more countries to test our findings' robustness and the generalizability of our results. Third, the research data was collected at a singular time; however, consumer behavior changes over time. Hence, future research should collect longitudinal data to validate the causal relationships in this study. Lastly, we did not inquire about the customers' knowledge of genetically modified foods in our investigations. Thus, it is recommended that customers' knowledge be included as a control variable in future research.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study of human participants in accordance with the local legislation and institutional requirements.

Author contributions

XH: Funding acquisition, Supervision, Writing – review & editing. RA: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. SA: Formal analysis, Investigation, Resources, Writing – review & editing. PG: Data curation, Formal analysis, Methodology, Writing – review & editing. MA: Project administration, Writing – review & editing. GB-M: Software, Writing – review & editing. EA: Investigation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1364052/full#supplementary-material

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