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RESEARCH ARTICLE

Understanding Thai Consumers' Intentions to Purchase Genetically Modified Foods

Bing Zhu [*] ***, Ananya Phunthasaen, Chainarong Rungruengarporn, Salila Pinpak***

Department of Marketing, Assumption University, Bangkok 10240, Thailand

ABSTRACT

This research explored the various factors affecting the purchase intention of Thai consumers towards genetically modified foods. To ensure the reliability of our findings, we conducted an extensive online survey in Bangkok over the course of three months, from June to August. The data analysis was mainly based on partial least squares structural equation modelling (PLS-SEM), a robust method for analyzing complex relationships. The results of the analysis confirmed the validity of all the hypotheses, with the exception of the direct relationship between food labels and purchase intention. Additionally, we found that all the mediation effects were statistically significant. In the study, we delve into a comprehensive discussion of the results and their corresponding implications, providing a thorough understanding of the factors influencing consumer behavior in the context of biotechnology and food choices.

Keywords: Genetically Modified Foods; Consumer Knowledge; Food Labels; PLS-SEM; Risk; Benefits

1. Introduction

With the ongoing global population growth, the demand for food continues to rise. Simultaneously, environmental degradation and climate change present considerable challenges to traditional food production [1]. In response to these challenges, biotechnology has been widely employed in agriculture, leading to increased food production, enhanced nutritional quality, and a

*CORRESPONDING AUTHOR:
Bing Zhu, Department of Marketing, Assumption University, Bangkok 10240, Thailand; Email: bingzhu@msme.au.edu

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wider range of consumer choices [1–4]. It can be argued that biotechnology's role in agricultural development is not merely a passing trend but rather a pivotal factor that provides reassurance about the future of agriculture [5]. Remarkably, the utilization of genetically modified organisms (GMOs) resulting from advancements in biotechnology warrants our careful attention [6–8].

World Health Organization (2014) [9] defines genetically modified organisms (GMOs) as "organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination." Per definition, foods that are derived from or incorporate genetically modified organisms (GMOs) are commonly categorized as genetically modified (GM) foods [9]. In general, the development of GM crops and GM foods is regarded as having promising potential. The International Service for the Acquisition of Agri-biotech Applications (ISAAA), which is a non-profit international organization committed to improving the lives of resource-poor farmers in developing countries by spreading the advantages of emerging bioscience technologies, highlights the widespread international acceptance of GM crops for cultivation and/or import, with approximately 46 countries granting approval since their initial commercialization in the United States in 1996 [10]. Notably, a coalition of Nobel laureates has strongly advocated for GMOs endorsement, emphasizing their role in uplifting developing nations [11, 12], particularly in terms of potential benefits, including increased crop yields, insect resistance, drought resistance, and high nutritional value [11, 13].

The continuing global development of GMOs [14] highlights the significance of consumer attitudes and consumption patterns towards GMOs in shaping the future economy [15]. It is important to note that consumers hold varying perspectives and preferences towards GM foods. On the one hand, the demand for GM foods has been steadily increasing [16], leading to the global GM food market reaching $109.17 billion in 2023 [17]. The market is anticipated to exhibit steady growth, characterized by a projected compound annual growth rate of 6.5%, ultimately reaching a valuation of $196.52 billion by the year 2033 [17, 18]. Interestingly, the AgbioInvestor GM Monitor highlighted the dominance of North America as the primary exporter of genetically modified crops, with Europe closely following as the second-largest market [19]. Furthermore, there are exciting growth prospects in the Asia Pacific region from 2022 to 2029 [20]. This expansion is attributed to a burgeoning population and amplified demand for nutritious and functional foods [18, 21]. More importantly, businesses are striving to stay ahead of the competition by implementing state-of-the-art technologies in the cultivation and production of crops [22, 23].

On the contrary, it is vital to acknowledge and address consumer concerns regarding the potential impact of GM foods on the environment, long-term health, food safety, sustainability, and ethics [11, 24, 25]. For instance, according to a survey conducted across 20 countries, 48% of respondents believe that GM foods may not be entirely safe [26]. In several Southeast Asian countries, such as Myanmar, Vietnam, and the Philippines, GMO biotechnology has notably been accepted [27], while the stance of Thai consumers towards GMOs has evolved over time, with a decreasing level of opposition [28]. This shift is evident from the decline in the average discount of GM food, which decreased from 6.74% in 2009 to 3.08% in 2021 [28]. This underscores the necessity for more research in emerging markets such as Thailand, where consumer behavior towards GM foods may differ significantly. In the midst of this enduring debate, a valuable opportunity emerges to gather profound consumer insights. It is imperative to thoroughly grasp and analyze consumer responses to GM foods to make well-considered and informed decisions.

Prior studies have exhibited that consumer attitudes and purchasing behavior are influenced by various factors, including demographics, knowledge of GM foods that consumers possess, consumer perceptions, and institutional settings (such as labelling schemes, scientific authority, and regulations) [1, 29–33]. It is quite intriguing that the majority of past scholarly inquiries into the acceptance and attitudes toward GMOs have been primarily centered on the United States and Europe, with a minimal investigation conducted in developing nations [34]. Consequently, there is merit in delving into consumer behaviors in underdeveloped markets.

Thailand has been actively involved in GMO biotechnology since the 1990s, although its implementation of biosafety legislation and adoption of GM crops have been slower than other countries in the region [27, 35, 36]. As a result, Thailand mainly imports GM crops [37]. Starting from 2003, Thailand made it mandatory to label genetically modified (GM) food products [10]. In 2022, the country updated its food labeling regulations to necessitate disclosure of the presence of genetically modified substances (GMOs) [10]. Moreover, if a product contains a single genetically modified ingredient, the label must prominently display "genetically modified" alongside the product's name [10, 38]. In the dynamic landscape of Thailand, a substantial body of research, spanning a period of two decades, has been devoted to genetic engineering, focusing primarily on augmenting the yield of genetically modified crop production [36]. Despite this extensive focus, there remains a research gap pertaining to consumer perspectives on this topic [28]. Consequently, our objective is to address this void by delving into consumer attitudes and purchasing intentions regarding GM foods in the context of Thailand since the interplay between attitudes and behavior has been the subject of research interest for over two decades [39–41].

In recent years, there has been a growing concern about the impact of food consumption on health and well-being [42, 43], particularly concerning novel food products such as genetically modified (GM) foods. Stakeholders have expressed both potential benefits and concerns about associated risks with the introduction of GM foods. Therefore, this study aims to integrate established models from the realm of consumer behavior, specifically the Theory of Reasoned Action (TRA) and the Net Valence Model (NVM), to construct the theoretical framework of this paper. Furthermore, consumer knowledge is essential to "theoretical models of consumer behavior and marketing practices" [44] and could shape consumer perception [45]. For this reason, consumer knowledge has been integrated into developing the research model to understand how consumers' knowledge might impact their assessment of the benefits and risks associated with GM foods. For instance, Hwang and Nam (2021) [1] integrated the concept of consumer knowledge with the Net Valence model, which includes consumer risk and benefit perception. This integration provided evidence that consumer knowledge plays a critical role in influencing consumer perception of GM (genetically modified) foods and shed light on the intricate interplay between consumer knowledge, risk perception and benefit perception regarding GM foods. Thus, following this rationale, the investigation in this study will delve into consumer knowledge, perceived benefits, perceived risks, food labelling, and attitudes to unveil their influence on the purchasing inclinations of Thai consumers towards GM foods. As part of this endeavor, we have developed the following objectives:

1) To disclose the influence of consumer knowledge on consumers' perception towards GM foods (perceived benefits and perceived risks)

2) To test the relationship between consumers' perception (perceived benefits and perceived risks) and their attitude towards GM foods

3) To reveal the role of GM food labels in influencing consumer attitude towards GM foods and consumer purchase intention

4) To examine the connection between consumer attitude towards GM foods and consumer purchase intention for GM foods

2. Literature Review

2.1. Theory of Reasoned Action (TRA)

The current research is grounded in the Theory of Reasoned Action (TRA), a highly influential framework for examining consumer behavior [46, 47]. The theory revolves around understanding whether an individual's likelihood to engage in a specific behavior is shaped by their attitude toward that behavior or object, as well as by the impact of others within their social environment [47, 48]. According to TRA, the more determined a person is to do something, the greater the likelihood they will follow through with the behavior in the future [49]. Webster et al. (1994) [50] suggest that consumer behavior is rooted in behavioral intentions, which, in turn, are influenced by consumer attitudes. It is crucial to recognize that an individual's attitude mirrors their perceptions of the potential consequences and outcomes of a specific situation or their actions, revealing a tendency

towards either positivity or negativity [51, 52]. For example, Bray and Ankeny (2017) [53], Xu et al. (2020) [54], and Vindigni et al. (2022) [55] have each delved into the pivotal role of consumer attitudes in influencing consumer behavior regarding GM foods.

The TRA is widely utilized to comprehend consumer behavior, mainly focusing on consumer attitudes towards products, brands, individuals, or societal issues [56]. In particular, the theory of reasoned action (TRA) has been employed by various scholars to examine consumer decision-making concerning the consumption of GM foods across diverse global markets. Noteworthy applications include studies on consumer purchasing intention in Lithuania [57], consumer attitudes in China [54, 58], consumer perceptions in the US [59], and consumer segmentation in the US [60], among others. Consequently, this study also adopts the TRA to reveal the substantial role of attitude in influencing consumer inclinations toward purchasing GM foods.

2.2. The Net Valence Model (NVM)

The Net Valence Model (NVM) was originally proposed by Peter & Tarpey in 1975 and serves as a conceptual framework for analyzing consumer behavior with regard to products, services, and behaviors [61]. It revolves around the holistic assessment of benefits and risks in determining the net price, which signifies the overall attractiveness of a specific option [62] The NVM elucidates how consumers perceive and evaluate the associated risks and benefits of a product or service, thereby influencing their acceptance [63]. Broadly, individuals with heightened risk perception are less inclined to partake in a specific behavior, while those with lowered risk perception are more likely to show intent to engage in it [64]. On the basis of this rationale, this research postulates that consumers' collective perceptions tend to impact their attitudes toward genetically modified foods, consequently influencing their purchase intentions. Furthermore, the NVM has gained widespread recognition for its efficacy in elucidating variations in consumer decision-making as it takes into account benefits, risks, and uncertainty expectations concurrently [65]. Hence, scholars have applied the NVM in various studies, encompassing e-waste recycling in Japan [62], cross-border e-commerce in China [66], fintech in Jordan [67] and Brazil [63], and e-health in South Africa [68], etc.

2.3. Consumer Knowledge

Understanding how consumers perceive GM foods from the aspects of benefits and risks requires a deep dive into their knowledge of GM technology [69]. The level of knowledge consumers possess significantly shapes their bias and intent toward GM foods [1, 70]. For instance, research by Zhou and Tian (2003) [71] as well as Huang et al. (2006) [72] demonstrates that as consumers in China become more knowledgeable about GM foods, they tend to exhibit greater receptivity. Conversely, studies conducted in European countries, the USA, and Japan suggest that as consumers are better informed about GM foods, they are less likely to embrace them [8, 73]. Moreover, a study by López et al. (2016) [74] highlights that consumers in Mexico with less information tend to have lower knowledge about GMOs and perceive higher risks. Therefore, exploring the extent to which Thai consumers' knowledge could influence their perceptions becomes a compelling area of study in this emerging market. Above-mentioned findings underscore the crucial role of consumer knowledge in shaping the acceptance of GM foods, forming the cornerstone of our hypotheses.

H1a. *Consumer knowledge significantly affects consumers' perceived risk.*

H1b. *Consumer knowledge significantly affects consumers' perceived benefit*.

2.4. Consumer Perceptions of GM Foods

The utilization of genetically modified technology in agriculture has become widespread. It is important to acknowledge that many consumers may still be unfamiliar with or have a limited understanding of it [1, 75]. This lack of knowledge regarding the potential benefits and risks of genetically modified foods is not just a challenge but a significant barrier to their acceptance [1, 76, 77]. Consumers' acceptance of GMOs is significantly influenced by their perception of the risks and benefits associated with these products [32]. Although genetic engineering

has undeniably brought benefits to producers regarding "crop resilience and longevity," consumers often encounter difficulties in comprehending how GMOs impact individuals' health and dietary preferences [78].

On the one hand, perceived risk refers to the risks that an individual perceives associated with a particular event or behavior, normally representing uncertainty [79]. Risk perception influences individuals' attitudes and behaviors [80, 81]. It often leads to substantial changes in purchase decisions [82]. When individuals perceive lower risks, positive attitudes and stronger intentions toward GM foods and biotechnology companies will be generated, emphasizing the importance of addressing this issue [32]. On the other hand, perceived benefit plays a significant role in influencing consumers' purchasing behavior, as highlighted by Kim et al. (2008) [83]. It encompasses the beliefs about the positive results related to a particular behavior, as explained by Liu et al. (2013) [84] and Chandon et al. (2000) [85]. Studies indicate that as consumers acquire more knowledge about GMOs, the advantages of consuming GM foods are starting to be viewed as more significant than the potential drawbacks [1, 75]. The perceived advantages of a product or service significantly influence consumers' perceptions and attitudes. Thus, gaining a comprehensive comprehension of the product or service typically results in more positive views grounded in these perceived benefits [1, 86]. These findings form the foundation of our hypotheses.

H2a. *Consumers' perceived risk significantly affects consumers' attitudes towards GM foods.*

H2b. *Consumers' perceived benefits significantly affect consumers' attitudes towards GM foods.*

2.5. Label

The debate about the inclusion of GM foods in our diets has been ongoing [87]. Genetic modification technology has increased use in the food industry [88]. Media coverage and sensationalized health concerns have led to misconceptions and uncertainty among consumers [59]. In this context, the act of labeling is not only desirable but essential. As Zafar et al. (2023) [33] pointed out, labels are fundamental in conveying information to customers about food characteristics.

Labels are indicated as "any words, trademarks, brand names, pictorial matter, or symbols related to food, placed on packaging, documents, notices, or accompanying the food" [89]. Food labels have been crucial in ensuring food safety [90]. Furthermore, label information is the most effective tool for reducing consumer uncertainty [91] and assisting consumers in making informed food choices [33, 85]. Interestingly, most food manufacturers tend to avoid labelling GM foods [59]. This lack of appropriate labeling contributes to consumer knowledge gaps about GM foods, a gap that our research aims to address. Previous studies have demonstrated the varying impact of food labeling on consumer attitudes and buying intentions. Escandon-Barbosa & Rialp-Criado (2019) [92] highlighted the pivotal role of labelling in shaping consumer buying intentions for wine products, while Zafar et al. (2023) [33] emphasized the significant influence of food labels on consumer attitudes and purchase intentions. In the context of GM products, López et al. (2016) [74] and Jiang & Zhang (2021) [93] revealed a positive correlation between meticulous reading of product labels, increased inclination to purchase, and heightened trust in genetically modified products. In contrast, extant research suggests that consumers are willing to incur higher costs to steer clear of GM-labeled foods [94, 95]. Given Thailand's status as an emergent market for GM foods, limited insights exist regarding the impact of labeling on consumer attitudes and buying intentions towards GM foods. As such, the following hypothesis has been formulated:

H3a. *Food label significantly affect consumers' attitudes towards GM foods.*

H3b. *Food label significantly affect consumers' purchase intention for GM foods.*

2.6. Attitude

The term "attitude" encompasses an individual's psychological orientation, manifested through the degree of inclination or disinclination toward a specific object [96]. Research has documented the significant influ-

ence of consumer attitudes toward food and nutrition on their purchasing and consumption behaviors [97, 98]. The TRA [47, 99, 100] postulates that individuals' attitudes play a crucial role in shaping their behavior by affecting their behavioral intentions [57].

In the realm of genetically modified (GM) foods, understanding whether consumers like or dislike GM foods is extremely important because it helps us grasp the significant value associated with their preferences. This comprehension is pivotal for apprehending the controversy and devising effective public policies and marketing strategies [8, 101, 102]. Consumer skepticism of GM foods is notably influenced by their attitudes towards GMOs [1]. Numerous sources have raised concerns regarding potential harm to the environment, public health, and food safety through the consumption and production of GM foods [103]. These concerns have detrimentally impacted consumer perceptions, resulting in unfavorable attitudes towards genetically modified foods [104–107]. Additionally, prior studies have demonstrated substantial variations in consumer attitudes towards GM foods across diverse cultures and geographical regions globally [108, 109]. In Europe, consumers have widely expressed their disapproval of the inclusion of genetically modified organisms (GMOs) in their food products, in addition to maintaining negative perceptions of the utilization of genetic modification in food production [34, 110]. In contrast, consumers in developed markets (e.g., the United States) and many developing nations have shown a more open attitude towards GM foods, which can lead to productive discussions and potential advancements in agricultural practices [111, 112]. Consequently, the subsequent hypothesis is formulated:

H4. *Consumers' attitude towards GM food significantly affects their purchase intention for GM foods.*

2.7. Purchase Intention

The term "intention" in the context of consumer behavior encompasses the probability or inclination of a consumer to buy a particular product or service [113]. It serves as a measure of consumers' planned or intended purchase decisions based on their perception, attitude toward the product, perceived value, and external influences [114]. It is essential to distinguish purchase intention from purchase desire, as the former represents the subjective willingness of consumers to pay for products or services [115, 116]. When consumer impressions or attitudes align with their expectations, purchase intention is activated [117]. Notably, purchase intention is widely recognized as a consistent predictor of purchase behavior [116]. The present study illustrated in **Figure 1** attempts to unpack the impact of various factors, including consumer knowledge, consumer perception, food labels, and consumer attitudes, on the purchase intentions of Thai consumers regarding GM foods, through an analysis of structural relationships. Accordingly, the conceptual framework is constructed as follows:

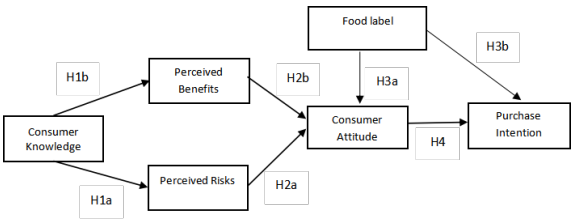

Figure 1. Conceptual framework.
Source: developed by authors (2024) based on the previous studies [74, 112, 118–120].

3. Research Design

Prior to conducting data collection, the research team obtained ethical approval from an Institutional Review Board (IRB) committee. The committee thoroughly evaluated the research proposal, participant information, and consent form to protect "the rights, dignity, and welfare of the study respondents" [121]. A comprehensive online consent form was developed to guarantee that participants were well-informed about the study and had the freedom to decide whether or not to take part [122].

Before commencing large-scale data collection, a pre-test was carried out to assess the internal consistency of the measurement items and to pinpoint any potential biases. This process allowed for necessary adjustments to be made. A reliability test was conducted, confirming that all constructs attained a Cronbach Alpha value greater than 0.7, thereby establishing the internal consistency of the measurement items [123]. Subsequently, the bustling and dynamic city of Bangkok was the setting for online data collection activities carried

out between June and August 2024. It is essential to highlight our intention to employ an online survey that ensures the anonymity of respondents as a proactive measure to tackle the prominent issue of social desirability bias in our data collection process. Social desirability bias is a phenomenon where individuals may be inclined to suppress socially undesirable attitudes and behaviors while accentuating socially desirable characteristics [124]. This method fosters a secure and non-judgmental space for participants, thus encouraging them to express their opinions candidly and without reservation [125]. Utilizing state-of-the-art online platforms, we employed a convenient sampling technique to capture a diverse and comprehensive range of insights.

In light of the exploratory nature of the study, a partial least squares structural equation model (PLS-SEM) was utilized for the purpose of statistical analysis. In order to attain a statistical power of 0.90, it is necessary to use an effect size of 0.15 [126]. Consequently, G*Power analysis determined that 116 valid questionnaires need to be collected to meet these statistical requirements. The questionnaire design encompassed four items on purchase intention [118], six on food labels [119], six on consumer attitudes towards GM foods [112], six on consumer knowledge of GMOs [74], along with six items each on perceived benefits and perceived risks [74, 120]. The questionnaire is provided in **Appendix A**. For data analysis, PLS-SEM was adopted for path analysis, and the influence of the mediators was appraised through the application of the bootstrapping technique [127].

4. Results

This study benefitted from 382 valid questionnaires that provided com_prehensive information. The findings of respondents' profiles have been thoroughly analyzed, and the measurement and structural models were meticulously assessed using SmartPLS 4 [128]. Furthermore, the mediation effect was carefully examined by implementing the Bootstrapping method.

4.1. Respondent Profile

In our recent survey, we found that a majority of the respondents, 57.6%, were female. The survey revealed that 75.4% of the respondents were from Generation Z, 22% were from Generation Y, and the rest were from Generation X. According to Kotler et al. (2021) [129], Generation X, also known as Gen X, encompasses individuals born between 1965 and 1980. Generation Y, or Millennials, includes those born between 1981 and 1996, while Generation Z, sometimes referred to as Gen Z, consists of individuals born between 1997 and 2009. When it comes to income, 34.6% reported earning less than 15,000 Thai baht per month, while 28.5% reported a monthly income ranging between 15,000 and 25,000 Thai baht. Furthermore, 78.8% of the respondents have a university-level educational background, with 46.3% currently being university students and 41.1% employed in the private sector.

4.2. Assessment of Measurement Model

4.2.1. Convergent Validity and Internal Consistency

The outcomes of the convergent validity and internal consistency tests are presented in **Table 1**. Convergent validity is assessed based on factor loading and the Average Variance Extracted (AVE), which is a frequently utilized metric for validating constructs in statistical analysis and quantifying the proportion of variance explained by a construct relative to the variance resulting from measurement error [130]. Regarding factor loading, three items (FLB2, FLB5, FLB6) were deleted due to a lower value than 0.6, which could damage the AVE performance in the construct. After that, all factor loadings are more significant than 0.7 except for KNOW 4 (0.682), which is still acceptable since it does not significantly affect the AVE value [131, 132]. Each of the constructs displays an AVE value higher than 0.5, indicating that a substantial amount of the variance in the indicators is captured by their respective constructs [133–135]. In assessing internal consistency, researchers often use measures, including "Cronbach's alpha, composite reliability (CR), and Dijkstra–Henseler's rho_A" [131, 136]. The Cronbach's alpha values in this study range from 0.720 to 0.903, all exceeding the recommended threshold of 0.7 suggested by Nunnally and Bernstein (1994) [137]. Additionally, all CR values meet the 0.7 threshold as well [107].

As for Rho_A, it is emphasized as a crucial and stable criterion to assess internal consistency reliability, particularly in PLS-SEM [131, 133]. In this study, all constructs demonstrate a Rho_A value greater than or equal to 0.7 [132]. To conclude, the values presented in **Table 1** affirm the validity and internal consistency of the data.

Table 1. Construct validity and reliability.

	Convergent Validity		**Internal Consistency**		
Construct	**Factor Loading**	**AVE**	**Cronbach's Alpha**	**rho_A**	**CR**
Attitude		0.643	0.888	0.890	0.915
ATT1	0.814				
ATT2	0.774				
ATT3	0.798				
ATT4	0.855				
ATT5	0.762				
ATT6	0.803				
Consumer Knowledge		0.553	0.837	0.841	0.881
KNOW1	0.716				
KNOW2	0.692				
KNOW3	0.796				
KNOW4	0.682				
KNOW5	0.786				
KNOW6	0.781				
Food Label		0.641	0.720	0.721	0.843
FLB1	0.798				
FLB3	0.777				
FLB4	0.826				
Perceived Benefits		0.661	0.897	0.898	0.921
PB1	0.809				
PB2	0.824				
PB3	0.840				
PB4	0.792				
PB5	0.807				
PB6	0.806				
Perceived Risks		0.675	0.903	0.906	0.925
PR1	0.763				
PR2	0.749				
PR3	0.818				
PR4	0.874				
PR5	0.862				
PR6	0.854				
Purchase Intention		0.733	0.878	0.879	0.916
INT1	0.832				
INT2	0.845				
INT3	0.880				
INT4	0.866				

4.2.2. Discriminant Validity

It is of great significance to acknowledge that if the utilization of PLS is preferred, assessing discriminant validity involves looking at the Heterotrait-Monotrait (HTMT) ratio of correlation [118], instead of applying the classical Fornell–Larcker criterion [133]. Accordingly, HTMT represents "the average value of the item correlations across constructs relative to the (geometric) mean of the average correlations for the items measuring the same construct" [134]. The cut-off threshold value of HTMT is recommended to be less than 0.9 [133, 134], and

the HTMT values in **Table 2** are all below the threshold of 0.9, which provides confirmation that discriminant validity has been achieved.

Table 2. Heterotrait-monotrait ratio (HTMT).

	ATT	CKNOW	FLB	INT	PB	PR
ATT						
CKNOW	0.614					
FLB	0.268	0.178				
INT	0.715	0.664	0.138			
PB	0.702	0.732	0.107	0.765		
PR	0.138	0.248	0.177	0.097	0.104	

4.3. Assessment of Structural Model

4.3.1. Collinearity and Path Coefficients

Table 3 firstly illustrates that the variation inflation factor (VIF) values for all variables are below the threshold of 5, suggesting no significant multicollinearity among the variables in the analysis [134]. Secondly, hypothesis testing based on the path coefficient (β), which measures the strength of the relationship between the independent variable and the dependent variable, as well as the t-value and p-value, revealed that only hypothesis H3b was rejected out of all the hypotheses tested. This means that food labels do not significantly affect consumers' intention to buy GMO food. The vital relationships are found between consumer attitude and consumer's purchase intention (β=0.638, t=16.768), followed by consumer knowledge and perceived benefit (β=0.632, t=18.774), perceived benefit and consumer attitude (β=0.623, t=17.875), food labels and consumer attitude (β=0.204, t=5.78), consumer knowledge and perceived risk (β=0.207, t=3.435), and perceived risk and consumer attitude (β=−0.172, t=3.435). In addition, a negative relationship between perceived risk and consumer attitude implies that as long as the risk of consuming GMO food perceived by consumers is low, a more positive attitude will be cultivated among consumers. **Figure 2** provides the structural modelling test results by exhibiting path coefficients and t-values.

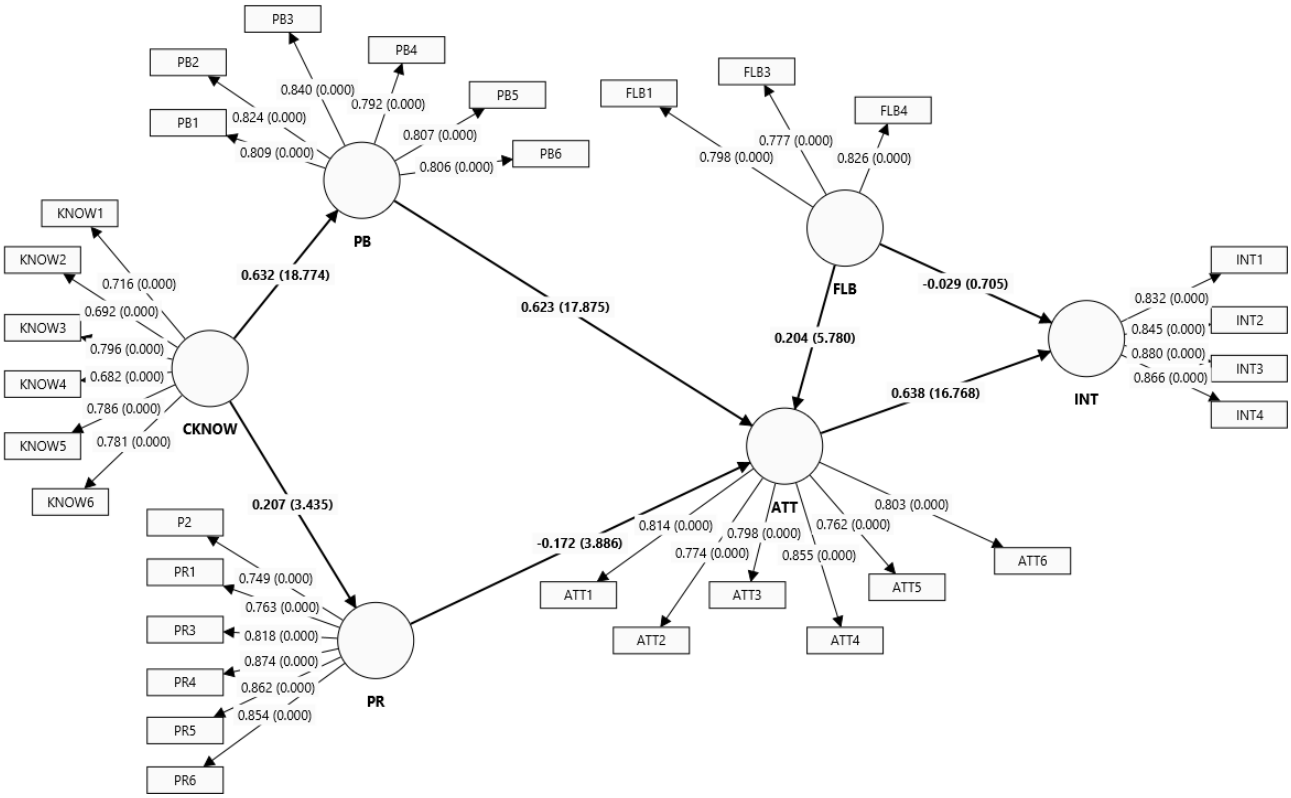

Figure 2. Structural model presenting path coefficients and t-values.

Table 3. Collinearity and path coefficients.

Hypothesis	Path	VIF	Path Coefficient (β)	T-Value	95% Confidence Intervals	P	Decision
H1a	CKNOW -> PR	1	0.207	3.435	[0.092, 0.324]	***	Accept
H1b	CKNOW -> PB	1	0.632	18.774	[0.562, 0.695]	***	Accept
H2a	PR -> ATT	1.021	−0.172	3.886	[−0.257, −0.085]	***	Accept
H2b	PB -> ATT	1.004	0.623	17.875	[0.551, 0.688]	***	Accept
H3a	FLB -> ATT	1.023	0.204	5.78	[0.134, 0.272]	***	Accept
H3b	FLB -> INT	1.047	−0.029	0.705	[−0.111, 0.050]	0.481	Reject
H4	ATT -> INT	1.048	0.638	16.768	[0.559, 0.708]	***	Accept

*Note: *** p < 0.01.*

4.3.2. In-Sample Prediction

In PLS-SEM, the coefficient of determination, R2, is identified as "in-sample predictive power"[134, 138]. The higher the value of R2, the stronger the explanatory power[134]. According to the guidelines of Henseler et al. (2009)[139] and Hair et al. (2011)[140], "R2 values of 0.75, 0.50 and 0.25 can be considered substantial, moderate and weak"[134]. In this study, the values of R2 for consumer attitude, intention, and perceived benefits are 0.455, 0.401, and 0.4, which explain a moderate in-sample explanatory power. As for perceived risk, the R2 value of 0.043 exhibits a weak explanatory power.

4.3.3. Out-of-Sample Prediction

In marketing research, practical relevance plays a crucial role in driving constructive outcomes[141–143]. When using PLS-SEM, it is strongly advised to incorporate out-of-sample prediction as part of model evaluation, as it is considered an effective way to assess the "model's practical relevance"[144]. To this end, PLSpredict, proposed by Shmueli et al. (2016)[145], is used to evaluate the out-of-sample predictive power of the proposed model in this study. It is worth noting that "to date, research has not yet developed clear guidelines for using PLSpredict, which hinders its application"[146]. Thus, in this study, we followed the guidelines of Hair et al. (2019)[134] and Shmueli et al. (2016)[145] to interpret the results of PLSpredict in **Table 4**, in which 10-fold is applied to unpack the predictive power of endogenous constructs (perceived benefits, perceived risks, consumer attitude, purchase intention).

First, the naïve benchmark Q2predict is evaluated, with all values greater than 0. Therefore, we can conclude that the prediction error from the PLS model is lower than the prediction error from the most naïve benchmark[144]. Additionally, all the values of the Root Mean Squared Error (RMSE) are higher than that of Q2predict, again confirming that "PLS-SEM-based predictions outperform the most naïve benchmark"[144]. Next, the RMSE values in PLS-SEM are compared with those of the naïve LM (linear regression model) benchmark. Based on the guidelines proposed by Shmueli et al. (2019)[144], the model in the study exhibits low predictive power, as the indicators in PLS-SEM consistently yield values that demonstrate considerable improvement over the naïve LM benchmark.

Table 4. PLSpredict assessment of manifest variables.

	PLS-SEM		LM	PLS-SEM-LM
	Q2 Predict	RMSE	RMSE	
ATT1	0.173	0.962	0.965	−0.003
ATT2	0.164	1.034	1.029	0.005
ATT3	0.165	0.915	0.914	0.002
ATT4	0.207	1.023	1.004	0.019
ATT5	0.185	0.906	0.876	0.030
ATT6	0.198	0.945	0.924	0.021
INT1	0.127	0.957	0.935	0.022
INT2	0.143	0.937	0.915	0.022
INT3	0.185	0.912	0.857	0.055
INT4	0.170	0.920	0.881	0.039
PB1	0.397	0.887	0.888	−0.002
PB2	0.280	0.884	0.893	−0.009
PB3	0.245	0.888	0.894	−0.006
PB4	0.204	0.880	0.889	−0.009
PB5	0.221	0.863	0.872	−0.009
PB6	0.220	0.852	0.849	0.004
PR1	0.029	0.915	0.908	0.006
PR2	0.056	0.970	0.956	0.014
PR3	0.047	0.961	0.949	0.012
PR4	0.022	1.015	1.021	−0.006
PR5	0.001	1.029	1.019	0.010
PR6	0.011	1.053	1.047	0.005

4.4. Mediation Test

Furthermore, mediation effects of consumer attitude (ATT), perceived benefits (PB), and perceived risks

(PR) are explored. As shown in **Table 5**, all paths are significant, as the 95% bootstrapped confidence interval bias-corrected values do not include zero [147]. Hence, it confirms the significant mediating roles of consumer attitude, perceived benefits, and perceived risks. More importantly, the most robust mediation effects are found when perceived benefits mediate the relationship between consumer knowledge and consumer attitude [CKNOW -> PB -> ATT], and attitude mediating the relationship between perceived benefits and consumer intention [PB -> ATT -> INT].

Table 5. Mediation test.

Relationships	Std. Beta	Std. Error	T-Values	95% Confidence Intervals	P Values	Decision
FLB -> ATT -> INT	0.130	0.023	5.681	[0.087, 0.175]	***	Accept
CKNOW -> PR -> ATT -> INT	−0.023	0.008	2.836	[−0.042, −0.010]	**	Accept
PB -> ATT -> INT	0.397	0.039	10.281	[0.319, 0.470]	***	Accept
PR -> ATT -> INT	−0.109	0.030	3.674	[−0.169, −0.054]	***	Accept
CKNOW -> PB -> ATT -> INT	0.251	0.030	8.323	[0.195, 0.313]	***	Accept
CKNOW -> PR -> ATT	−0.035	0.012	2.916	[−0.065, −0.016]	**	Accept
CKNOW -> PB -> ATT	0.394	0.034	11.448	[0.328, 0.461]	***	Accept

*Notes: *** p < 0.01; ** p < 0.05.*

5. Discussion and Conclusions

This research is among the few consumer studies focusing on genetically modified foods in Thailand. Its goal is to research how consumer knowledge, perceived benefits, perceived risks, consumer attitude, and food labels influence consumer purchase intentions for GM foods. The study also confirms the significant mediating roles of consumer attitude, perceived benefits, and perceived risks. Notably, several important issues require attention.

The research reveals that food labels do not have a direct impact on purchase intention (H3b), contrary to previous studies such as Rahman et al. (2020) [148] and Alsini et al. (2023) [149]. Instead, they influence purchase intention through consumer attitude, which corresponds to the study of Zafar et al. (2023) [33]. This finding reveals that consumers' choices regarding GM foods in the Thai market are not significantly and directly swayed by the details provided on the label. The lack of direct impact of food labels on consumer purchase intention for GM foods in Thailand may be influenced by various factors, including the level of awareness about GM ingredients, trust in regulatory bodies, etc. This finding represents a significant contribution as it sheds light on the potential for food labels to serve as a pivotal influencer in the decision-making process of consumers with regard to genetically modified (GM) foods. This information can be highly beneficial for businesses and policymakers aiming to develop strategies and frameworks enabling food labels to shape consumer choices in the context of GM foods effectively.

Next, a significant negative relationship between consumers' perceived risks and their attitude (H2a) is found, which supports previous studies by Choi et al. (2013) [43] and Guo et al. (2020) [150]. Bauer (1967) [151] emphasized that risk is generally a part of consumers' decision-making process. In the context of genetically modified (GM) foods, consumers may harbor apprehensions pertaining to potential health risks, environmental ramifications, and ethical considerations associated with GMOs. As their perception of these risks diminishes, their attitudes tend to become more favorable, thereby resulting in a heightened inclination towards making a purchase. (PR -> ATT -> INT). Similarly, when consumers strongly believe that consuming GM food will have positive outcomes, they tend to have a positive attitude (H2b). Additionally, as consumers become more informed about GM foods, they are more likely to believe that the benefits outperform the risks (CKNOW -> PB -> ATT) [1, 75]. Thus, it is crucial for practitioners to devise strategies aimed at reducing consumer risk perception in this context.

Additionally, the study has found a strong connection between attitude and intention (H4), supporting the classic Theory of Reasoned Action (TRA), which suggests

that a more assertive attitude leads to a higher intention [46]. This result highlights the enduring relevance of this theory, making it a fundamental framework for analyzing consumer behavior across different times and locations.

6. Implications

This section offers closure for the paper. An effective conclusion will need to sum up the principal findings of the paper, highlighting their importance and relevance and their implications for further research.

6.1. Theoretical Implications

The integration and application of the net price model and TRA have significantly advanced consumer research in the field of food consumption in Thailand. The results not only contribute to the existing literature but also provide strong validation for the applications of the two theories. They underscore the crucial roles of consumer knowledge, perception, and attitude towards GM food products in shaping consumers' purchase intentions. Moreover, this study sheds light on the influence of food labels on consumer purchase intentions through consumer attitudes, highlighting the importance of nurturing positive attitudes towards GM foods to enhance the promotion of GM food products in the Thai market. By integrating these insights, this study enriches the theoretical framework of consumer behavior related to GM foods in Thailand, which could be a valuable reference for academics in other Southeast Asian countries.

6.2. Practical Implications

Businesses and policymakers have an opportunity to enhance food labelling, consumer education, and communication strategies to emphasize the benefits of GM foods and address consumer concerns and perceived risks. Clear and distinct labelling of products containing GM ingredients is crucial, and ensuring that the information is easily readable and understood by consumers is equally important.

To enhance consumer perception, packaging can incorporate QR codes that provide access to comprehensive information about genetically modified (GM) ingredients, including their advantages, potential risks, and the regulatory procedures they undergo. This strategy has the potential to diminish perceived risks and heighten the perceived benefits of GM foods. From a stakeholder standpoint, it is crucial to prioritize transparent communication and education about GMOs. Furnishing clear and easily accessible information regarding the safety, benefits, and regulations associated with GMOs can help address consumer concerns and potentially shift attitudes. Engaging with consumers and addressing their specific concerns can also aid in fostering trust and improving attitudes towards GMOs. Furthermore, involving stakeholders in open dialogues and decision-making processes can yield more inclusive and well-informed perspectives on GMOs.

Consumer education is incredibly important in influencing how consumers feel about GMO foods. It's essential to communicate effectively through a variety of channels such as social media, websites, in-store displays, and brochures in order to create a positive image around GM foods. By partnering with influencers, nutritionists, and credible sources, we can not only spread these messages more widely, but also help people understand what GMOs actually are, ultimately shaping public opinion in a more positive way.

By implementing these practical strategies, stakeholders can work toward cultivating more positive consumer attitudes toward GM foods, as suggested by the study's findings. Future research could further explore the long-term impact of these efforts on consumer behavior and market trends, providing additional insights for refining policies and marketing strategies.

6.3. Societal Implications

Understanding the above-mentioned findings can help various groups, including the government, consumers, farmers, and non-profit organizations, take steps to ensure the responsible adoption and acceptance of GM food. This can benefit society by leading to a more informed and healthier population. Educating consumers about the benefits of GM food can lead to more accepting attitudes toward scientific advancements in agriculture and food production, resulting in better di-

etary choices and improved public health.

The government also needs to implement policies promoting transparency and education about GM food. This includes mandating clear labels on GM food products and organizing public education campaigns to emphasize their benefits and safety. These efforts can help address public concerns and increase acceptance and consumption of GM food, ensuring an adequate food supply to meet market demand.

Besides, Non-profit organizations are crucial in bridging the gap between scientific research and public perception. They can advocate for transparent labelling and improved educational resources on GM food and collaborate with experts to disseminate accurate information, which can help build public trust and acceptance.

7. Limitations

The findings of this study carry a significant weight, but it is crucial to consider specific limitations when analyzing the results. To begin with, the questionnaire utilized in this study omitted safety-related inquiries about GMOs. This omission means that the study does not capture participants' perceptions and concerns regarding the safety of GMOs, which could influence their attitudes and acceptance of these organisms. To progress, it is recommended to embark on a qualitative study for our next research endeavour. Specifically, conducting in-depth interviews with consumers is desirable. This approach will provide invaluable insights into consumers' perceptions regarding GM foods' safety, thus enhancing our understanding of this significant subject.

Second, the study has certain limitations due to the use of a convenient sampling technique, which involves selecting participants based on their easy availability and accessibility. This approach raises concerns about the generalizability of the findings to the broader population, as the sample may not accurately represent the entire target population due to the lack of random selection [152]. It is important to note that the findings derived from this sampling method may not be reliably extended to the larger population [153]. Therefore, we recommend employing a simple random sampling technique in future research to ensure more representative and unbiased data collection.

Third, Thailand is currently experiencing a significant deficit in research that explicitly explores the implications of GMOs within its food sectors. This absence of research may affect the thoroughness of the study's background and results, as it may not fully capture local viewpoints and concerns regarding GMOs. Consequently, the conclusions may not be as widely applicable or relevant to contexts beyond the study's focus.

Additionally, due to the exploratory nature of the research in Thailand, the study would benefit from including the demographic characteristics of the respondents as control variables or moderators for a more comprehensive analysis. Future research could be explored further by incorporating different moderating variables or conducting multi-group analysis.

These limitations suggest that future research should address these gaps by including safety-related questions in surveys and exploring the topic further within the Thai context to provide a more robust understanding of GMOs and their societal implications.

Author Contributions

Bing Zhu: Conceptualization, Formal analysis, Investigation, Project administration, Validation, Visualization, Writing—original draft, Writing—review & editing; Ananya Phunthasaen: Investigation, Resources, Data collection, Organization, Writing—original draft, Writing—review and editing; Chainarong Rungruengarporn: Investigation, Data collection, Writing—original draft, Writing—review & editing; Salila Pinpak: Investigation, Data collection, Writing—original draft, Writing—review & editing.

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Data Availability Statement

Raw data were generated in Thailand. The questionnaire and derived data supporting this study's findings are available from the first author, Bing Zhu, on request.

Conflict of Interest

The authors report that there are no competing interests to declare.

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Appendix A. Questionnaire Used in the Study

Part I: General Information

1. Have you ever heard about genetically modified foods before?
   _____ yes [please continue] _____ No [No further, thank you]
2. Have you ever bought genetically modified foods before?
   _____ yes [No further, thank you]_____ No [please continue]

Part II: Factors related to consumers' buying behavior of vegetarian food

Purchase Intention (*adapted from Immonen & Luomala, 2017)*

- I would be ready to taste GM food products.
- I would be ready to consume GM food products regularly if they meet my demands in terms of taste, price, and other qualities.
- If GM food products were introduced into the local consumer market today, I would not delay purchasing them, at least for now (reversed).
- I prefer to buy GM food products in the near future.

Food labels (*adapted from Latiff et al., 2015)*

- Ingredient labels can create awareness of the food product quality
- I sometimes have difficulties in understanding scientific terms on the ingredient label
- The information on the label should be easily understood.
- I believe checking nutrition labels can lead me to a healthier choice.
- I am very concerned about the country of origin of the GMO logo.
- The variety of GMO logos in the market confuses me.

Consumer attitude towards GM foods (*adapted from Chen, 2011*)

- I can accept the pest-resistant GM foods
- I can accept the longer shelf-time GM foods
- I can accept oil from GM soybeans.
- I can accept the disease- or pest-resistant GM rice.
- I can accept the nutrition-improved GM rice.
- I can accept livestock fed by GM maise

Consumer Knowledge *(adapted from López et al., 2016)*

- I know what genetically modified organisms are
- I know some crops may become resistant to certain pests by genetic modification.
- I know the difference between "genetically modified organisms" and "conventionally modified organisms"
- I know what the GM food products are for human consumption.
- I know which GM food we eat in our country.
- I know a GM food product for human consumption that is imported into Thailand.

Perceived benefits *(adapted from López et al.,2016; Chang et al. (2017)*

- I know GM foods will benefit Thailand's environment.
- I think the production of GM foods will benefit me and my family.
- I think GM foods will help to improve the nutrition of Thais.
- I believe that GM foods have extra nutrition.

- I believe that GM foods have the advantage of helping the body absorb nutrition more efficiently.
- Generally, I believe that GM foods are beneficial.

Perceived Risks (*adapted from López et al., 2016)*

- I think the consumption of GM foods is a risk to the health of Thais
- I think that the cultivation of genetically modified crops will cause severe environmental damage in Thailand.
- I think GM foods will significantly affect my quality of life
- I think the consumption of GM foods could have adverse effects on my descendants.
- I think that the production and consumption of GM foods threaten human nature
- I think GM foods can cause diseases in my family

Part III: Demographic Information

1. What is your gender? _____
2. What is your age? I am_(____) years old
3. What is your monthly net income?
   a) _____
   b) Not specified
4. What is your highest educational level?_____
5. What is your employment status?
   a) Unemployed
   b) Private-sector employed
   c) Public-sector employed
   d) Government officer
   e) Student
   f) Self-employed
   g) Others_____