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The decision to buy genetically modified foods in China: what makes the difference?

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Abstract
Genetically modified (GM) food products have been commercialized and promoted in China. Despite assurances from the China Ministry of Agriculture that certified GM food products are safe to consume, most consumers are reluctant to purchase GM foods. Given the benefits of GM foods, this study investigates Chinese consumers' purchase intentions and purchase behavior toward GM foods and the associated influential factors. The theory of planned behavior with the consumers' demographics and product-related factors supports our study. Data were collected from 477 Chinese consumers across 26 provinces in China. The study uses binary logit regression and ordinal logit regression to estimate the relationship among variables. The results reveal that Chinese consumers' awareness, products' available information, trust in sellers, long product life, GM foods' taste and consumers' experience in buying GM food products are positively related to their willingness to buy GM foods. The number of family members, the habit of checking GM labels and a preference for nutrition value are associated with Chinese consumers' lower intention to buy GM foods. We demonstrate that product variety and trust are two determinants that could change Chinese consumers' attitudes toward buying GM foods. Our study contributes new insights into Chinese consumers' decision to purchase GM foods at the national scale. We consider a wide range of factors not tested in previous studies. Further, the study's findings provide a better understanding of consumers' GM foods purchases and purchasing behavior toward the Chinese government and entrepreneurs.

Keywords China · Genetically modified food products · Attitudes · Safety · Purchase intentions

1 Introduction

Genetically modified (GM) foods refer to those derived from genetic engineering technology that modifies the genetic material (DNA) of organisms in a way that does not occur naturally (World Health Organization—WHO, 2021). This agricultural technology was initially developed for crop protection from pests and diseases and improved nutritional

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value, thus reducing production costs and enhancing the productivity of agricultural products (Klümper & Qaim, 2014; López Montesinos et al., 2016; Zhu & Xie, 2015). Paarlberg (2010) and Gurău and Ranchhod (2016) add that GM food products could be a source of therapeutic substances that replace conventional medicines or vaccines, improve environmental quality and become a resolution of the worldwide food crisis, especially in low-income countries where farm productivity is low.

China was one of the first nations worldwide to commercialize GM technologies (Huang et al., 2017). In 1990, the Chinese started commercializing GM products with virus-resistant tobacco plants (Raman, 2017). Up to 2019, seven GM crops may be cultivated in China (Turnbull et al., 2021) but only cotton and papaya are widely grown (International Service for the Acquisition of Agri-biotech Applications—ISAAA, 2019). In 2019, China ranked seventh worldwide and second in Asia and the Pacific in terms of GM crop cultivation with 3.2 million hectares. From 1996 to 2018, it is estimated that GM technology brought US$23.2 billion of economic profit and made China the world's fifth largest country after the USA, Brazil, Argentina and India benefiting from GM crops (ISAAA, 2019). However, Chinese consumers have a low willingness to pay for GM foods (Zhan et al., 2020), although the Ministry of Agriculture has ensured since 2015 that all certified GM foods sold on the Chinese market are safe for consumers (Wang, 2015). Chinese consumers are not only concerned about the specific ingredients of GM food, but also whether GM foods contain allergens; studies found Chinese consumers are hostile toward GM foods because of their low-level of product knowledge (Ishii & Araki, 2016; Zhang et al., 2010). Chinese consumers' perceptions of GM foods may also be influenced by negative external media information (Huang & Peng, 2015), such as "GM foods will cause cancer and infertility," and "Americans sell GM foods to the Chinese, but they do not eat GM foods themselves." (Hu et al., 2011; Pu, 2013).

Understanding consumers' attitudes toward GM foods is imperative not only to the decision makers, but also to the biotechnology industry, food manufacturers and food retailers (Zhang et al., 2018). Our study investigates Chinese consumers' willingness to purchase GM foods using comprehensive national scale survey data. We test consumers' demographic factors and product-related factors that affect the consumers' GM food purchasing intentions. Understanding consumers' purchase behavior toward GM foods is important for farmers and food companies in trying to take advantage of GM products. The study is also necessary for the policymakers to design appropriate policies to promote the development of GM foods since GM use is not only significant for resolving food security and environmental problems in the world's most populated nation, but also greatly influences what the rest of Asia does about GM food innovation and technology development (Huang et al., 2017).

Based on the planned behavior theory, we examine the consumers' demographic related factors and GM foods products related factors that affect the Chinese customers' GM purchasing decisions and their future purchase intention. Our study extends the theory of planned behavior constructs with additional consumer demographic variables and product-related variables in the GM food purchasing context. The findings of our study have practical and theoretical implications for GM foods product promotion in China and other Asian countries due to cultural similarity. This study contributes to current literature in the following ways. First, the study considers a wide range of factors in exploring Chinese consumers' willingness to purchase GM foods. These factors include demographic characteristics, consumers' perceptions and product-related factors. Secondly, our study differs from other studies by distinguishing the behavior of purchasers and non-purchasers. We argue that non-purchasers may have different reasons for not buying GM products.

Thus, we investigate factors that may influence the buying decisions of non-purchasers. No previous studies have investigated factors that might influence non-purchasers' potential purchasing decisions for GM foods. Understanding the non-purchasing group behavior is important in promoting GM products' development in China. Thirdly, to our knowledge, this is the first study to use binary logistics regression to estimate the factors that affect the non-purchasers' future buying decisions of GM foods. This approach provides a more comprehensive understanding of Chinese consumers' GM food purchasing behavior. Finally, to the best of our knowledge, the study has a good representation of Chinese consumers since our survey covers Beijing and 26 other provinces.

Previous studies were scattered across China such as Jinan, Shandong Province (Zhu et al., 2018), Jiangsu and Anhui Provinces (Wang et al., 2020), and Shandong Province (Guo et al., 2020). Despite a nationwide survey of Chinese people in Cui and Shoemaker's (2018) study, the study is purely descriptive. Using a consumer survey of GM food in China, Cui and Shoemaker's (2018) study explores how the industrialization of GM technology might impact the future food supply in China. However, our study used quantitative approaches with survey data to identify the factors that influence the respondents' willingness to purchase GM foods, the impact of personal preferences on respondents' willingness to purchase GM foods, and further evaluate factors that would attract future buying decisions of non-purchasers in China. Our results can provide a better reference for exploring Chinese consumers' willingness to purchase GM foods.

This paper is organized as follows. Section 2 summarizes prior studies related to our topic. The data description and analytical methodology are presented in Sect. 3. The empirical findings are discussed in Sect. 4. Section 5 presents the study's conclusion, implications and limitations.

2 Literature review of the theory and research on consumers' willingness to purchase GM food

2.1 Theory review

An individual's intention to use a product is well-explained by the theory of planned behavior (Ajzen, 1985, 1991). An individual's behavioral intention is influenced by three psychological constructs: behavioral attitude, subjective norms, and perceived behavioral control. Fishbein (1963) develops a multi-attribute attitude model that provides relevant insights into consumer behaviors. This was followed by a number of attitude models that suggest the impact of consumers' risk and benefit perceptions on their purchase intentions (Chen & Li, 2007; Costa-Font et al., 2008; Rodríguez-Entrena et al., 2013). Therefore, consumer-perceived risks and benefits are recognized as key factors affecting consumer behavior regarding GM food (De Steur et al., 2010; Kikulwe et al., 2011; Rodríguez-Entrena et al., 2015). In the context of GM food, a benefit-risk analysis (BRA) framework has been widely adopted to investigate the consumers' willingness to consume (Ayyagari et al., 2011).

Perceived risk about GMO foods refers to an individual's interpretation of the uncertainty and possible negative effects related to GMO food. Risk perception is based on a consumer's assessment of the negative effects of GM foods (Sun et al., 2017). According to Xu et al. (2020), perceived risks include health risks that relate to toxicity and allergenicity, ecological risks related to the environment and ecosystems, social risks

related to potential changes in the norms, values and beliefs of human society, and ethical risks related to the impact and shock of the production of GM food on social ethics and human values. The high level of risk perception about GM foods causes a negative attitude (De Steur et al., 2010; Zhu & Xie, 2015). Perceived benefits relate to the potential gains from using GM products such as better nutrition, better health and better taste (Chen, 2007; Thøgersen & Zhou, 2012). The BRA framework suggests that consumers are reluctant to purchase GM food because of a high perception of risks but accept them when the perceived benefits are greater than the perceived risks (Huang & Peng, 2015).

2.2 The determinants of consumers' purchase willingness for GM food

The literature identifies many factors that affect the perceived risk and benefits of GM foods, and, consequently, a consumer's purchase willingness. These include knowledge, safety, public perspectives about probable threats, price, information and demographic factors.

2.2.1 Knowledge

Consumers' knowledge of GM food is important in predicting consumers' risk perception and acceptance (De Steur et al., 2010; Frewer et al., 2013). In general, consumers' knowledge of GM food is quite limited. For instance, Dang et al.'s (2017) study based on different countries finds that most consumers do not have sufficient knowledge about GM products and, thus, there is low GM food acceptance among consumers. Similarly, Nowicka and Kalinowski (2012) conducted research in Poland to reveal that 66% of the respondents could not interpret what GMO (genetically modified organisms) stands for about 50% of respondents confirmed no contact with this term before. In Poland's and UK's capital cities, 47.7% of surveyed respondents knew the term GMO (Popek & Halagarda, 2017).

Greater knowledge can reduce uncertainty about the benefits of GM food, which can help consumers make better purchasing decisions (Rodríguez-Entrena et al. 2013; Wunderlich et al., 2018) and increase their acceptance of GM food (Vecchione et al., 2015; Wunderlich & Gatto, 2015). Huang et al.'s (2006) large-scale investigation of Chinese consumers' levels of understanding, acceptance, and willingness to purchase GM foods in 2002 and 2003 reveals that information plays an important role in Chinese consumers' attitudes toward GM products. Zhu et al.'s (2018) study also shows that knowledge, among other factors, plays a critical role in risk perception and consumer purchase intentions in Jinan, Shandong Province, China.

2.2.2 Safety

In addition to consumers' lack of knowledge about GM foods, there is an ongoing debate over the safety of the food produced by GM technology. On the one hand, proponents of GM food, including the WHO (2021) and the US Food and Drug Administration (FDA, 2020), recommend that the GM foods that pass safety assessments and are currently available in the international market are not substantially different from those grown by the conventional techniques and, therefore, are safe to eat. On the other hand, there is growing concern that GM foods are associated with allergy reactions in humans and animals, create unexpected health problems in the liver, reproductive health, and infant mortality and cause natural and environmental stress (Zheng et al., 2017).

2.2.3 Public perspectives about probable threats

Consumers generally refuse to buy foods that are associated with negative images. Their attitudes and consumption behaviors are highly affected by public perspectives of probable threats (Frewer et al., 2004; Rollin et al., 2011). Nevertheless, the public's perspectives may differ from one culture to another, among different countries, individuals, and contexts (Burger et al., 2001). For instance, 70% of respondents in Croatia consider GM foods as risky products for human well-being (Cerjak et al., 2011). Tas et al. (2015) surveyed consumers in Turkey to reveal that consumers were afraid of natural products' disappearance from the market (83%), carcinogenicity (80.7%), harm to environment (57.2%), and being allergic when using GM foods (47.7%). Anxiety about harmful influences on health was the main reason that stopped Italian high school students from buying GM foods (Boccia, 2016). In Poland and Britain, surveyed consumers were most worried about unexpected effects of DNA modification, the growth of species-specific poisonous substances, and GM food allergenicity. However, about 15% of respondents had no idea of the potential risks of GM products (Popek & Halagarda, 2017).

2.2.4 Price

Price has an important influence on the decision to purchase GM foods. A survey conducted at several Alabama grocery stores to evaluate consumer willingness to purchase GM tomatoes indicated that the consumers would buy more GM tomatoes if there was a significant price difference between GM and non-GM tomatoes (Bukenya & Wright, 2004). In urban China, 21% of consumers were willing to buy GM food products if the price of GM foods was lower than that of non-GM food products (Chen et al., 2017). A study of consumers in Norway by Grimsrud et al. (2004) finds that substantial discounts were required to get Norwegian consumers to purchase GM bread. The authors find that to entice consumers to purchase GM bread, a price discount of 49.5% was required. A similar study by McCluskey et al. (2003) examined consumers' response to GM food products in Japan and finds that, without a discount, only 3% decided to buy GM noodles. The study shows that a discount of 62% was required to generate the purchase of GM noodles. Knight et al. (2005) conducted a purchasing experiment in New Zealand and find that 27% of consumers would purchase more GM-labeled cherries if the price dropped. Most British consumers would buy GM foods if they had attractive prices (Siegrist, 2008). Mexican respondents questioned by Montesinos-López et al. (2016) have positive responses to GM food products that were less fat and cheaper than traditional products and were cropped organically. This willingness to pay highlights that every market is different; there are consumers who will purchase when there is a slight reduction in the price, whereas there are consumers who are less pliable to price adjustments.

2.2.5 Information

Labeling is an important information source that can provide a communication mechanism to help consumers make an informed decision. In other words, it can raise consumers' awareness and increase product transparency. Some studies (e.g., Chen et al., 2017; Ma & Gu, 2011; Zheng et al., 2017) conclude that consumers' attitudes toward GM food products are negatively related to increased product information. Conversely, other studies (e.g., Bai

et al., 2013; Cicia & Golantuoni, 2010; Ortega et al., 2011) reveal that providing additional positive label information, such as clear consumer benefits, changes consumers' attitudes. GM food labeling information has a greater impact on non-purchasers than purchasers of GM foods (Zhan et al., 2020). Apparently, consumers want GM food products to be labeled, but providing a lot more information about some key aspects of the production process, such as why the food was modified and/or the source of the DNA used, could further influence the purchase of GM foods.

2.2.6 Demographic factors

Lin et al. (2019) argue that attitudes varied among respondents with different characteristics and personalities, such as risk-averse nature, age, gender, and education. For example, Hursti et al. (2002) show that Swedish male consumers had a more positive attitude toward GM foods than females. Similarly, Costa-Font and Gil's (2012) study shows that females found fewer GM food benefits and were less willing to buy than males. The Eurobarometer Survey 2006 revealed that women and elderly people were less likely to buy GM foods. Huang et al. (2017) discovered that Irish males and younger respondents were more likely to accept GM products than females and middle-aged respondents. Popek and Halagarda (2017) show respondents aged 18–25 years were more confident in GM food benefits than respondents aged 26–40 years. Conversely, Costa-Font and Gil (2012) indicate that young and middle-aged people were more worried about GM technology. DeLong and Grebitus (2018) discovered people with more organized and higher self-control characteristics were likely to prefer GM products. Other studies (e.g., Bardin et al., 2017; McFadden & Lusk, 2015) indicate that information, trust, and knowledge play critical roles in consumers' acceptance of GM food.

2.3 Empirical studies on consumer attitudes toward GM foods in China

Chinese consumers' perceptions and their willingness to pay for GM foods are debatable. For instance, Zhang (2002) and Li et al. (2003) find that Chinese consumers were willing to pay extra for GM foods such as GM rice. Huang et al. (2006) also conclude that Chinese consumers are likely not to oppose the commercialization of GM foods. Han et al. (2015) discover that consumers in more developed areas of China were inclined to have greater acceptance of and willingness to pay for GM foods than those in other regions. However, Greenpeace (2004) indicates that Chinese people did not accept GM foods. Zheng et al. (2017) find the acceptance level of Chinese consumers toward GM foods reduced remarkably from 2002 to 2013. Huang et al. (2017) claim that community concern about GMOs resulted in the stagnation of GM crop expansion since the 2000s. Based on a 2016 nationwide survey in China, Cui and Shoemaker (2018) find that 13.8% of respondents considered GMO as a type of bioterrorism targeting China. Recently, Li et al. (2020) explored Chinese people's perceptions of GM food using data from Sina Micro-blog, one of the largest social networks in China. The authors show that users' negative emotions about GMOs were three times the positive emotions of the social network. Likewise, food safety and government policy-related topics significantly relate to the feelings of Micro-blog users.

Previous studies have linked GM food risks and benefits to consumers' attitudes and acceptance rate in China. Zhu and Xie (2015) investigated the influence of risk and benefit awareness on Chinese respondents' attitudes toward GM foods. The authors suggest that

risk and benefit-related knowledge had a negative and positive association with attitude, respectively. The risk-related knowledge had a longer and stronger impact on attitude change, thus bringing about a lower acceptance level of GM foods. Zhu and Xie's (2015) finding is consistent with Han et al.'s (2015) conclusion that education played an essential role in enhancing consumers' acceptance of GM foods. Huang and Peng (2015) investigated consumers' attitudes toward GM food safety in China. The authors indicate that the proportion of consumers in urban areas who felt GM foods were unsafe increased by 30% from 2002 to 2012.

Scholars have further explored other factors that affect Chinese consumers' decision to purchase and consume GM foods. Huang et al. (2006) conducted a large-scale investigation in 2002 and 2003 on Chinese consumers' levels of understanding, acceptance, and willingness to purchase GM foods. They reveal that information and price play important roles in deciding Chinese consumers' attitudes toward GM products. De Steur et al. (2012), when examining the determinants of Chinese consumers' willingness to pay for GM rice, find that the levels of acceptance, awareness, information obtained, and perceived benefits from GMOs significantly impacted consumer willingness to purchase GM rice in China. Zheng et al.'s (2017) study of consumers' attitudes toward GM food in urban areas in China from 2002 to 2013 shows significant negative impacts of subjective knowledge and media coverage of consumers' acceptance level of GM food. Chen et al. (2017) evaluated the determinants of consumers' willingness to pay for GM lamb products and demonstrate that product information and risk-related knowledge (i.e., customers consider the product to be safe) were positively associated with product price.

Huang and Peng (2015) discover several demographic factors that significantly affect Chinese consumers' attitudes toward GM food safety. According to the authors, older people, females, lower educational levels, personal food-allergic history, and residents in bigger cities were likely to exhibit lower trust in GM food safety. Lu et al. (2015) suggest that social trust contributed to the reduction in community awareness about GM food-related risks. Li et al. (2020) confirm that Chinese women, more than men, were likely to have more negative feelings about GM foods since women are inclined to be more upset with risk-related information. In Zhang et al.'s (2021) study, 56.5% of Chinese consumers exhibit a positive preference for the traceability feature of GM soybean oil products.

Overall, the literature identifies several factors that affect Chinese consumers' attitudes and decisions to purchase GM foods. The factors include the consumers' demographic characteristics (e.g., age, educational level, gender) and their knowledge of GM foods and several product-related factors. Despite vast studies on consumers' attitudes toward GM food products, no studies have been conducted on non-purchasers' behaviors. Understanding this consumer group is as important as identifying factors affecting the consumer purchasing behavior toward the development of GM products in China.

3 Data and methods

3.1 Data

We use a structured questionnaire to gather relevant data[1] from the Chinese respondents' experience and knowledge of GM products in the marketplace. The questionnaire

[1] Data will be made available on reasonable request.

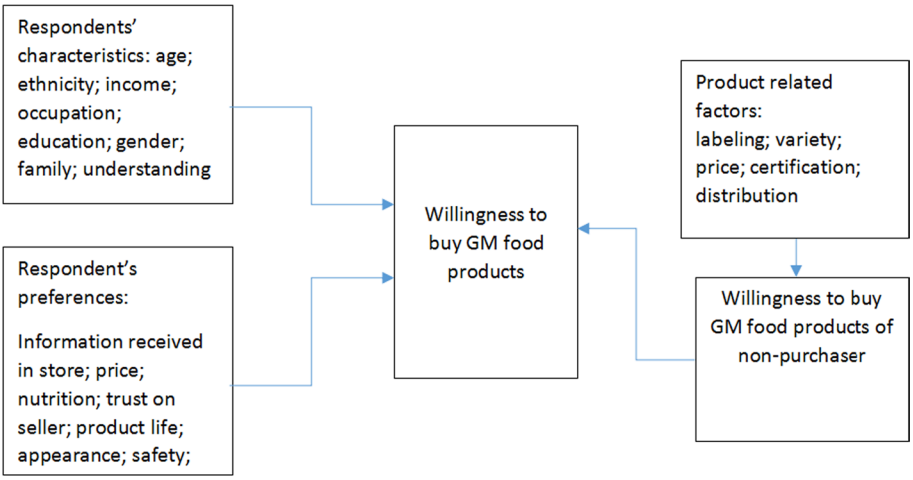


Fig. 1 Theoretical framework of the study

was derived from the literature and translated into Chinese before being administered online. The questionnaire was pilot-tested with a random sample of 30 consumers in Dalian city. The pilot test assessed the internal reliability of the approach and identified misunderstandings of questions subsequently clarified.

We adopted a snowball sampling approach for data collection. The snowball sampling method is based on referrals from initial respondents to generate additional respondents (Naderifar et al., 2017). A number of university students were enumerators and collected data via Questionnaire Star (an online questionnaire App) from their friends, relatives and neighbors. Respondents less than 16 years old were excluded from the survey since they might have difficulty understanding the questions. The survey was administered online from June 2020 to January 2021 and, except Henan, Hubei, Jiangxi, and Shanghai, covered most Chinese provinces and cities.

The survey included general information about GM foods, consumers' experiences with and knowledge of GM foods, GM food product buyers, non-GM food product buyers and respondents' profiles. The survey questions contained questions with checklists, Likert and rating scales. A total of 477 usable questionnaires were completed.

3.2 Theoretical framework

We investigate Chinese consumers' characteristics and preferences that affect their willingness to pay decisions on GM food products. We also explore the factors that may influence the buying decision of non-purchasers of GM food products. Figure 1 presents the study's theoretical framework.

In Fig. 1, the willingness to purchase GM food products is a dependent variable measured by a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Therefore,

we use *the ordered logit regression* to explore the determinants of Chinese customers' willingness to purchase GM foods (see Models 1 and 2). We also use *binary logit regression* to identify the factors that prompt the buying decisions of non-purchasers of GM food products in China (see Model 3).

3.2.1 Binary logistic regression model

Assume $U_i(Y_i, w_i, z_i)$ is the utility function of respondent i. Y_i is the response variable that equals 1 if the respondent is willing to buy GM food and 0 otherwise. W_i is the respondent's wealth, and z_i is the respondent's characteristics vector. Let c be the average price of buying GM foods, so the respondent will purchase GM food products if:

$$U_i\left(Y_i = 1,\ w_i - c, z_i\right) \geq U_i\left(Y_i = 0,\ w_i, z_i\right) \tag{1}$$

Though respondents' decisions are straightforward, their individual choices are not provided adequately in the dataset. Instead, it is possible to identify the association between respondents' characteristics and choices. Assume x_i is a respondent's characteristics and wealth vector, $x_i = (w_i, z_i)$, Eq. (1) can be presented as:

$$Y_i = f(x_i) + \varepsilon_i \tag{2}$$

where ε_i is the random term. If ε_i is assumed to have a logistic distribution, Eq. (2) has a logit distribution. If ε_i is normally distributed, Eq. (2) is a binary probit model (Greene, 1990; Maddala, 2001). In our study, the logit model is adopted for convenience because the differences between the two models are small.

To describe the binary characteristic of Y in Eq. (2), the probability of the choice, $p = P(Y = 1)$, is used (Bender & Grouven, 1997). Y can take values of 0 or 1, whereas p can take values from 0 to 1. The odd ratio is provided by calculating the ratio between the probability of success ($Y = 1$) and the probability of failure ($Y = 0$) as:

$$\text{Odd-ratio} = \frac{p}{1-p} \tag{3}$$

Next, we take the natural log of both sides to obtain

$$\text{Logit} = L = \ln\left(\frac{p}{1-p}\right) = \beta_0 + B\prime X \tag{4}$$

$$\text{or } p = \frac{\exp\left(\beta_0 + B'X\right)}{1 + \exp(\beta_0 + B'X} \tag{5}$$

, whereas

$$B\prime X = \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_j X_j$$

The binary logistic model in Eq. (4) is estimated by the maximum likelihood method via STATA software.

3.2.2 Ordinal logistic regression model

The ordinal logistic regression (OLR) is a nonlinear regression model with an ordinal response variable. To handle the ordered information, cumulative probabilities, cumulative odds, and cumulative logits are adopted (Bender & Grouven, 1997). Assume there are "n" categories, so, for any category "k":

$$\text{Cumulative probability } P(Y \le k) = p_1 + p_2 + \cdots + p_k \tag{6}$$

$$\text{Odd-ratio}(Y \le k) = \frac{P(Y \le k)}{1 - P(Y \le k)} = \frac{p_1 + p_2 + \cdots + p_k}{p_{k+1} + p_{k+2} + \cdots + P_n} \tag{7}$$

$$\text{Logit}(Y \le k) = \ln\left(\frac{P(Y \le k)}{1 - P(Y \le k)}\right) = \beta_k + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{kj} X_{kj}, \quad k = 1, \ldots, n \tag{8}$$

Equation (8) is an ordinal logistic model estimated by the maximum likelihood method via STATA software.

Following previous studies (Huang et al., 2017; Vlontzos & Duquenne, 2016; Zheng et al., 2017), we use logit regression models in our study.

Model 1: Ordinal logistic regression model to assess the relationship between consumers' demographic characteristics and their willingness to buy GM foods

$$\begin{aligned} \text{buy\_gm}_i = {} & \alpha_1 \text{understand}_I + \alpha_2 \text{young}_i + \alpha_3 \text{ethnicity}_i \\ & + \alpha_4 \text{lowincome}_i + \alpha_5 \text{professional}_i + \alpha_6 \text{highedu}_i \\ & + \alpha_7 \text{gender}_i + \alpha_8 \text{familymember}_i + \alpha_9 \text{checkgm}_i + \varepsilon_{i0} \end{aligned} \tag{9}$$

Table 1 presents Model 1's variables' definitions and measurement.

Model 2: Ordinal logistic regression model to assess the impact of personal preferences on consumers' willingness to buy GM foods

$$\begin{aligned} \text{buy\_gm}_i = {} & \beta_1 \text{store\_gminfo}_i + \beta_2 \text{price}_i + \beta_3 \text{nutrition}_i \\ & + \beta_4 \text{trust\_seller}_i + \beta_5 \text{longlife}_i + \beta_6 \text{appearance}_i \\ & + \beta_7 \text{safe}_i + \beta_8 \text{taste}_i + \beta_9 \text{bought}_i + \varepsilon_{i1} \end{aligned} \tag{10}$$

Table 2 presents Model 2's variables' definitions and measurement.

Model 3: Binary logistic regression models to evaluate product-related factors that may influence buying decision of non-purchasers of GM food products

To better understand Chinese consumers' purchasing behavior toward GM foods, Model 3 explores the product-related factors that may influence the buying decision of non-purchasers of GM food products. The model includes without and with control variables (respondents' demographic characteristics) to test the robustness of the coefficient estimates.

- Model 3a (without control variables):

Table 1 Variables' definitions and measurement (Model 1)

Variable	Definition	Measurement	Mean	SD
Willingness to buy GM foods (full sample)				
buy_gm	Willingness to buy GM foods	Likert scale from 1 (Strongly disagree) to 5 (Strongly agree)	2.687	1.043
Personal profile				
understand	Respondent's self-evaluation of understanding about GM food products	Average of knowledge about different GM terms (see Table 4)	1.876	0.778
young	Respondent is younger than 25 years old	1 If yes; 0 otherwise	0.602	0.490
ethnicity	Respondent's ethnicity	1 If Han; 0 otherwise	0.503	0.501
low-income	Respondent's household annual income	1 If annual income lower than 40,000 RMB; 0 otherwise	0.727	0.446
professional	Respondent's occupation	1 If yes (lawyer, scientist, engineer, teacher, doctor, etc.); 0 otherwise	0.048	0.214
highedu	Respondent's education level	1 If bachelor or higher degree, 0 otherwise	0.711	0.454
gender	Respondent gender	1 If female, 0 otherwise	0.727	0.446
familymember	Number of family members	Persons	3.656	1.157
checkgm	Habit of checking whether the food is GM food product when buying	1 If check before buying; 0 otherwise	0.456	0.500

$$\begin{aligned}\text{nonbuy\_will}_i = {} & \gamma_1 f\_\text{label}_i + \gamma_2 f\_\text{variety}_i + \gamma_3 f\_price_i \\ & + \gamma_4 f\_trustworthy_i + \gamma_5 f\_distribution_i + \varepsilon_{i2}\end{aligned} \tag{11}$$

- Model 3b (with control variables):

$$\begin{aligned}\text{nonbuy\_will}_i = {} & \gamma_6 f\_\text{label}_i + \gamma_7 f\_\text{variety}_i + \gamma_8 f\_\text{price}_i \\ & + \gamma_9 f\_\text{trust}_i + \gamma_{10} f\_\text{distribution}_i + \gamma_{11}\text{young}_i \\ & + \gamma_{12}\text{low income}_i + \gamma_{13}\text{highedu}_i + \gamma_{14}\text{gender}_i + \varepsilon_{i3}\end{aligned} \tag{12}$$

Table 3 presents Model 3's variables' definitions and measurement.

Table 2 Variables' definitions and measurement (Model 2)

Variable	Definition	Measurement	Mean	SD
Willingness to buy GM products (full sample)				
buy_gm	Willingness to buy GM products	Likert scale from 1 (Strongly disagree) to 5 (Strongly agree)	2.687	1.043
Personal preference				
store_gminfo	Level of GM information received from stores	Likert scale from 1 (Strongly disagree) to 5 (Strongly agree)	3.249	1.664
price	Importance of price when buying		3.548	1.185
nutrition	Importance of nutrition level when buying foods		3.961	1.114
trust_seller	Importance of trust on the sellers when buying foods		3.078	0.863
longlife	Importance of foods' not quickly spoiling feature		2.914	0.995
appearance	Importance of product attractive appearance		2.941	0.942
safe	Opinion that GM products are not as safe as normal products		3.048	1.126
taste	Opinion that GM products taste better than normal products		2.801	0.977
bought	Respondent's last year buying history	1 if bought GM products; 0 otherwise	0.392	0.489

4 Empirical results

4.1 Statistical analysis

4.1.1 Profiles of the surveyed respondents

Figure 2 summarizes the profile of the surveyed respondents. Most respondents were younger than 25 years old (287 respondents, 60.17%), female (347 respondents, 72.75%), Han ethnicity (240 respondents, 50.31%), have a household income less than 40,000 RMB (347 respondents, 72.75%), non-professional occupation (454 respondents, 95.18%), and have attained a bachelor or higher degree (339 respondents, 71.07%). The GM non-purchaser group, were younger on average, had a higher percentage of females, Han ethnicity, lower household income, higher educational level, and fewer professional jobs than the GM consumer group. Statistically significant differences between GM foods buyers and non-GM foods buyers for gender, ethnicity and annual income are shown in Fig. 2.

Using a Likert scale from 1 (strongly disagree) to 5 (strongly agree), we asked respondents' preference for GM product features. The results reveal nutrition and price are the two most popular factors that respondents consider (means of 3.96 and 3.55, respectively), followed by the trust in sellers (mean 3.08), product appearance (mean 2.94), and long-life feature (mean 2.91). The respondents also indicated that GM foods are not as safe as non-GM products (mean 3.05), even though the taste of GM foods may be better than the non-GM foods (mean 2.80).

Table 3 Variables' definitions and measurement (Model 3)

Variable	Definition	Measurement	Mean	SD
Non-purchase customers' decision to purchase GM foods				
nonbuy_will	Intention of GM non-purchasers to buy GM food products	1 If yes, 0 if no	0.881	0.325
Changing factor				
f_label	Respondent will buy if more information on the labels	1 If yes, 0 if no	0.266	0.442
f_variety	Respondent will buy if more product variety	1 If yes, 0 if no	0.324	0.469
f_price	Respondent will buy if price is cheaper	1 If yes, 0 if no	0.255	0.437
f_trust	Respondent will buy if GM food products have trustworthy certification on packages	1 If yes, 0 if no	0.338	0.474
f_distribution	Respondent will buy if GM food products are easier to find	1 If yes, 0 if no	0.183	0.387
Control variables				
young	Respondent younger than 25 years old	1 If yes; 0 otherwise	0.621	0.486
low-income	Respondent's household annual income	1 If annual income < 40,000 RMB	0.745	0.437
highedu	Respondent's education level	1 If having Bachelor or higher degree; 0 otherwise	0.717	0.451
gender	Respondent's gender	1 If female; 0 if male	0.748	0.435

4.1.2 Respondents' understanding and opinions about GM foods

Respondents' understanding of GM products was measured by their awareness level of different GM concepts that are available in the marketplace. Based on a scale from 1 (do not understand at all) to 5 (understand very well), the means of the respondents' understanding of different GM terms such as biotech food (1.765), genetically engineered food (GE) (1.830), genetically modified food (GM) (2.714), genetically modified organisms (GMOs) (1.874) and bioengineered food (1.736) are around 2, which implies they have minimal understanding of GM foods. These statistics agree with earlier studies by Nowicka and Kalinowski (2012), Dang et al. (2017), and Popek and Halagarda (2017) that most consumers in different countries have little knowledge about GMO products.

Respondents were also asked about their opinion of GM products in the market (see Fig. 3). Nearly half of the respondents agreed that GM foods should be clearly identified on their labels and labeling of GM products should be required by law. One-third of the respondents think that GM foods are more likely to have negative health effects than ordinary foods. The concern about GM food safety of Chinese consumers in this study confirms the findings in previous studies by Cerjak et al. (2011), Tas et al. (2015), and Zheng et al. (2017) that consumers worry about GM foods' potential health risks. Some 17.61% of respondents agree that GM foods taste better than non-GM foods. Our study's statistics indicate that a considerable percentage of the respondents have an unfavorable attitude toward GM products. This result is similar to the conclusion of Li et al. (2020) that there

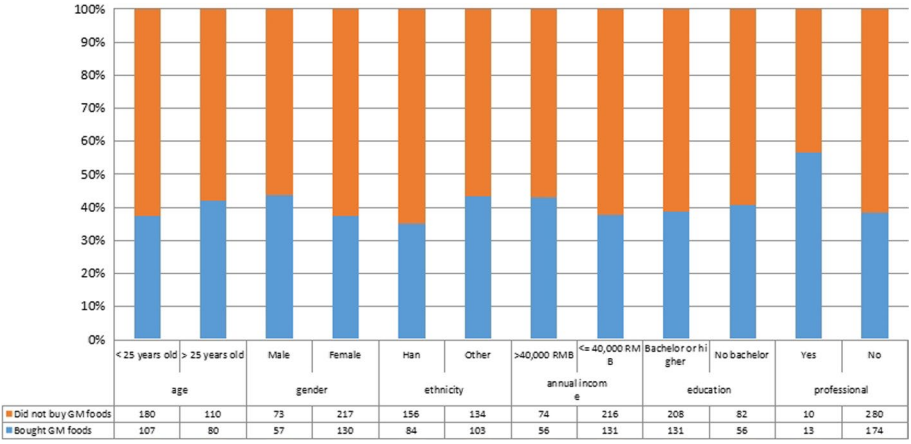


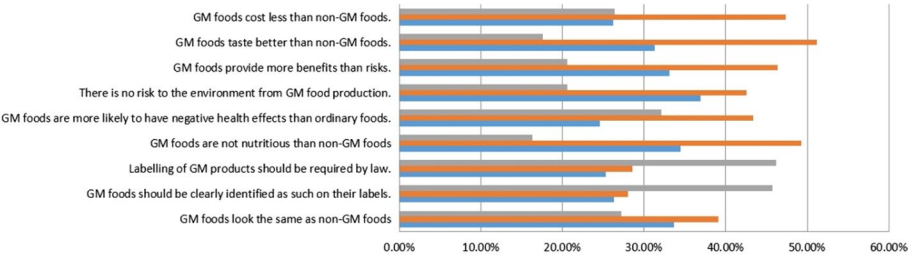
Fig. 2 Profiles of the surveyed respondents

are more Chinese citizens with negative emotions about GMOs than people with positive emotions.

The results show that nearly two-thirds of the respondents (64.13%) are willing to buy GM foods (i.e., neutral to totally agree to buy). This result is similar to Zheng et al.'s (2017) finding that 56–66% of Chinese respondents are likely to accept (i.e., neutral to fully accept) certain GM foods. Respondents who bought GM foods are more inclined (i.e., agree or totally agree) to buy GM food products than the GM non-purchasers. The survey results also demonstrate over three quarters of the non-purchasers of GM food products (82.41%) would consider buying GM food products in the future but 17.59% are reluctant to buy and consume GM foods.

There are several reasons why 290 of the surveyed respondents did not buy GM foods. The most dominant reasons are confusion about the terminology, certification bodies, etc. (40.69%), concern that GM foods may not be safe (36.21%), and insufficient information about the products (34.14%). The results indicate that trustworthiness and information play essential roles in non-purchasers buying decision of GM foods.

For the factors that would influence non-purchasers to purchase GM foods, the results show one-third of the respondents would consider buying GM products that have a greater variety (mean 0.324) and trustworthy certification on packages (mean 0.338). In addition, about a quarter of the respondents would choose GM foods if there was more information on the labels, or the price of products was cheaper; 18% of the respondents chose distribution (easier to find) as an attractive factor for buying GM products. The results reinforce the claims of De Steur et al. (2012) and Chen et al. (2017) that trustworthiness and information play essential roles in the buying decision of GM foods in China. Therefore, adding more GM-related information to labels and ensuring the quality and safety of GM products may be a sound strategy for GM food suppliers to reach more Chinese customers.



	GM foods look the same as non-GM foods	GM foods should be clearly identified as such on their labels.	Labelling of GM products should be required by law.	GM foods are not nutritious than non-GM foods	GM foods are more likely to have negative health effects than ordinary foods.	There is no risk to the environment from GM food production.	GM foods provide more benefits than risks.	GM foods taste better than non-GM foods.	GM foods cost less than non-GM foods.
Agree and strongly agree	27.21%	45.73%	46.19%	16.34%	32.08%	20.55%	20.55%	17.61%	26.42%
Neutral	39.09%	28.01%	28.54%	49.24%	43.40%	42.56%	46.33%	51.15%	47.38%
Disagree and strongly disagree	33.69%	26.26%	25.27%	34.42%	24.53%	36.90%	33.12%	31.24%	26.21%

Fig. 3 Surveyed respondents' opinions on GM foods

4.2 Ordinal logistic regression results: factors affecting the willingness of Chinese respondents to buy GM foods

Table 4, Panel A (Model 1), shows respondents' characteristics and their willingness to buy GM products. The results show respondents' understanding and willingness to buy GM foods is significant and positive at the 5% level. With a unit rise in GMO understanding, the odds of an increase in willingness to buy from a lower to a higher level are 1.545 times. Respondents with a bachelor degree also respond more positively (at the 10% significance level) to GM products than respondents without a bachelor degree. In other words, the odds of willingness to buy GM products is 1.956 times more when the respondent has a bachelor or higher degree. These findings are consistent with the conclusions of Han et al. (2015), Huang and Peng (2015) and Zhu and Xie (2015) that education is essential for enhancing consumers' acceptance of GM foods. In contrast, the number of family members and the habit of checking GM labels negatively affect respondents' willingness to buy GM products at 5% and 1% levels, respectively.

Our results show that if respondents have a bachelor or higher degree and shows a better understanding of GM foods, they are more likely to buy GMO foods. Therefore, manufacturers must ensure that the product label is easy to read and that the label content is understandable. In contrast, a respondent who lives in a big family or normally checks products before buying, he or she is not likely to buy GM products. The findings indicate that people in a big family and having a habit to check product labels are likely to be more conservative and reluctant to buy GM foods than other respondents. These results are similar to the findings of Xia (2014) that attitudes toward GM products vary when considering different consumers' characteristics and backgrounds.

Table 4, Panel B (Model 2), shows respondents' preferences for products that have a long life and have available information are positively, significantly associated (at the 1% level) with the likelihood to buy GM foods. The odds ratios of these factors indicate that, with a unit level rise in preference for products' long-life feature or information availability, the odds of increasing willingness to buy from a lower to a higher level are 1.396 and 1.192 times, respectively. Respondents' experience in buying GM products and that GM products taste better than non-GM products are also positive and significant at the 1% level. Therefore, manufacturers

Table 4 Ordinal logistic regression results for models 1 and 2

buy_gm	Coef	(Std. err.)	Odds ratio	(Std. err.)
Panel A (Model 1)				
understand	0.435**	(0.187)	1.545**	(0.289)
young	−0.544	(0.437)	0.580	(0.253)
ethnicity	−0.032	(0.286)	0.969	(0.277)
low-income	0.226	(0.395)	1.254	(0.496)
professional	−0.198	(0.547)	0.820	(0.448)
highedu	0.671*	(0.391)	1.956*	(0.764)
gender	0.0002	(0.309)	1.000	(0.309)
familymember	−0.288**	(0.117)	0.750**	(0.087)
checkgm	−0.825***	(0.291)	0.438***	(0.128)
Obs	427			
LR chi2(9)	21.64			
Prob > chi2	0.010			
Panel B (Model 2)				
store_gminfo	0.175***	(0.058)	1.192***	(0.069)
price	0.036	(0.086)	1.036	(0.090)
nutrition	−0.156*	(0.093)	0.855*	(0.079)
trust_seller	0.199*	(0.119)	1.220*	(0.145)
longlife	0.334***	(0.101)	1.396***	(0.140)
appearance	0.124	(0.108)	1.132	(0.122)
bought	0.512***	(0.188)	1.669***	(0.314)
safe	−0.037	(0.089)	0.964	(0.086)
taste	0.431***	(0.110)	1.539***	(0.169)
Obs	427			
LR chi2(9)	75.94			
Prob > chi2	0.000			

*, **, ***Significant at 1%, 5% level and 10%, respectively

The correlation values of the explanatory variable are lower than 0.7. VIF test values are lower than 10 for all explanatory variables, indicating no multicollinearity problem

should take more opportunities to promote their products to inform consumers of their products' tastes and features.

Other factors such as preference for nutrition and trust in sellers are positively associated, at the 10% significance level, with respondents' higher likelihood of buying GM products. Our results are similar to Tas et al.'s (2015) and Vlontzos and Duquenne's (2016) findings that higher nutritional value would possibly increase the demand for GM foods in Turkey and Greek, respectively. Product price, however, is insignificant in explaining respondents' willingness to buy GM foods. This result shows that Chinese consumers' GM foods buying decisions are not affected even if the products are offered at a lower price.

4.3 Binary logistic regression results: product factors that affect future buying decisions of non-purchasers of GM food products

Table 5 presents the factors that may attract non-purchasers to buy GM food products in the future. In both Model 3a (without control variables) and Model 3b (with control variables), product variety and trustworthiness significantly, positively affect (at the 1% and 5% level, respectively) the decision of non-purchasers of GM products. The odds ratios of the variety and trust factors indicate that GM products with more variety or trustworthy certification on packages have more than four times and twice the odds, respectively, of being very likely to be bought than products with less variety or untrustworthy certification. To increase the consumption of GM foods, the Chinese government should monitor the production process closely and provide certificates to guarantee GMO products' authenticity and quality.

In summary, the regression results suggest that respondents' profile factors (education level, understanding level of GM products, number of family members, and habit of checking GM labels) are associated with willingness to buy GM products. Likewise, the respondents' preference factors (preference for available information, nutrition value, trust in sellers, long product life), their experience in buying GM products, and their opinion that GM foods taste better than non-GM products significantly affect their choice of buying GM products. For non-purchasers of GM products, however, product variety and trust are two critical factors that could change the respondents' attitudes toward buying GM foods.

5 Conclusions and implications

5.1 Conclusions

Our study explores consumers' willingness to buy GM foods and evaluates the factors that influence GM food non-purchasers' buying intentions. Most surveyed consumers (60.8%) in our study are GM food non-purchasers. The result reveals that Chinese consumers have a minimal understanding of GM foods. Nearly, two-thirds (64.13%) of Chinese consumers will purchase GM foods in the future. Our study findings (in terms of low level of awareness and comparable rate of GM-food acceptance) indicate that the Chinese consumers' understanding of GM products and willingness to buy GM food has not changed over time. We use ordered logit regression models to explore the determinants of Chinese customers' willingness to purchase GM products. We find that respondents' awareness level (education level and understanding level of GM products), a group of preference factors (preference for available information, trust in sellers, long product life, GM foods' taste), and GM food buying experience are positively related to greater willingness to buy GM foods. The number of family members, the habit of checking food labels, and a preference for nutrition value, however, reflect lower intentions to buy GM foods. We also use binary logit regression models to explore the factors that would attract future buying decisions of non-purchasers in China. We identify product variety and trust are two crucial factors that would change respondents' attitudes toward buying GM foods.

Table 5 Logistic regression results for non-purchasers of GM products

nonbuy_will	Model 3a (without control variables)				Model 3b (with control variables)			
	Coef	Std. err	Odds ratio	Std. err	Coef	Std. err	Odds ratio	Std. err
f_label	0.303	0.447	1.354	0.605	0.373	0.458	1.453	0.665
f_variety	1.448***	0.499	4.255***	2.124	1.464***	0.509	4.323***	2.199
f_price	0.586	0.451	1.796	0.81	0.606	0.466	1.833	0.855
f_trust	0.872**	0.435	2.392**	1.041	0.914**	0.449	2.494**	1.119
f_distribution	0.957	0.64	2.604	1.665	0.891	0.648	2.438	1.580
highedu	0.736	0.209	2.088	0.437	−0.452	0.428	0.636	0.272
young					0.003	0.454	1.003	0.455
gender					0.623*	0.361	1.864*	0.673
low-income					0.614	0.432	1.847	0.798
Obs	290				290			
LR chi2(9)	29.47				36.99			
Prob > chi2	0.000				0.000			

***, **Significant at 1% and 5% level, respectively

5.2 Study implications

GM food was introduced into China over a decade ago. Since 2013, some celebrities have taken a public stand against GM food. They argue that GM food is highly related to cancer and infertility and, following these celebrities' views, Chinese consumers' attitudes toward GM food have become more negative. Thus, it is imperative to investigate the factors that affect Chinese consumers' willingness to purchase GM foods. We identify the consumer demographic factors and product related factors that influence the GM food purchasers' buying decisions and non-purchasers' buying future intentions. Our study extends the theory of planned behavior's constructs with additional consumer demographic variables and product related variables in the context of GM food purchasing. The study's findings have practical and theoretical implications for GM food product promotion in China (and other Asian countries because of cultural similarity).

The results present several implications for GM food producers and policymakers to manage the production and consumption of GM products in China. For GM food producers, based on the empirical results, the most important approach to increase consumer demand is to enhance people's knowledge of GM foods, since higher awareness brings about a higher willingness to buy. More advertisements and educational programs about GMO and GM foods are recommended. GM food producers also need to introduce a greater variety of GM foods, trustworthy label certificates, and sufficient information on the products to attract current non-purchasers. Enhancement of GM foods' taste and product life would also help to promote GM food sales.

To improve media coverage of GM foods in China, the government should exert tight control on GM foods to increase consumers' trust in GM products and attract non-buyers. Consumers need to be assured that GM products with labeling and trustworthy certificates on the packages are authentic and safe to consume. Any slack regulations would lead to a loss of trust and reduce consumption for the whole GM food market; meaningful

minimum certification standards need to be put in place. Organizations that are responsible for enforcing the standards should then be communicated to the public.

5.3 Limitations and future studies

We investigated consumers' attitudes and willingness to buy GM foods and explored the determinants of consumers' willingness to buy GM products in China. However, the number of respondents in the study is low compared with the Chinese population. Also, the distribution of respondents' characteristics (e.g., age, gender, occupation, income, location) does not fully represent Chinese consumers' demographic factors. Therefore, the study's results cannot be generalized to all Chinese consumers. Future research may include longitudinal studies so that any change in willingness and buying behaviors can be documented and more fully investigated. Research should also extend the number of respondents across different regions of China, so that it better reflects Chinese consumers' demographic characteristics making the empirical results and findings more robust.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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