Assessing Moderated Mediation Effects Influencing Consumer Acceptance of Cell-cultured Meat: A PLS-SEM Modeling Approach

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Abstract:

Cell-cultured meat, as a novel food, is often met with limited consumer understanding, leading to a predominantly conservative attitude and lower acceptance. To gain insights into the key factors influencing consumer acceptance of cell-cultured meat, this study constructs a moderated mediation model to examine the relationship between food techneophobia (FTN), food disgust sensitivity (FDS), and acceptance of cell-cultured meat. Moreover, we investigate the mediating effects of perceived benefits (PB) and perceived risk (PR), as well as the moderating effect of information acquisition (IA). A field survey was conducted in 2020 with 4,841 Chinese consumers in households. The data were analyzed using partial least squares structural equation modeling (PLS-SEM). The findings reveal that PB is the strongest positive influencing factor of acceptance. FTN has a better predictive effect on acceptance than FDS. Both FTN and FDS can reduce PB and increase PR, thereby lowering acceptance. Partial mediation of PB and PR between FTN and acceptance of cell-cultured meat is observed, while full mediation of PB and PR exists between FDS and acceptance. IA can mitigate the negative impact of FDS on PB, thereby enhancing consumer acceptance of cell-cultured meat. This study contributes to the current literature by employing PLS-SEM as an assessment model for examining direct and mediation relationships.

Understanding the factors that shape consumers' perceptions and influnce their acceptance is essential for effective forecasting and strategic decision-making in the novel food industry.

Keywords: Cell-cultured meat; Moderated mediation effects; Food techneophobia; Perceived risk; Acceptance; Partial least square structural equation model

1. Introduction

Ensuring global food security in the face of a growing population presents a critical challenge. The conventional production of meat, which is a key component of the Western standard diet, raises concerns about its negative environmental impact and health effects. In search of a sustainable and ethical alternative, novel meat products have emerged, attracting significant attention as a potential solution to traditional livestock farming. However, the success of these products in the market depends on consumer acceptance. Therefore, it is crucial for stakeholders in the food industry to understand the factors that influence consumer perceptions and shape their acceptability.

Cell-cultured meat, also known as lab-grown meat, has garnered considerable interest as a potential alternative source of animal protein (Kumar et al., 2021). It involves culturing animal cells in a laboratory environment rather than relying on traditional animal farming and slaughter. Small samples of animal cells are nurtured and provided with the necessary nutrients and conditions for growth, eventually forming muscle tissue that can be harvested and processed into meat products. Cell-cultured meat offers a sustainable and ethical alternative to conventional livestock farming, addressing concerns related to greenhouse gas emissions, land use, water consumption, and animal welfare.

The acceptability of cell-cultured meat among consumers remains an ongoing subject of research and discussion. Despite advancements in cell-cultured and genetically modified technologies, consumer attitudes toward these novel food technologies have generally been cautious and conservative. Embracing novel food is intricate and influenced by personality factors and diverse food perceptions (Egolf et al., 2019; Su et al., 2023). Perceived benefits (PB) linked to animal welfare, nutritional value, and environmental considerations enhance consumers' acceptance (Weinrich et al., 2020), while PR, including unfamiliarity, unnaturalness, and disgust, reduce consumer acceptance instead. Consumers with different food neophobia or disgust sensitivity levels form different perceptions of novel meat (Verbeke, 2015), ultimately affecting consumer acceptance. Additionally, cell-cultured meat represents a novel food product that is still relatively unknown to consumers, leading to a lack of familiarity and subsequently low levels of acceptance. In order to bridge this knowledge gap and enhance consumer acceptance, it is essential to employ effective educational strategies aimed at promoting awareness and understanding of cell-cultured meat. One significant factor that can influence consumer perceptions of this innovative food product is their trust in the food-related information conveyed by communicators (Rolland et al., 2020). Trust in information plays a crucial role in shaping consumers' perceptions of the benefits and risks associated with cell-cultured meat.

Past studies on novel meat acceptance mainly examined its direct influencing factors, such as consumer awareness (Zhang et al., 2020), perceptions (Siegrist & Hartmann, 2020), attribute preferences, social companions, and purchase venue (Motoki et al., 2022), environmental-related message (Sheng et al., 2023), heuristics and individual differences (Siegrist & Hartmann, 2020). Moreover, previous studies have found the negative role of FTN, FDS and acceptance (Hamlin et al., 2022; Erhard et al., 2023). However, this study uniquely examines the mediation role of PB and PR as well as the moderation role of IA in the relationship between FTN, FDS and cell-cultured meat acceptance. Furthermore, the study assesses acceptance across endorsement, willingness to eat, and overall evaluation, offering a nuanced, multifaceted understanding of this complex construct. Importantly, we used the partial least squares structural equation modeling (PLS-SEM) for data analysis. The use of PLS-SEM allows us to model the complex interrelationships between perceptual, psychological and acceptance factors - an approach that has not been widely applied in past research on novel food technologies. Our findings offer invaluable, context-specific insights that can guide policy and communication strategies to shape Chinese consumers' acceptance of novel food products within this important, emerging market.

2. Literature review and hypotheses development

2.1 Acceptance for cell-cultured meat

Consumer attitudes and beliefs, shaped by risk and benefit perceptions, play a significant role in food choices (Kenny et al., 2023). Understanding consumer attitudes toward cell-cultured meat is crucial due to its potential impact on the food industry (Daniel & Janet, 2023). Unlike other alternatives, cell-cultured meat resembles conventional meat in physical properties, differing only in production methods (Bryant et al., 2020; Siddiqui et al., 2022). Consumer acceptance of cell-cultured meat is relatively lower than that of alternative proteins like pulses, algae, or plant-based substitutes (Bryant and Barnett, 2018; Onwezen, 2021). Cultural differences have a significant impact on consumer acceptance. Research conducted in China, England, France, Germany, Mexico, South Africa, Spain, Sweden, and the United States has revealed differences in acceptance levels, with French consumers being less accepting of cultivated meat compared to consumers in other countries (Siegrist and Hartmann, 2020). Li et al., (2023) also found most Chinese consumers were unfamiliar with and had negative attitudes about cultured meat, and consumers' intention to try or purchase cultured meat was low. The United States and several European Union countries have strongly supported the development of cultured meat, as evidenced by the proliferation of startups in this sector and the provision of government subsidies and other financial incentives (Failla et al., 2023; Dueñas-Ocampo et al., 2023). Barriers to acceptance include safety concerns, nutrition, perceptions of unnaturalness, trust, disgust, food neophobia, economic anxieties, and ethical considerations (Lee & Lee, 2024; Engel et al., 2024). Despite these barriers, many consumers express openness to trying cell-cultured meat (Sikora & Rzymski, 2023). Limited direct consumer engagement with cell-cultured meat, as it is not widely available, suggests that attitudes may be more malleable. Well-designed interventions such as name framings have the potential to increase acceptance significantly (Li et al., 2024). Consumers tend to hold divergent perceptions of cell-cultured meat, and that the manner in which individuals acquire information regarding this novel food technology can significantly influence the attitudes and beliefs about the product (Siegrist & Sütterlin, 2017; Heidmeier & Teuber, 2023).

2.2 Perceived benefits

Perceived benefits (PB) refer to consumers' evaluation of the positive outcomes or advantages associated with accepting or consuming a particular food. Bronfman et al., (2011) demonstrate that PB (rather than PR) in the indirect effect of trust on acceptance. Several studies have suggested that cell-cultured meat offers potential advantages over conventional meat production (Li et al., 2024). These advantages include a reduction in the utilization of natural resources such as land, water, energy, and fodder. Additionally, cell-cultured meat has the potential to decrease livestock pollution (Bryant & Barnett, 2020) and provide animal welfare benefits. When consumers perceive these benefits, they are more inclined to accept cell-cultured meat (Kantono et al., 2022). Rolland et al. (2020) have demonstrated that PB of cell-cultured meat may result in a willingness to pay a premium price. Therefore, this study proposes the impact of PB on acceptance.

Hypothesis 1: PB has a significant positive impact on consumer acceptance.

2.3 Perceived risk

Perceived risk (PR) is a central concern when introducing cell-cultured meat to consumers. It refers to the consumer's evaluation of the potential negative consequences or disadvantages associated with accepting or consuming a particular food. It includes concerns about food safety, health risks, ethical concerns, or environmental impact. High levels of perceived risk can lead to decreased acceptance or avoidance of certain foods. Consumers often form PR in aspect of food safety, quality, and cultural norms. Investigating the impact of the PR on acceptance is crucial as it may elicit negative attitudes and resistance to consuming cell-cultured meat. Consumer acceptance is conditioned by the risk that they perceive from introducing food into their consumption habits processed through technology that they hardly understand (Africa et al., 2009). Martínez-Poveda et al. (2009) developed a model of consumer-perceived risk. Pakseresht et al., (2022) reviewed the factors affecting consumer acceptance of cultured meat, and summarize that PR is one of the most important factors influencing consumer acceptance/rejection of cultured meat. It has been identified as a major barrier to accepting novel food alternatives Whereas early contributions focused on risk perception and the lay-expert divide in objective and subjective risk perception, more recent research has turned to the role of emotions, moral judgments, and worldviews (Lusk et al., 2014). Therefore, this study proposes that:

Hypothesis 2: PR has a significant negative impact on consumer acceptance.

2.4 Food techneophobia

Food techneophobia (FTN) describes consumers fears of novel or unfamiliar food techonology (Cox & Evans, 2008; D'Antuono et al., 2012). An individual’s FTN level has been found to be the most important barrier to acceptance of novel foods. A recent systematic review showed that the FTN is a valid and reliable predictor of responses to novel food (Wendt & Weinrich, 2023). People with high FTN have lower expected liking of novel foods. Martins and Pliner (2012) found that FTN was a significant factor in determining consumers’ perception towards foods produced by nanotechnology in Canada. An online study (n = 418) assessed the level of neophobia in Italian consumers to a shelf life extension technology (Demartini et al., 2019). Siegrist and Hartmann (2020) found that food neophobia and disgust sensitivity are crucial personality factors for explaining individual differences of food choice. To understand the effect of FTN, this study proposes the relationship as follows:

Hypothesis 3: FTN has a significant negative impact on consumer acceptance of cell-cultured meat.

Hypothesis 4a: FTN has a significant negative impact on PB.

Hypothesis 4b: FTN has a significant positive impact on PR.

2.5 Food disgust sensitivity

Food disgust sensitivity (FDS) refers to an individual's susceptibility to feel disgusted by specific food-related stimuli (Monteleone et al., 2017). Consumers characterized by heightened disgust sensitivity possess a heightened perception towards potential risks or hazards in their environment, which extends to novel foods (Verbeke et al., 2015). FDS has been identified as one of the strongest predictors of willingness to consume a particular food. Previous studies have shown that individuals who oppose gene technology exhibit higher levels of general disgust sensitivity compared to those who accept it (Scott et al., 2016). Additionally, FDS has been found to predict the disgust response towards new food technology applications and influence willingness to consume them (Aisha et al., 2019). It also plays a significant role in shaping consumer acceptance of cell-cultured meat (Wilks et al., 2019; Siegrist and Hartmann, 2020). Various scales have been proposed to measure disgust sensitivity, encompassing different domains of disgust (Hartmann & Siegrist, 2018; Ainslee et al., 2023). These scales have demonstrated predictive power in assessing individuals' behavior when confronted with foods that may evoke disgust. This study proposes the effect of FDS as follows:

Hypothesis 5: FDS has a significant negative impact on consumer acceptance.

Hypothesis 6a: FDS has a significant negative impact on PB.

Hypothesis 6b: FDS has a significant positive impact on PR.

2.6 Mediation of perceived benefits and perceived risk

The impact of FTN and FDS on acceptance can be influenced by consumers' PB and PR associated with cell-cultured meat. Several studies show that the negative impact of food neophobia and food disgust sensitivity on acceptance can be mitigated when consumers perceive significant benefits associated with cell-cultured meat. Martins et al. (2019) found that consumers with high food neophobia perceived juices processed by both conventional and innovative technologies more negatively than those with low or medium levels of neophobia. Individuals with higher food disgust sensitivity may exhibit a cognitive bias that focuses more on potential risks rather than benefits. This bias can influence how they process information about novel foods, leading to a diminished perception of benefits and subsequently lower acceptance. Siegrist et al., (2020) found that participants having higher FDS perceived more risks compared with participants having lower FDS. Individuals with higher levels of food disgust sensitivity may be more attentive to the negative aspects of novel foods, such as their appearance, smell, or texture. This heightened attention to potential disgust-inducing characteristics could overshadow any PB associated with the food, leading to a lower perception of benefits. Understanding the underlying factors that trigger PR and examining its effect on acceptance is crucial in predicting consumer behavior. This study proposes the relationship as follows:

Hypothesis 7a: PB negatively and significantly mediates the relationship between FTN and consumers' acceptance of cell-cultured meat.

Hypothesis 7b: PB negatively and significantly mediates the relationship between FDS and consumers' acceptance of cell-cultured meat.

Hypothesis 8a: PR negatively and significantly mediates the relationship between FTN and consumers' acceptance of cell-cultured meat.

Hypothesis 8b: PR negatively and significantly mediates the relationship between FDS and consumers' acceptance of cell-cultured meat.

2.7 Moderation of information acquisition

The food market exhibits severe information asymmetry, where buyers and sellers possess unequal information, leading to issues such as adverse selection, market failure, and inefficient resource allocation (Akerlof, 1970). Information provision reduces information asymmetry while lowering consumer information costs. Effective communication enables rational decision-making and influences risk perception (Li, 2014). The provision of informational incentives can revise the perception of consumers about the profit-effectiveness of new food technologies. When individuals actively seek and acquire information about novel food technologies, they are more likely to gain a comprehensive understanding of the potential benefits and risks associated with these technologies. Scholars confirm the significant role of information, including product formulation, certification labels, and product features, in improving consumer acceptance and willingness to pay for novel technology foods (Lusk et al., 2014). Previous studies demonstrate the impact of information on consumer acceptance, trust, and preferences for new food technologies (Siegrist et al., 2020).

Consumers high in FTN may be more reluctant to perceive the benefits of cell-cultured meat due to general reluctance towards new food technologies. However, exposure to information that addresses their concerns and provides reassurance about the safety and advantages of cell-cultured meat can help reduce the negative impact of FTN on PB. Additionally, access to information that transparently communicates the production processes and safety features of cell-cultured meat can help mitigate the influence of FTN on PR. The informational content and source can shape how techno-fearful consumers evaluate the potential benefits and risks of this novel food technology. Furthermore, providing detailed information about the safety and production processes of cell-cultured meat can help alleviate disgust-related concerns, reduce the influence of FDS on PR, and mitigate the negative impact of FDS on PB. The informational channels and content play a crucial role in shaping perceptions and acceptance for disgust-sensitive consumers. Therefore, we proposes the moderating role of information acquisition as follows:

Hypothesis 9a: IA moderates the relationship between FTN and PB.

Hypothesis 9b: IA moderates the relationship between FTN and PR.

Hypothesis 10a: IA moderates the relationship between FDS and PB.

Hypothesis 10b:IA moderates the relationship between FDS and PR.

2.8 Partial least square structural equation model

This study utilizes structural equation modeling (SEM) as a robust analytical approach to ensure methodological reliability and rigor. SEM, a second-generation multivariate data analysis technique, allows for the examination of relationships between constructs, including both direct and indirect effects, within theoretically supported linear and additive causal models. SEM consists of two interrelated models. One is the inner model or structure model, which evaluates relationships among latent constructs. Constructs in our study like PB, PR, FTN, and FDS are latent variables that cannot be directly observed. The other is the outer model or measurement model, which explores connections between latent constructs and their observed indicators. PLS-SEM is adept at modeling and testing moderating effects, allowing for a more comprehensive understanding of the underlying mechanisms. Multiple regression, on the other hand, is limited to working with observed variables, which may not capture the full complexity of our conceptual model, and it typically requires larger sample sizes to ensure reliable and stable estimates. In situations where sample sizes are limited, predictive accuracy is crucial, partial least squares SEM (PLS-SEM) serves as a viable alternative to covariance-based SEM (CB-SEM). PLS-SEM, compared to CB-SEM, delivers similar results (Dash & Paul, 2021), but does not assume specific data distribution, and is more robust to multicollinearity issues (Afthanorhan, 2013; Hair et al., 2016； Ringle et al., 2022). Past research has used PLS-SEM in multiple disciplines such as purchase intention of genetically modified food (Rodríguez-Entrena et al., 2013) or novel insect food (Petrescu-Mag et al., 2022). Our research draws upon the insights gained from Rodríguez-Entrena et al. (2013) 's study to investigate the influence of demographic characteristics and perceptions on consumer acceptance of cell-cultured meat.

Based on the above discussion, this study proposes the research model in Fig 1.

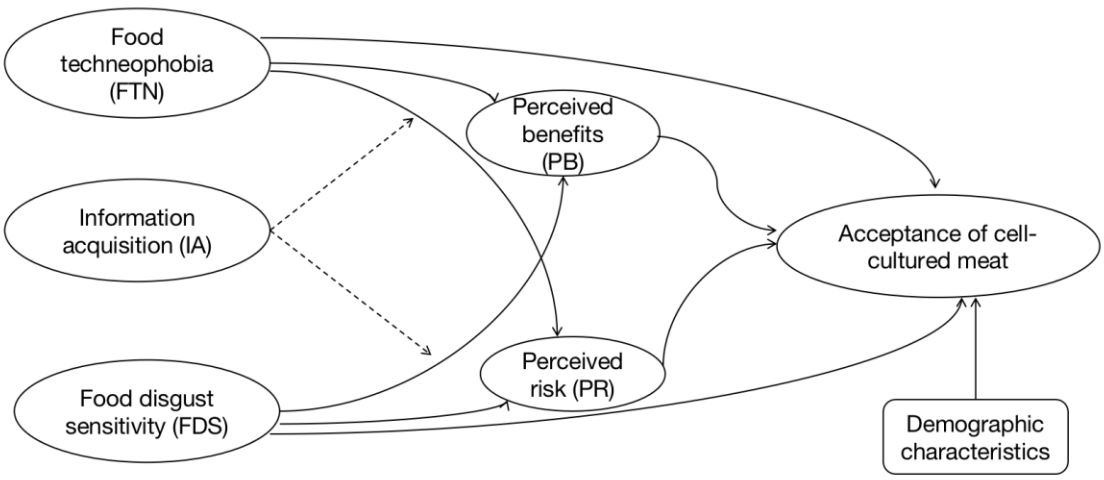

Fig. 1. Theoretical framework

3. Research methodology

3.1 Participants

The study used a cross-sectional survey design. The field survey (in households) was conducted in 17 provinces or municipalities and 2 autonomous regions of China in 2020. The sampling method employed a multistage cluster sampling approach. First, 1-5 prefecture-level cities were randomly selected as clusters within each province, yielding a total of 40 prefecture-level cities across the sample. Then, within each selected prefecture-level city, simple random sampling was used to draw 100-120 respondents from the resident population. The participants were representatives of their family members, chosen to provide a wide range of socioeconomic levels and diverse ethnic groups. Interviews were conducted in a 1-on-1 setting, each interview lasting approximately 30 to 45 minutes. The sample comprised 4,841 participants, with 2,421 males and 2,420 females (see Table 1). The majority (4527) were of Han ethnicity. Over half the respondents were aged 40 or above, with a mean age of 48. Similarly, more than 50% did not hold a college degree. The vast majority (96%) reported liking to consume meat. These were basically in line with reality, and our samples were extensive and representative.

Table 1

Sociodemographic variables of samples.

Sociodemographic variables		Frequency
Gender	Female=0	2421
	Male=1	2420
Nationality	Ethnic minorities=0	314
	Han nationality=1	4527
Age	Actual age	Mean=48, Std. Dev. =12.72
Education level	Without college degree=0	2962
	With college degree=1	1879
Health status	Good health=1	1297
	Other=0	3544
Appetite for meat	Dislike eating meat=1	181
	Like eating meat=0	4660

3.2 Questionnaire/Measures

In the present study, five variables were to be measured using Likert 5-point scales from 1 compeletely disagree to 5 compeletely agree, including FTN, FDS, PR, PB, and acceptance. The scale of FTN was adapted from Henriëtte et al. (2022). The scale of FDS was adapted from Hartmann & Siegrist (2018). This study focused on four dimensions of PB including food safety, nutrition, animal welfare, environmental benefits adapted from the study of de Groot et al., (2020). These dimensions described the best possible benefits that consumers will perceive. As for PR, this study focused on four dimensions including negative taste expectation, perceived unnaturalness, disgust, and risk perception adapted from the study of Tenbült et al., (2005) and Siegrist (2000). These four dimensions described various aspects of consumers' concerns and apprehensions regarding cell-cultured meat. We also measured consumers' IA, using the frequency of consumer usage of information channels for acquiring food-related information as proxy variables. The respondents rated the frequency of their utilization of four information channels, namely television, radio, community events/lectures, and newspapers/magazines/books, using a five-point scale (Almost never = 1; Rarely = 2; Sometimes = 3; Frequently = 4; Almost always = 5).

To measure the level of acceptance of cell-cultured meat, this study focused on three dimensions including willingness to eat, endorsement, and evaluation. To further understand regional differences in consumer acceptance of cell-cultured meat, we categorized the acceptance for the cell-cultured meat among participants from diverse regions into distinct groups. In the visual representation, the intensity of color corresponds to the number of sample observations in each province of China (Fig.2). In general, the sample numbers of all provinces are relatively balanced, among which Shandong Province, Jiangsu Province, Inner Mongolia Autonomous Region and Henan Province have relatively more observed samples. Furthermore, we conducted a statistical analysis of the acceptance of cell-cultured meat among participants from various provinces and regions and created a bubble chart. In the chart, regions with higher overall acceptance, such as Hebei Province, Inner Mongolia Autonomous Region, Shandong Province, Henan Province, Gansu Province, and Liaoning Province, were represented by red bubbles. Hebei Province and Inner Mongolia Autonomous Region exhibited the highest acceptance and can be recommended as pilot regions for promoting cultured meat.

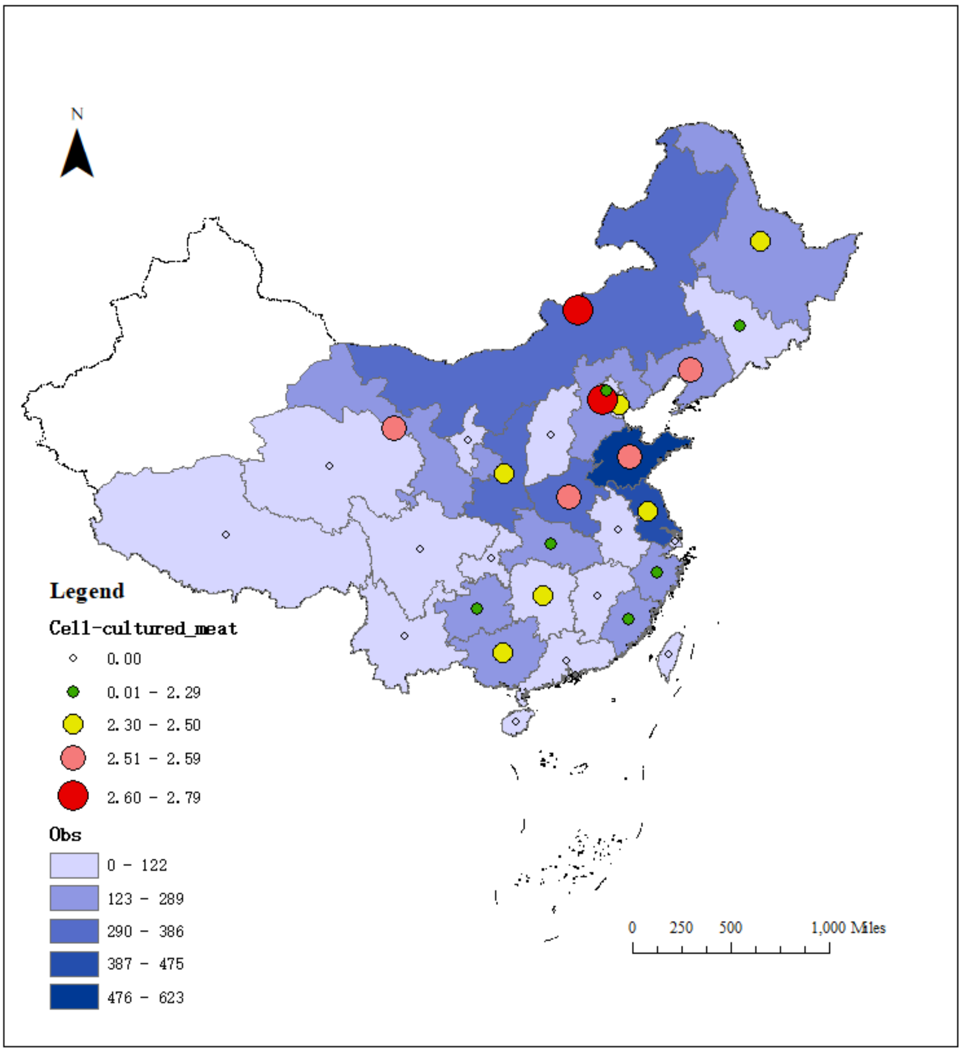

Fig. 2. Provincial distribution map of sample observations and acceptance of cell-culture meat

4. Results

4.1 Reliability and validity

4.1.1 Measurement model assessment

In line with previous research on assessing the measurement model (Hair et al., 2016), the reliability and validity of latent variables was examined, as depicted in Table 2. All of the individual item reliability (Loadings) are 0.536 or more, meeting the criteria for individual item reliability (Hajjar, 2018). The obtained Cronbach's alpha values for the present study ranged from 0.777 to 0.848, meeting the rule of thumb for acceptable reliability. The composite reliability of each item for the present study ranges between 0.839 and 0.908, adequate internal consistency in all constructs was measured.

Additionally, all constructs achieved a minimum average variance extracted (AVE) value of 0.50 (see Table 2), and the square roots of AVE were higher than the inter-construct correlations (see Table 3). These results indicate satisfactory convergent validity of the constructs employed in this study (Bagozzi and Yi, 1988; Cheung et al., 2023). Table 3 displays the correlations among latent variables, such as the positive correlation of 0.648 between PB and acceptance, and the negative correlation of -0.428 between PR and acceptance. All correlations were significant at the 0.01 level (Henseler et al., 2015). The measures employed in this study exhibit an adequate level of discriminant validity, indicating that they effectively distinguish between different constructs.

Table 2

Measurement model.

Construct	Item code	Outer loading	Outer weights	Cronbach's α	Composite reliability (ρ_c)	Average variance extracted (AVE)
Food techneophobia (FTN)				0.777	0.848	0.529
	FTN1	0.713***	0.268***			
	FTN2	0.716***	0.262***			
	FTN3	0.680***	0.256***			
	FTN4	0.774***	0.303***			
	FTN5	0.749***	0.283***			
Food disgust sensitivity (FDS)				0.777	0.839	0.512
	FDS1	0.681***	0.206***			
	FDS2	0.802***	0.333***			
	FDS3	0.643***	0.171***			
	FDS4	0.728***	0.248***			
	FDS5	0.722***	0.417***			
Perceived risk (PR)				0.821	0.882	0.651
	PR1	0.763***	0.294***			
	PR2	0.821***	0.330***			
	PR3	0.814***	0.310***			
	PR4	0.827***	0.304***			
Perceived benefits (PB)				0.782	0.848	0.530
	PB1	0.738***	0.257***			
	PB2	0.755***	0.323***			
	PB3	0.597***	0.172***			
	PB4	0.740***	0.245***			

	PB5	0.794***	0.355***			
Information acquisition (IA)				0.779	0.851	0.589
	IA1	0.830***	0.451***			
	IA2	0.670***	0.188			
	IA3	0.786***	0.404***			
	IA4	0.775***	0.234*			
Acceptance (ACCEPT)				0.848	0.908	0.767
	ACCEPT1	0.868***	0.380***			
	ACCEPT2	0.898***	0.392***			
	ACCEPT3	0.861***	0.369***			
Demographic characteristics (DC)				n.a.	n.a.	n.a.
	Male	0.756	0.515**			
	College degree	-0.122	-0.054			
	Han nationality	0.209*	0.282*			
	Good health	0.540**	0.416**			
	Dislike meat	-0.368*	-0.662**			

n.a.. - non- applicable. *** $p < 0.001$. ** $p < 0.01$. * $p < 0.05$.

Table 3

Discriminant validity .(Fornell-Larcker criterion)

	ACCEPT	DC	FDS	FTN	IA	PB	PR
ACCEPT	**0.876**						
DC	0.101	**0.460**					
FDS	-0.119	-0.076	**0.717**				
FTN	-0.211	-0.064	0.178	**0.727**			
IA	0.091	0.023	0.001	-0.063	**0.747**		
PB	0.648	0.076	-0.066	-0.100	0.047	**0.728**	
PR	-0.428	-0.099	0.247	0.458	-0.458	-0.272	**0.807**

Values on the diagonal (bold) are square of the AVE while the off-diagonals are correlations.

Table 4

Heterotrait-monotrait ratio (HTMT) matrix .

	ACCEPT	DC	FDS	FTN	IA	PB	PR	IA×FDS	IA×FTN
ACCEPT									
DC	0.299								
FDS	0.128	0.545							
FTN	0.259	0.285	0.193						
IA	0.108	0.448	0.110	0.081					
PB	0.768	0.254	0.100	0.172	0.064				

PR	0.511	0.361	0.280	0.572	0.043	0.323		
IA×FDS	0.003	0.220	0.039	0.079	0.025	0.023	0.036	
IA×FTN	0.018	0.184	0.038	0.040	0.054	0.041	0.015	0.251

4.1.2 Descriptive statistics

The descriptive statistics for items and variables are presented in Tables 6, which display the range and interval of all values in the data. The range of all variables is from 1 to 5, representing the minimum and maximum values. The mean represents the central tendency of the sample observations. For instance, the mean value for FTN3 is 3.078. Higher standard deviation values indicate a greater spread in the data. Skewness reveals the asymmetrical pattern of the data, and our study's sample exhibits both left-skewed and right-skewed data. Furthermore, the negative excess kurtosis values indicate a relatively flatter distribution compared to a normal distribution. Considering that PLS-SEM is a nonparametric method capable of accommodating non-normal data, we employ the Cramér-von Mises test to verify the non-normal distribution of the suspected endogenous construct (Ringle et al., 2023). The results indicate significant Cramér-von Mises statistics for each item, leading us to reject the null hypothesis of identical normal distribution samples.

Table 6

Descriptive statistics for variables (n=4841)

Items	Measurement item*	Mean	Standard deviation	Excess kurtosis	Skewness	Cramér-von Mises test statistic
Food techneophobia (FTN)						
FTN1	The benefits of novel food technologies are often overstated.	3.410	0.844	-0.221	-0.194	53.118***
FTN2	Novel food technology makes food lose its nature.	3.262	0.869	-0.314	-0.103	49.016***
FTN3	Novel food technologies may have long-term negative impacts on the environment.	3.078	0.784	-0.025	0.127	66.342***
FTN4	There are risks in adopting novel food technologies too quickly.	3.377	0.846	-0.259	-0.098	52.325***
FTN5	Society should not rely too heavily on technology to solve food problems.	3.363	0.858	-0.261	-0.156	50.822***
Food disgust sensitivity (FDS)						
FDS1	When eating in a restaurant, there is a hair in the bowl	3.149	1.118	-0.920	0.097	30.363***
FDS2	Eat moldy bread	3.512	1.106	-1.071	-0.123	30.843***

FDS3	Eat apple slices that have changed color after a day	2.753	1.200	-0.801	0.329	29.452***
FDS4	Eat slimy fish	3.412	1.182	-0.941	-0.203	27.173***
FDS5	There is half a cockroach in the cold dish	4.329	0.940	0.330	-1.188	105.909***
Perceived risk (PR)						
PR1	Long-term consumption of cell-cultured meat is likely to have more negative effects on health compared to consuming conventional meat.	3.287	0.862	-0.159	0.020	53.565***
PR2	Cell-cultured meat goes against the laws of nature.	3.355	0.887	-0.341	-0.032	47.638***
PR3	The thought of consuming cell-cultured meat elicits feelings of disgust and aversion.	3.217	0.884	-0.130	0.137	54.889***
PR4	Cell-cultured meat will pose a high risk to me and my family.	3.169	0.841	-0.050	0.184	60.480***
Perceived benefits (PB)						
PB1	Cell-cultured meat can prevent animal-borne diseases, enhancing safety.	2.757	0.905	-0.262	0.102	45.938***
PB2	Cell-cultured meat may be more nutritious than conventional meat.	2.408	0.812	0.027	0.242	58.547***
PB3	Cell-cultured meat processing reduces the need for slaughtering livestock and poultry.	3.017	0.931	-0.390	-0.047	42.174***
PB4	The production process of cell-cultured meat is likely to be more environmentally friendly and hygienic than traditional agricultural farming.	2.812	0.871	-0.101	0.119	51.585***
PB5	Cell-cultured meat will bring significant benefits to me and my family.	2.497	0.769	0.189	0.082	65.971***
Information (IA acquisition)						
IA1	Acquire food-related information from television.	2.073	.936	-0.428	0.507	43.641***
IA2	Acquire food-related information from radio.	2.334	1.009	-0.684	0.253	36.162***
IA3	Acquire food-related information from community events/lectures.	2.218	.955	-0.543	0.342	39.795***
IA4	Acquire food-related information from newspapers/magazines/books.	2.075	.947	-0.288	0.553	43.274***
Acceptance (ACCEPT)						
ACCEPT1	Overall, cell-cultured meat is a promising product.	2.517	0.799	0.068	0.023	62.174***
ACCEPT2	Overall, I am satisfied with cell-cultured meat.	2.433	0.811	-0.182	-0.041	59.147***
ACCEPT3	I am willing to try cell-cultured meat.	2.450	0.891	-0.331	0.051	48.671***
Demographic characteristics						
Male	Male=1; Female=0	0.500	0.500	-2.001	0.000	141.247***
College degree	With college degree=1; Without college degree=0	0.388	0.487	-1.790	0.459	156.670***
Nationality	Han nationality=1; Ethnic minorities=0	0.935	0.246	10.499	-3.535	353.438***

Good health	Good health=1; Other=0	0.268	0.443	-0.901	1.048	206.305***
Dislike meat	Dislike meat=1; Like meat=0	0.037	0.190	21.808	4.878	376.377***

* p<0.10, ** p<0.05, *** p<0.01.

4.1.3 Structural model assessment

To examine potential collinearity in the structural model, we computed Variance Inflation Factor (VIF) values, all of which were below 3.30, suggesting the absence of common bias issues (Kock, 2015, 2017). Additionally, to ensure multicollinearity problems were adequately addressed, we calculated the Heterotrait-Monotrait (HTMT) ratio, with a recommended threshold of 0.9 (Farrell, 2010). As shown in Table 4, the highest construct value in our model was 0.768, indicating no multicollinearity concerns. Furthermore, the coefficient of determination (R^2) at 0.486 reveals that FTN, FDS, PB, and PR collectively account for 49% of the variance in acceptance (refer to Table 5; Hair et al., 2016). Moreover, the cross-validated redundancy (Q^2) exceeds zero, demonstrating the predictive relevance of our model.

Table 5

Saturated model results.

Construct	R^2	Adj.R^2	Q^2	RMSE	MAE	SRMR	VIF	BIC	Chi-square
Acceptance	0.490	0.489	0.059	0.971	0.786	0.064	<3.30	-3222.628	10730.337
PB	0.016	0.015	0.012	0.995	0.790			-27.188	
PR	0.238	0.237	0.235	0.875	0.650			-1266.785	

R2 (R-Squared/Coefficient of determination), F2 (The effect size), Q2 (The predictive relevance), VIF (Variance inflation factor), SRMR (Standardized Mean Root Square Residual), BIC (Bayesian information criterion)

4.2 Structural equation modeling

The standard bootstrapping (5000 bootstrap samples) was used with 4841 sample observations for the present study to examine the significance of path coefficients. Figure 3 shows the full estimates of the structural equation model and moderated mediation effects. As shown in Table 8, PB has a positive and significant effect on the acceptance of cell-cultured meat (H1: β=0.574, t=44.551, p<0.000), and PR has negative and significant effects on acceptance (H2: β=-0.249, t=16.126, p<0.000). FTN has a negative and significant effect on PB and acceptance of cell-cultured meat (H3: β=-0.036, t=2.727, p<0.000; H4a: β=-0.091, t=5.029, p<0.000), while it has a positive and significant effect on PR (H4b: β=0.426, t=28.847, p<0.000). Similarly, FDS has significantly negative effects on PB and a positive effect on PR (H6a: β=-0.052, t=3.466, p<0.000; H6b: β=0.173, t=13.015, p<0.000), while it has no significant effect on acceptance of cell-cultured meat (H5: β=-0.011, t=1.032, p>0.05).

Mediation analysis was performed to assess the mediating role of PR and PB in the relationship between FTN, FDS and acceptance. The findings (ref Table 8) reveal that PB significantly and negatively mediated the relationship between FTN and acceptance (H7a: β=-0.052, t=5.114, p<0.000) as well as the relationship between FDS and acceptance (H7b: β=-0.030, t=3.480, p<0.01). Moreover, PR significantly and negatively mediated the relationship between FTN and acceptance (H8a: β=-0.106, t=14.048, p<0.000) as well as the relationship between FDS and acceptance (H8b: β=-0.043, t=9.903, p<0.000). Hence, the effect of the independent variable FTN, FDS, on the dependent variable ACCEPT is mediated by PR and PB. Partial mediation of PB and PR between FTN and acceptance occurred when both direct and indirect effects were significant, while full mediation of PB and PR between FDS and acceptance occurred when direct effects were not significant, but both indirect effects and total effects were significant. Hence, H1-H8b were supported except H5.

We also examined the moderating effect of IA in the relationship between FTN/FDS and PB/PR. The results show that IA can mitigate the negative impact of FDS on PB, thereby enhancing consumer acceptance of cell-cultured meat (H10a: β=-0.020, t=2.185, p<0.05) Fig. 4 shows the moderating effect of IA between FDS and PB. Through access to accurate and comprehensive information about the scientific basis, safety protocols, and potential advantages of cell-cultured meat, consumers can overcome initial aversion and make more informed decisions, leading to increased acceptance of this novel food product. Hence, H10a was supported. As for demographic characteristics, we can see that being male and in good health has a significant positive effect on acceptance (Fig.3).

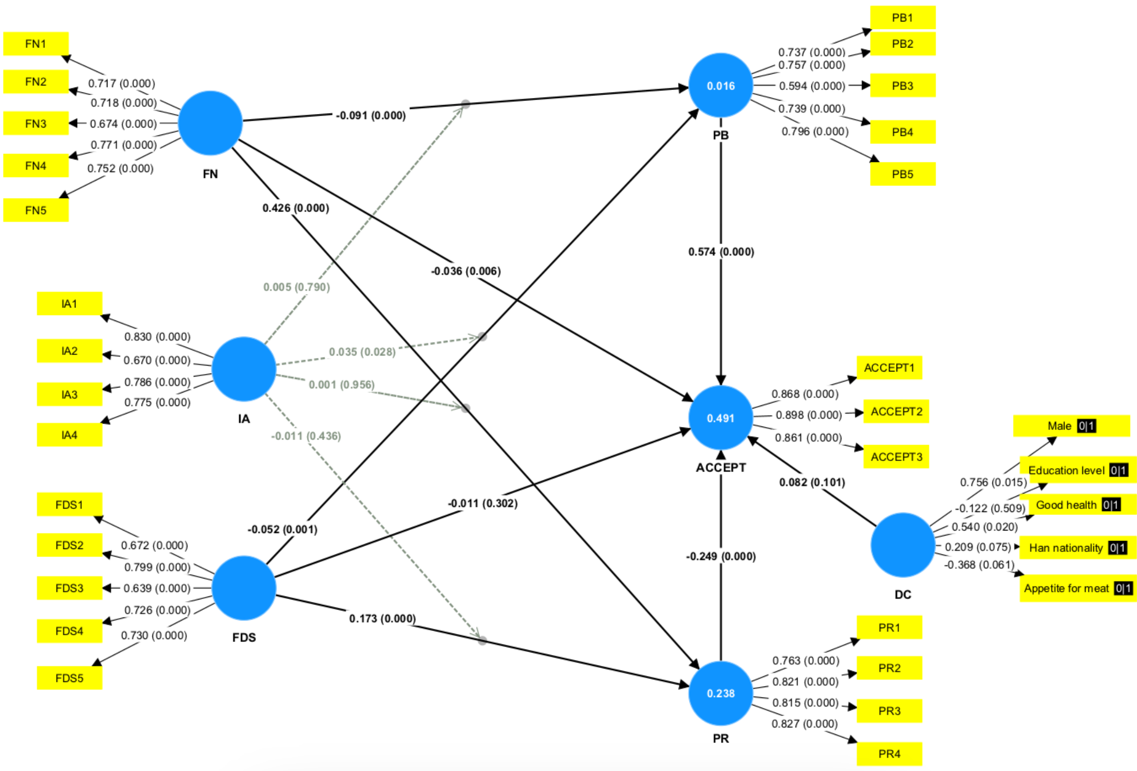

Fig. 3. Partial least square SEM model

Table 8

Path coefficients and hypothesis testing.

Effect	Relationships	β	Mean	Standard deviation	t-value	Decision
Direct effects						
H1	PB→ACCEPT	0.574***	0.574	0.013	44.551	Supported
H2	PR→ACCEPT	-0.249***	-0.249	0.015	16.126	Supported
H3	FTN→ACCEPT	-0.036***	-0.036	0.013	2.727	Supported
H4a	FTN→PB	-0.091***	-0.092	0.018	5.029	Supported
H4b	FTN→PR	0.426***	0.426	0.015	28.847	Supported
H5	FDS→ACCEPT	-0.011	-0.011	0.011	1.032	Unsupported
H6a	FDS→PB	-0.052***	-0.053	0.015	3.466	Supported
H6b	FDS→PR	0.173***	0.173	0.013	13.015	Supported
Indirect/mediating effects						
H7a	FTN→PB→ACCEPT	-0.052***	-0.053	0.010	5.114	Supported
H7b	FDS→PB→ACCEPT	-0.030**	-0.031	0.009	3.480	Supported

H8a	FTN→PR→ACCEPT	-0.106***	-0.106	0.008	14.048	Supported
H8b	FDS→PR→ACCEPT	-0.043***	-0.043	0.004	9.903	Supported
Total effects						
	FTN→ACCEPT	-0.168***	-0.168	0.013	7.505	
	FDS→ACCEPT	-0.077***	-0.076	0.010	12.668	
Moderating effects						
H9a	IA×FTN→PB→ACCEPT	0.003	0.003	0.012	0.265	Unsupported
H9b	IA×FTN→PR→ACCEPT	-0.000	-0.000	0.004	0.055	Unsupported
H10a	IA×FDS→PB→ACCEPT	0.020*	0.020*	0.009	2.185	Supported
H10b	IA×FDS→PR→ACCEPT	0.003	0.003	0.004	0.776	Unsupported

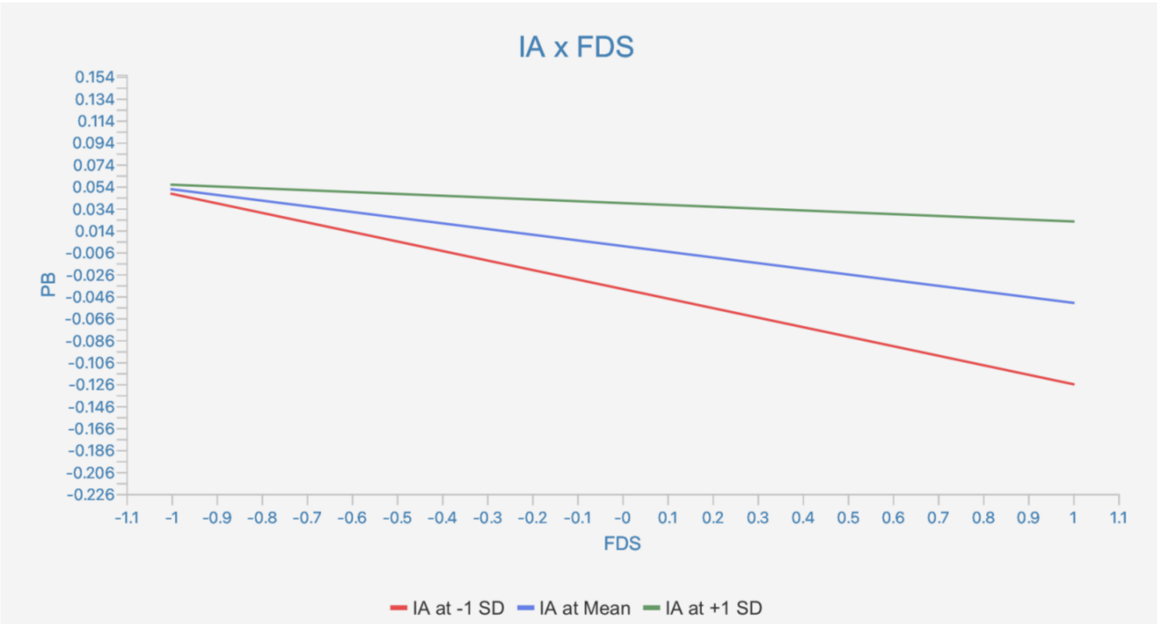

Fig. 4. Moderating effect of IA

5. Conclusions and discussion

This study is the first to measure the acceptance of cell-cultured meat among consumers in different provinces of China, including dimensions of endorsement, willingness to eat, and evaluation. Overall, the acceptance level was found to be moderately low. Hebei and Inner Mongolia showed the highest acceptance among the provinces, making them potential pilot regions for promoting cell-cultured meat. Males, and individuals in good health were more inclined to accept cell-cultured meat.

The study validated multiple hypotheses regarding factors influencing acceptance. Hypotheses 1 and 2 confirmed that PR significantly negatively impacts the acceptance of cell-cultured meat, while PB has a significant positive impact. Among the four dimensions of PR, perceived unnaturalness scored the highest, indicating that consumers strongly perceive cell-cultured meat as unnatural. Furthermore, the study results showed that PB had a greater impact on acceptance than PR, making it the strongest positive influencing factor. Compared to PR, consumer acceptance of cell-cultured meat is more influenced by PB. It is consistent with Frewer et al. (2011) 's study that acceptance may occur where PB outweighs PR. Hypothesis 1 was supported by previous research (Nucci et al., 2015; Bearth et al., 2016), as was Hypothesis 2 (Im et al., 2008; Lee et al., 2013).

FTN and FDS, as innate food-related characteristics, can effectively predict consumers' PB, PR, and acceptance of cell-cultured meat. FTN had a significant negative effect on acceptance of cell-cultured meat while the effect of FDS on acceptance is negative but not significant, suggesting that FTN has a better predictive effect on acceptance than FDS. FTN can be seen as representing a psychological cost or barrier that inhibits consumers from trying and accepting the new cell-cultured meat technology. The stronger predictive power of FTN compared to FDS indicates that reducing technology-related concerns and increasing familiarity may be more important for driving acceptance than addressing disgust reactions alone (White et al., 2023). Some studies have supported a positive correlation between FTN and PR (Smith et al., 2019) and a positive correlation between FDS and PR. Our results are consistent with previous research of Pliner and Hobden (2019) exploring these factors' influence on the acceptance of novel foods. Additionally, studies by Siegrist et al. (2020) and Hartmann and Siegrist (2017) demonstrated a negative relationship between FDS and acceptance of novel foods like sustainable protein.

This study validated the mediating role of PB and PR as negative mediators in the relationship between FTN, FDS, and acceptance of cell-cultured meat. FTN and FDS can reduce PB and increase PR, thereby lowering the acceptance. Many studies have investigated similar structures and reported findings consistent with this study (Johnson et al., 2018; Smith, 2019). Johnson et al. (2018) found that PR negatively mediated the relationship between FTN and acceptance of genetically modified food. Similarly, Smith et al. (2019) found a negative mediating effect of PR in the relationship between FTN and acceptance of novel foods. Higher levels of FTN and FDS are associated with lower PB, indicating a greater focus on the potential risks or drawbacks of novel foods associated with lower acceptance.

The results also demostrated that IA can mitigate the negative impact of FDS on PB, thereby enhancing consumer acceptance of cell-cultured meat. Some studies have emphasised the significance of information acquisition in the new technologies adoption process (Abdulai et al., 2008), and the moderating effect of the exposure to information between PB and behaviors (Wang et al., 2017). Our study further complements the moderated mediation mechanism of IA and consumers' cell-culture meat acceptance. IA serves as a mechanism to bridge the gap between consumers' initial FDS and their perception of the benefits associated with cell-cultured meat. By providing accurate and comprehensive information, it enables consumers to make more informed decisions and potentially overcome aversion, resulting in openness towards novel food technologies.

5.1 Theoretical implications

This study confirms the predictive roles of FTN and FDS in the acceptance of cell-cultured meat and the moderated mediating effects of IA, PR and PB. Through the moderated analysis of mediating mechanisms, a deeper understanding of the underlying processes and pathways by which psychological factors influence acceptance can be obtained, supporting precise interventions targeting PB and PR.

5.2 Practical implications

Firstly, precise science communication strategies are needed to promote public scientific understanding of cell-cultured meat. The study results show that the positive impact weight of PB on acceptance is higher than that of PR, and obtaining more information can reduce the negative impact of food neophobia on perceived risk. Launching a series of accurate information communication that align with the cognitive characteristics of the audience and the communication rules of the post-truth era is recommended, resonating with the public. In addition to scientifically presenting objective risks, it is important to tell compelling stories about the PB of cell-cultured meat, promoting informed and rational decision-making among the public and facilitating the healthy development of the emerging food industry.

Secondly, the research demonstrates that FTN significantly influences people's perceptions of risks and benefits, reducing acceptance. Risk communicators must pay attention to technophobia and the social risks associated with emerging technologies and food products. Different communication strategies should be tailored to specific groups, such as developing effective risk communication strategies for those with high technophobia and disgust tendencies to reduce unnecessary panic. Considering the potential dynamic changes in public attitudes, regular surveys on public awareness and attitudes towards cell-cultured meat are necessary throughout the promotion process. This will help systematically develop relevant communication strategies, identify effective communication focal points, and enhance communication effectiveness and quality while reducing social risks and avoiding misinterpretation and even confrontational interpretations.

Thirdly, consumer-driven innovation in food sector is needed. Policymakers can encourage and support research and innovation in the food industry that prioritizes consumer preferences, concerns, and values. By involving consumers in the early stages of product development, decision-makers can ensure that novel foods meet consumer expectations and are more likely to be accepted by the public.

5.3 Limitations and future research directions

The measurement of consumer acceptance is influenced by product naming and descriptions. As cell-cultured meat has not yet been officially named, this study used terms such as "lab" when describing cell-cultured meat to consumers, which may exacerbate consumers' neophobia and lead to lower acceptance measurements. Future research should explore appropriate official naming for cell-cultured meat and investigate the impact of naming on consumer acceptance. Furthermore, the cross-sectional design used in this study limits the establishment of causal and temporal relationships. Future research employing longitudinal or experimental designs will provide stronger evidence. Additionally, acceptance does not necessarily equate to purchase intent or willingness to pay. Future research will expand to explore consumers' willingness to pay and purchase intent for cell-cultured meat. Integrating both acceptance and economic measures will provide more comprehensive insights to guide the successful commercialization of cell-cultured meat in China.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets are available from the corresponding author upon reasonable request.

Declaration of competing interest: The authors declare no conflict of interest.

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Ethical approval: All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of School of Agricultural Economics and Rural Development, Renmin University of China (Approval Reference Number: SARD-2023-06) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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