Consumer preference for fresh produce: Does the natural enrichment of micronutrients influence their choices?

Abstract : This study explores consumer preferences for naturally enriched micronutrient attributes in fresh pears, particularly through Biological Control (BC) methods. A Choice Experiment (CE) with 758 respondents from key Chinese regions was conducted, employing mixed Logit and Latent Class (LC) models to understand preference heterogeneity. Results show a strong consumer preference for pears enhanced with vitamin C and fiber through BC, indicating a higher willingness to pay (WTP) for naturally improved functional attributes. Consumers prioritize food safety and eco-friendliness in their food choices and are indifferent to the methods used for these improvements, including BC. Significant heterogeneity in preferences highlights the need for market segmentation. The study suggests visualizing these quality attributes through effective labeling and branding strategies. Understanding these consumer choices provides valuable insights for producers, helping align product offerings with market demands and supporting the transition to natural production methods. This research underscores the multifaceted nature of consumer demand for fresh produce, offering guidance on leveraging "natural" enhancement techniques to meet evolving consumer expectations in a competitive market.

1. Introduction

The internal quality attributes or edibility of food are pivotal determinants influencing consumer repurchase decisions (McCluskey et al., 2007). With advancements in agricultural production technology and improvements in living standards, the market has witnessed a significant expansion in product variety. Concurrently, consumer preferences for food have diversified. The concept of food quality has thus evolved beyond traditional aspects such as taste and flavor, encompassing a multidimensional framework that includes food safety, nutritional or functional characteristics, and environmental impact (Marija et al., 2020; Michael et al., 2011; Hu et al., 2004).

While modern biotechnologies like genetic modification (GM) are employed in some countries to alter specific food characteristics, GM foods often face resistance due to consumer concerns about their perceived "unnatural" aspects (Ding et al., 2015; Hu et al., 2004). In such scenarios, enhancing food attributes through natural production techniques presents a viable alternative for consumers. Biological control (BC) is an effective pest management strategy that exemplifies how the intrinsic quality of agricultural products can be naturally improved during the production process.

Experimental findings from the Chinese Agricultural Research System (2017) revealed that pears subjected to BC exhibited higher levels of hardness, moisture, vitamins, reducing sugars, and crude fiber compared to those treated with conventional chemical control methods. Specifically, the implementation of the Beneficial Microbial Motivated Organic (BeMMO) system significantly increased the vitamin C and fiber content in pear fruit[1]. Vitamin C provides antioxidant properties, immune support, and skin-whitening effects, while dietary fiber aids in the prevention of cardiovascular disease, the treatment of diabetes, and the lowering of blood pressure (Xie et al., 2007). Given the rising demand for high-quality agricultural products, consumers increasingly prefer functional attributes that fulfill the human body's nutritional needs, such as vitamin C and fiber, in processed foods like beverages (Bitzios et al., 2011). Consequently, these functional elements are often labeled and segmented within the food market to cater to consumer demands. However, there is a dearth of comprehensive information available on fresh produce. Considering the uniqueness of fresh agricultural products, we have chosen pear as our research subject.

BC not only changes the functional characteristics of agricultural products, but also effectively reduces the use of inputs such as chemical pesticides during production, depending on the extent of BC measures adopted. Therefore, it can mitigate the potential issues of food safety and environmental pollution caused by the excessive use of chemical pesticides (Liu et al., 2022). The current literature generally defines food safety as the assurance that food should not contain a variety of chemical, physical, or microbial toxic and hazardous substances or ingredients that may harm or endanger human health, while the main sources of food safety risks primarily include pesticide and veterinary drug residues as well as microbial contamination (Wang and Gao, 2020). Moreover, chemical pesticides contribute to agricultural surface pollution (Fantke et al. 2012; Landrigan et al. 2018), underlining the ecological importance of transitioning to BC methods. The increasing consumer

[1] Source from the study on the effect of BeMMO system on pear quality conducted by the College of Plant Protection, Nanjing Agricultural University, Handan, Hebei, China, 2017

concern for food safety and enhanced awareness of ecological environments (Klopčič, Marija et al., 2020; Hu et al., 2004) demonstrate the growing influence of these food attributes in the consumer market. We consider the aforementioned functional attributes, food safety, and environmental attributes as internal quality attributes of pear fruit to assess consumer preferences for the "natural" production approach of BC and its potential market value, as an alternative to address consumer concerns regarding "unnatural" food quality improvement technologies such as GM.

The purpose of this study is to: 1) ascertain consumers' preferences and willingness to pay (WTP) for the intrinsic quality attributes of pears, including functional attributes, food safety attributes, and ecological sustainability; 2) determine the extent to which consumers are willing to pay for agricultural products produced using BC as a representative of "natural" production methods; 3) examine the consistency of consumers' preferences for specific quality attributes of food products. This study aims to enhance understanding of the economic value of BC, provide recommendations for future market participation by producers, and facilitate the transition of production methods, and offer market support for the future fresh produce industry.

2. Literature Review

Recent research has highlighted the evolving trends in consumer demand for specific food quality attributes and functional attributes (Edenbrandt et al., 2024; Klopčič, Marija et al., 2020; Ding et al., 2015). While numerous studies have investigated the role of external quality attributes in influencing product pricing and demand, such as size, variety, and glossiness (McCluskey and Loureiro, 2003), there is a growing interest in the intrinsic quality attributes and sensory traits of food that drive repeat purchases (Miller et al., 2005; McCluskey et al., 2007). However, the current research landscape lacks comprehensive exploration in this area.

Intrinsic quality attributes, such as the sugar-to-acid ratio (Campbell et al., 2008), sweetness, and moisture content (Miller et al., 2005; McCluskey et al., 2007), have been shown to significantly impact consumer preferences and willingness to pay for agricultural products. For example, Kajikawa's (1998) research on apples emphasized how these intrinsic qualities can influence the pricing of imported apples from Japan. Studies have also explored how food labeling and quality information influence consumer willingness to pay for organic, natural, and conventionally produced foods.

Consumer preferences for eco-friendly, green, organic, and sustainable labels are gaining traction, especially in emerging markets like China (Zhou, J. et al., 2017).

While consumers show a willingness to pay a premium for specific food attributes, research indicates a certain resistance towards genetically modified organisms (Ding et al., 2015; Hu et al., 2004). Consumers tend to prefer natural methods for enhancing functional properties in food products. However, there is a scarcity of studies focusing on the detailed quality attributes of fresh agricultural products, highlighting a gap in the current research landscape.

As consumer demand for specific food quality attributes and functional properties continues to grow, there is a need for more in-depth exploration of intrinsic qualities that drive repeat purchases. Understanding consumer preferences regarding these attributes, along with the impact of quality information disclosure, is crucial in catering to evolving consumer needs and preferences.

3. Methodology

A Choice Experiment (CE) was designed to elicit consumers' preferences for different quality attributes of pears. The CE in this study includes a total of five attributes. Four of the attributes are set at 2 levels, and the price attribute is set at 4 levels. Furthermore, a partial factorial design based on D-efficiency optimality was employed. As a result, 16 attribute combinations (products) were selected and randomly assigned to two groups, each containing 8 choice sets. Each consumer was randomly assigned to one of the two groups and asked to select between two types of pear fruit and an opt-out option. A "cheap talk" script was included in the careful design of hypothetical scenarios to mitigate any bias.

3.1 Choice Experiment Design

This paper utilizes Choice Experiment (CE) methodology to analyze consumers' preferences for various quality attributes of pears. CE is grounded in Lancaster's utility maximization theory and random utility theory, positing that consumers derive utility from products through a combination of product attributes (Lancaster, 1966). By presenting consumers with different purchase scenarios and asking them to make choices based on these attributes, CE allows for the estimation of consumer preferences for multiple product attributes and the relative importance of each attribute.

Given that this study aims to investigate consumers' preferences and the relative importance of quality attributes of pears, the CE approach is deemed suitable. Pears were chosen as the subject of research due to China's prominent position as the world's largest producer and consumer of pears, with Chinese production accounting for 73.65% of global pear production (FAO, 2024). Analyzing consumer preferences for fruit quality attributes not only helps to clarify market demand and guide industrial development but also provides insights for improving production technologies in response to consumers' demands for enhanced functional content through "natural" means and addressing food safety and other intrinsic quality needs.

By considering the impact of biological control on agricultural product quality and existing literature on consumer preferences for food attributes, this study selected five product attributes for the Choice Experiment: vitamin C and fiber content, pesticide application level, environmental impact, adoption of biological control technology, and price. These attributes were used to differentiate the products in the Choice Experiment with pears as the research focus, as detailed in Table 1.

Table 1 Attributes description and attribute levels used in the CE

Attributes	Levels	Description
Functional contents	Regular; Rich in vitamin C and fiber	The content of vitamin C and fiber in pear fruit
Food safety	Conventional; Pesticide reduction	Application level of pesticides
Eco-friendly	Yes; No	Environmental impact of the production process
Biological control	Yes; No	Pest control methods in the production process
Price (yuan/500g)	4.8 yuan, 6 yuan, 7.5 yuan, 8.8 yuan	Price of pear fruit (yuan/500g)

3.2 Selection of attributes and choice sets

The scenario of this study is described as follows: Imagine you are buying pears in a supermarket, and the following pears are identical in appearance, color, size, packaging, freshness, etc., except for the attributes listed in the table. In each scenario, you have to choose the pear you most prefer among the two different options. If you are not satisfied with either of the pears in the scenario, please choose "neither of them", just as you would in real life. The Choice experiment aims to simulate consumer consumption behavior in a virtual setting to closely replicate real-life scenarios. Therefore, it is important to describe the products being sold as realistically and comprehensively as possible. The fundamental premise of this study is to ensure that consumers fully understand the scenarios. To guarantee a thorough understanding of the hypothetical scenario and product features, four quality attributes and a price attribute were described and defined in the questionnaire.

The descriptions of the different pear attributes are specified as follows: ***Functional attribute*** refers to the content of vitamin C and dietary fiber in pear fruit. Specifically, when we mention pears rich in vitamin C and dietary fiber, it means that the content of vitamin C and dietary fiber in pear fruit is significantly higher than that of pears produced in the current market using conventional methods. For example, under conventional production methods, the vitamin C content of each 250g pear is about 8.5 mg, while pears rich in vitamin C can reach approximately 12.2 mg, an average increase of about 45%. The increased levels of vitamin C and fiber set by this study have been experimentally confirmed to be achieved by means of biological control. ***Food safety attribute*** in this study specifically refers to the reduced use of chemical pesticides, indicating that the frequency and amount of chemical pesticide application on pear fruit during production are significantly lower than the application levels when relying entirely on chemical control. ***Eco-friendly*** attribute refers to the production method that causes less pollution to the soil, water bodies, air, etc., making the production process ecologically sustainable. ***Biological control attribute*** refers to the use of biological control methods in the production process. Biological control involves primarily utilizing beneficial organisms such as predatory natural enemies, parasitic natural enemies, pathogenic microorganisms, or other organisms to suppress or eliminate pests (Debach, 1964). It is characterized by ecological sustainability, environmental friendliness, and harmlessness to humans. Four price levels were set at 4.8 yuan, 6 yuan, 7.5 yuan, and 8.8 yuan, based on a pre-study of pear fruit prices in supermarkets. Following the approach of Gao (2009), the median market price was used as a benchmark, and the final price levels were determined by adjusting the benchmark price upward or downward by approximately 30%.

The choice experiment comprised five product attributes, four of which were set at two levels, and the price attribute at four levels, resulting in 64 potential product combinations. To reduce the cognitive burden on respondents, a partial factorial design based on D-efficiency optimality was employed, selecting 16 attribute combinations. These combinations were randomly assigned to two groups, each containing eight choice sets. Participants were randomly assigned to one of the two groups, and in each choice set, they were asked to choose between two types of pear fruit or opt out. Figure 1 illustrates a sample choice set from the study.

Attributes	Pear A	Pear B	C

			(Neither)
Functional Attributes	Regular	Rich in vitamin C and dietary fiber	
Food safety	Pesticide reduction	Conventional	
Eco-friendly	Yes	□	
Biological control	Yes	□	
Price (Yuan/500g)	6 Yuan/500g	7.5 Yuan/500g	

Figure 1 An example of choice set

To mitigate potential hypothetical bias arising from the hypothetical nature of the choice experiment, we introduced a "cheap talk" script (Cummings and Taylor, 1999; List, 2001) before respondents began making choices. The script emphasized the importance of treating the choices as if they were real purchase decisions, stating: *You will be asked to choose from the following pears. Please ensure that the choices you make in this survey are as close as possible to the choices you would make when purchasing pears in your daily life. You will make a total of eight choices, each of which should be treated as a separate decision, independent of the other choices*.

4. Data source and sample description

4.1 Data sources

We collected data for this study in January 2022 through the professional data research company "Questionnaire Star" via online research. Online research offers advantages such as random sample selection, convenient questionnaire quality screening, and efficient target identification compared to traditional field interviews. Studies (Nielsen, 2011; Marta-Pedroso et al., 2007) have indicated that there is no significant difference in the outcomes of selection experiments between web-based research and field interviews. An investigation by the authors across nine agricultural economics journals[2] from 1998 to 2022 revealed that web research and field

[2] The nine agricultural economics journals collated in this study include: ①American Journal of Agricultural Economics ②Agricultural Economics ③European Review of Agricultural Economics ④Journal of

interviews are the primary methods of data collection for choice experiments. The similar utilization rates of these methods suggest that both approaches yield equally valid data outcomes.

Questionnaire Star maintains a sample database exceeding 6.2 million entries, enabling pre-survey screening of sample information. Additionally, IP and cookie controls are enforced to ensure respondents are geographically restricted and limited to one response. Unsuitable participants are filtered out using screening and trap questions during the survey process. The study targeted consumers who had engaged in pear consumption in the past three months, excluding those who did not meet the criteria or failed the trap question assessments, resulting in 758 valid responses. The research area covered Beijing, Shanghai, Guangdong, Hebei, Shandong, and Hubei, encompassing key provinces and cities representing both significant pear consumption (Beijing, Shanghai, and Guangdong) and production areas (Hebei, Shandong, and Hubei). This selection ensured a representative sample of pear consumers from these regions.

4.2 Sample description

Table 2 illustrates a descriptive statistical analysis comparing the samples across each research region, highlighting a relatively even distribution among the six provinces and cities, with comparable sample sizes in each region. The study population comprised 64.12% female and 35.88% male respondents, showing consistent gender distribution across regions, albeit with minor variations. Respondents had an average age of 33 years, indicating a relatively young demographic, potentially influenced by the online research methodology.

The survey categorized consumers based on their typical pear purchasing price preferences into three groups: low price tendency, medium price tendency, and high price tendency. The majority of respondents (69.53%) fell into the medium price tendency group, with Shanghai exhibiting a slightly higher proportion of high price tendency consumers. Conversely, the main pear production regions of Hebei, Hubei, and Shandong had a higher proportion of consumers with a low price tendency.

Regarding personal monthly income, consumers in Shanghai and Beijing reported the highest income levels, with over 55% of respondents earning more than 10,000 yuan per month and approximately 20% earning over 15,000 yuan. Income

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Agricultural Economics ⑤Agribusiness ⑥Journal of Behavioral and Experimental Economics ⑦Food Policy ⑧Australian Journal of Agricultural and Resource Economics ⑨Canadian Journal of Agricultural Economics distribution across various brackets was relatively balanced, with only 7.78% of respondents earning less than 4,000 yuan monthly.

A significant portion (80%) of surveyed consumers indicated having children at home, and the majority (84%) were married. Most consumers allocated over 50 RMB per month for fruit purchases, with only 16.36% spending less than 50 RMB monthly and half of the sample spending more than 100 RMB. Notably, 70% of respondents reported consuming pears 1-2 times weekly, indicating a high frequency of pear consumption among the surveyed population.

Table 2 Descriptive analysis and comparison of samples (%)

Sample variables	Beijing N=115	Guangdong N=124	Hebei N=139	Hubei N=131	Shandong N=129	Shanghai N=120	Total Sample N=758
Gender							
Male	35.65	37.1	32.37	39.69	37.98	32.50	35.88
Female	64.35	62.9	67.63	60.31	62.02	67.50	64.12
Age	35.79 (7.52)	31.03 (6.44)	32.5 (7.33)	32.20 (6.93)	32.76 (7.14)	36.16 (8.02)	33.33 (7.45)
Consumption category							
Low price preference	6.09	5.65	25.18	9.92	13.95	2.5	10.95%
Medium price preference	71.3	70.97	62.59	76.34	77.52	69.17	69.53%
High price preference	22.61	23.39	12.23	23.66	7.53	28.33	19.53%
Personal monthly income							
< $4000	0.87	9.68	12.95	9.92	7.75	4.17	7.78
4000-5999 Yuan	6.96	20.97	20.86	19.08	20.93	5.00	15.96
6000-7999 Yuan	13.91	17.74	23.74	24.43	23.26	10.00	19.13
8000-9999 RMB	21.74	15.32	17.27	16.03	19.38	17.5	17.81
10,000-14,999 Yuan	36.52	26.61	17.99	20.61	14.73	41.67	25.86
≥ 15,000 Yuan	20.00	9.68	7.19	9.92	13.95	21.67	13.46
Children (under 18 years old)							
None	26.09	16.13	8.63	12.98	12.4	30	17.28
Yes	73.91	83.87	91.37	87.02	87.6	70	82.72
Marital Status							
Unmarried	13.92	23.39	10.08	14.5	13.17	19.17	15.57
Married	86.08	76.61	89.02	85.5	86.83	80.83	84.43
Fruit consumption expenditure (yuan/month)							
<=$50	5.22	27.42	14.39	21.37	13.95	15	16.36
51-100RMB	39.13	38.71	30.22	31.3	22.48	38.33	33.11
101-200 RMB	34.78	20.16	28.06	21.37	28.68	26.67	26.52
Over 200 RMB	20.87	13.71	27.34	25.95	34.88	20	24.01
Pear consumption frequency							
Multiple times per week (greater than or equal to 2 times)	19.13	19.35	29.50	23.66	31.01	20.83	24.14
Once a week	57.39	45.97	43.88	44.27	43.41	45.83	46.57
Once every two weeks	18.26	20.97	22.3	21.37	20.16	24.17	21.24
Once a month (or more)	5.22	13.71	4.32	10.69	5.43	9.17	8.05

Regarding consumers' perceptions and attitudes towards the quality attributes of pears investigated in this study, our statistical analysis indicates that consumers are relatively satisfied with the current food safety situation. Only 1.98% of consumers are very dissatisfied with the current food safety conditions, and overall, approximately 13% of consumers believe there are issues with current food safety. More than 85% of consumers believe the use of chemical pesticides causes food safety problems, while 10.42% of consumers are uncertain about the relationship between chemical pesticides and food safety. This suggests that this group of consumers is not particularly concerned about the impact of chemical pesticides on food. A very small minority of consumers believe chemical pesticides do not cause food safety issues, accounting for only 3.43% of the total sample.

Figure 2 illustrates the prioritization of quality attributes of pears by consumers. Functional attributes receive the highest scores, highlighting consumers' primary concern for the nutritional value, antioxidants, and other functional qualities when purchasing pears. Food safety and disease prevention functions follow closely behind in importance. Conversely, the environmental impact of pear production is rated lowest, indicating that, compared to other quality dimensions, consumers place less emphasis on environmental considerations.

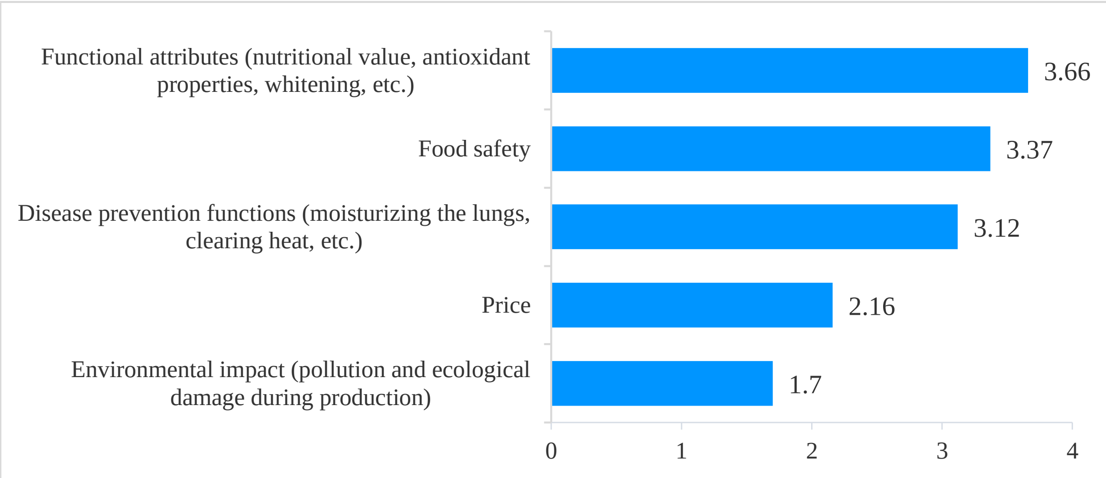

Figure 2 Consumers' ranking of the importance of pear quality attributes

5 Empirical Model and Results

5.1 Mixed Logit Model and Latent Class Model

This study used the Mixed Logit model to estimate consumers' utility functions. The Mixed Logit model was chosen for its ability to overcome the limitations of the standard Logit model, which assumes homogeneous preferences among individuals and limited substitution among options (Train, 2003). This approach allows for a more accurate assessment of consumer preferences and differences across product attributes.

In the Mixed Logit model, attribute coefficients are set to be non-random if consumers are assumed to have homogeneous preferences for that attribute. However, if heterogeneity among individuals is observed, the coefficient is set to be random. In this study, price attribute coefficients are assumed to be non-random, while the coefficients for functional attributes, food safety, and environmental attributes are random due to the belief that these attributes vary by individual preference.

The theoretical basis of choice experiment is random utility theory, which assumes that a consumer *n,* faced with *T choice situations* and each choice situation has *J options,* the indirect utility V_{njt} of consumer *n* is determined by the vector of attributes observable x_{njt} in the specific alternative option *j* and is transformed via the individual specific characteristics c_n and thus, $V_{njt}=f\left(x_{njt}, c_n\right)$, assuming that V_{njt} is a linear function of the vector x_{njt} , the utility level of choosing the *jth* product attribute combination in situation *t* can be expressed as

$$U_{njt} = \beta x_{njt} + \varepsilon_{njt} ,$$

Where: $n = 1, \dots, N,\ j = 1, \dots, J,\ t = 1, \dots, T.$

It is assumed that the consumer seeks to maximize utility and therefore will choose the option with the highest utility in each choice scenario.

In this study, the observable fixed component of the consumer utility function is assumed to be:

$$V_{njt}=\alpha_{nj}+\beta_p p_{njt}+\beta_1 nutri_{njt}+\beta_2 safe_{njt}+\beta_3 env_{njt}+\beta_4 bio_{njt} \qquad (1)$$

where *n* denotes the interviewed individuals, *j* denotes the product in the choice scenario,$nutri_{njt}$ denotes whether the content of vitamin C and fiber in pear fruit is increased (with conventional pear fruit as the control group), $safe_{njt}$ is the food safety attribute of pear, which represents the level of pesticide application on pear fruit, env_{njt} denotes whether the pear production process is environmentally friendly, and the control group is non-environmentally friendly, bio_{njt} denotes whether the pear fruit uses biological control technology during production, and p_{njt} is the price of pear fruit. ε_{njt} is the unobservable random perturbation term, which is random and follows some probability distribution. The Conditional Logit model is obtained when perturbation terms are assumed to be independent and follow the first type of extreme value distribution. This assumes no heterogeneity in consumers' preferences for product attributes (Greene, 2007). The Mixed Logit model effectively captures heterogeneity among attribute coefficients due to unobservable individual differences by assuming that the unknown parameter β is random rather than fixed. This allows for capturing the differences in individual preferences, and its probabilistic model can be expressed as

$$\mathrm{Prob}\left(y_{njt}|\beta\right) = \int \frac{\exp\,(V_{njt})}{\sum_{j=1}^{J} \exp\,(V_{njt})} f(\beta) d\beta \quad (2)$$

The Latent Class (LC) model assumes that the sample can be divided into S clusters based on differences in consumer preferences and individual characteristics. Each consumer is assigned to a group with a certain probability. This allows for the identification of potential categories of consumer preferences and the calculation of the weight of each category in the sample. The LC model can be written as:

$$\pi'_{njt} = \sum_{s=1}^{S} \pi_{njt|s} \pi_{ns} \quad (3)$$

Where s is the number of groups. $\pi_{njt|s}$ represents the probability that consumer n chooses option j in scenario t within the consumer group s. π_{ns} indicates the probability that consumer n belongs to the consumption group s. Similar to equation (2), the LC model can be expressed as:

$$\pi_{ns} = \frac{exp(\gamma_s c_n)}{\sum_{s=1}^{S} exp(\gamma_s c_n)} \quad (4)$$

Where c_n is the observable individual characteristics, which in this study include gender, age, education level, income level, and city of residence. γ_s is the grouping coefficient associated with individual characteristics to be estimated.

5.2 Consumers' willingness to pay (WTP) for different quality attributes

This study investigated the impact of various biological control methods on vitamin C and dietary fiber, the application of chemical pesticides, and environmental effects, either individually or simultaneously. Therefore, this study, while exploring consumers' preferences for different intrinsic quality attributes of pears, aimed to determine whether consumers have a particular preference for the improvement of quality attributes resulting from the use of this "natural" production method, namely biological control. To this end, Model I and Model II were developed for comparative analysis.

Model I incorporated five dimensions of product attributes: functional attributes, food safety attributes, eco-friendly attributes, biocontrol adoption, and price attribute. Model II comprised the price attribute and the interaction term between biocontrol and the other three quality attributes, resulting in a total of four dimensions. The analysis focused on consumers' WTP for enhanced functional content, food safety, and eco-friendly attributes brought about by the adoption of biocontrol methods. Table 3 presents the estimations for Mixed Logit model I and model II. The results indicate a strong fit for both models, with the chi-square values showing significance at the 1% level. The mean values of the parameters for various random variables in the models, with the exception of the price attribute, are deemed significant. This suggests that enhancements to the quality attributes examined in this study—such as increased levels of vitamin C and dietary fibre, reduced pesticide usage, and environmental conservation—can notably boost consumer utility. Moreover, the enhancement of these quality attributes through biocontrol methods also significantly increases consumer utility.

Furthermore, the significant standard deviation of the stochastic parameters reveals substantial variability. The noteworthy coefficient associated with the standard deviation of the random parameter underscores the existence of heterogeneity in consumer preferences across multiple quality dimensions concerning pears.

Table 3 Estimation results of Mixed Logit model

	Attributes	Model I		Model II	
		Coefficient	St.Dev	Coefficient	St.Dev
Fixed parameter	Price	-0.166***	0.014	-0.146***	0.013
	ASC	-1.692***	0.111	-2.481***	0.098
Random parameter	Functional content	1.102***	0.058		
	Chemical pesticide	0.386***	0.054		
	Eco-friendly	0.563***	0.050		
	Biological control	0.579***	0.050		
	Functional content * BC			1.054***	0.074
	Pesticide application * BC			0.225***	0.067
	Eco-friendly *BC			0.252***	0.072
St.Dev of random parameters	Functional content	0.970***	0.060		
	Chemical pesticide	0.954***	0.064		
	Eco-friendly	-0.563***	0.075		
	Biological control	0.762***	0.062		
	Functional content * BC			1.117***	0.095
	Pesticide application * BC			0.938***	0.108
	Eco-friendly *BC			0.811***	0.119
Log likelihood		-4700.43		-4951.81	
Prob > chi2		0.0000		0.0000	
Number of obs		18192		18192	

** p<0.05, ** p<0.01, *** p<0.001*

The sign of the estimated standard deviations is irrelevant: interpret them as being positive.

Consumer preferences for various product attributes can be elucidated through their Willingness to Pay (WTP), which is derived from random utility theory. WTP reflects a consumer's valuation of an attribute by considering the price they would pay for an increase in that attribute. By examining consumers' WIP for each attribute k, we can gain insights into their preferences for different dimensions of a product. Therefore, consumer's WTP for the attribute k can expressed as:

$$E(\,WTP^{k}) = -\frac{E(\,\beta^{k})}{\beta^{price}} \qquad (5)$$

As per equation (5), the estimation of consumers' WTP for different quality attributes of pears can be derived. Table 4 details consumers' WTP for each attribute based on the Mixed Logit model. The findings suggest that consumers exhibit a willingness to pay a premium for pears enriched with vitamins and fiber compared to conventionally produced pears available in the market.

In the context of this study, taking the example of vitamin C content, a 250g pear produced using conventional methods contains approximately 8.5mg of vitamin C, while a pear enriched with vitamin C can reach around 12.2mg, representing an average increase of about 45%. Consumers' average WTP for enhanced functional components amounts to 6.62 RMB/500g. Additionally, consumers are willing to pay an extra 3.48 RMB/500g and 3.38 RMB/500g, respectively, for pears treated with biocontrol methods and those produced in an environmentally friendly manner. Compared to pears treated with chemical pesticides under current production practices, consumers are willing to pay an additional 2.3 RMB/500g for pears with reduced chemical pesticide application. These results indicate that consumers' fruit consumption trends are becoming more diversified, emphasizing not only the aesthetic quality but also a strong preference for the functional aspects of fruits, while also demonstrating a growing demand for environmentally friendly agricultural products.

Table 4 Estimation of WTP

	Model I			Model II		
Attributes	WTP (yuan/500g)	95% confidence interval		WTP(Yuan/500g)	95% confidence interval	
ASC	-10.168***	-11.258	-9.078	-17.051***	-19.008	-15.093
Functional content	6.621***	5.407	7.835			
Chemical pesticide	2.317 ***	1.575	3.058			
Eco-friend	3.383 ***	2.626	4.141			
Biological control	3.478 ***	2.720	4.237			
Functional content * BC				7.243***	5.702	8.784
Pesticide application * BC				1.548***	0.619	2.476
Eco-friendly *BC				1.730***	0.733	2.725

In addition to examining consumers' preferences for the quality attributes of pears, this study focuses on whether consumers show a specific inclination toward certain approaches to these quality attributes. For instance, the increase in vitamin C and fiber content in pears can be achieved through specific biocontrol methods or through the addition of production additives. Similarly, eco-friendliness during production and reductions in pesticide use can be attained through the implementation of biocontrol, although it is not the sole method. Thus, this study incorporates interactions between biocontrol and the aforementioned attributes to explore whether consumers prefer changes in the quality attributes of products produced using specific methods. The results from Model II indicate that consumers exhibit a WTP of 7.24 RMB/500g for pears with increased vitamin C and fiber content achieved through biocontrol, which is higher than the WTP observed in Model I. This suggests that, relative to enhancements in the functional attributes of products produced through other unspecified methods, consumers are more willing to pay a higher price for quality improvements in agricultural products achieved through biocontrol, a "natural" approach.

Furthermore, in Model II, the WTP for eco-friendly and food safety attributes under biocontrol is lower than the results from Model I. This indicates that consumers' concerns regarding the environmental impact of food and the demand for food safety attributes are not confined to specific production methods, at least not exclusively related to biocontrol, but rather focus more on the inherent improvement of these quality attributes in food products.

5.3 Estimation results of Latent- Class model and WTP

Based on the previous discussion, it is evident that there exists heterogeneity in consumer preferences regarding different quality attributes of pears. The Latent Class (LC) model can effectively categorize consumers into distinct groups based on their preferences and personal characteristics, thereby capturing the diversity in consumer inclinations. Hence, this study utilizes the LC approach to investigate the variations in consumer preferences. The determination of the optimal number of latent classes in the LC model cannot be solely achieved through parameter estimation (Swait, 1994). Commonly methods employed to determine the number of classes include the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Smaller values of AIC and BIC indicate a better fit of the model. Table 5 shows the comparison of AIC and BIC values under different latent classes.

Table 5 Comparison of AIC and BIC values under different latent classes

Number of categories	LLF	Nparam	BIC	AIC
2	-4895.462	11	9863.861	9812.924
3	-4797.121	17	9706.964	9628.242
4	-4668.533	23	9489.572	9383.066
5	-4611.75	29	9415.79	9281.5
6	-4624.292	35	9480.658	9318.584

The classification results derived from the LC model are presented in Table 6, where consumers are grouped into five distinct categories, with the distribution of each group detailed in the final row of Table 6. The prevalence of consumers within each category is as follows: category 1 (35.4%), category 2 (20.9%), category 3 (25.5%), category 4 (4.4%), and category 5 (13.8%).

Table 6 Estimation results of LC-Logit model

Attributes	Class1 Coefficient	Class2 Coefficient	Class3 Coefficient	Class4 Coefficient	Class5 Coefficient
Fixed coefficient attributes					
Price	-.161*** (0.014)				
Neither purchase	-1.734*** (0.113)				
Random coefficient attributes					
Functional content	0.407*** (0.063)	2.638*** (0.260)	0.377**(0.149)	1.816*** (0.400)	2.433**(1.048)
Chemical pesticide	0.028 (0.076)	0.839*** (0.236)	1.568*** (0.207)	3.726*** (0.760)	0.293(0.338)
Eco-friendly	0.167*** (0.064)	0.649*** (0.202)	1.235*** (0.155)	2.10*** (0.546)	1.076*** (0.182)
Biological control	0.023 (0.061)	0.576*** (0.170)	0.528*** (0.129)	2.505*** (0.720)	3.006*** (1.019)
Individual Characteristics					
Monthly income	-0.246* (0.130)	-0.201 (0.158)	-0.261* (0.146)	-0.321* (0.193)	
Age	-0.003 (0.021)	-0.103*** (0.030)	-0.050* (0.027)	-0.030 (0.036)	
Education level	-0.375 (0.376)	-0.123 (0.508)	-0.510 (0.435)	0.313 (0.647)	
Exercise frequency	0.498** (0.200)	0.076 (0.257)	-0.025 (0.244)	-0.000 (0.319)	
Consumption category	-0.267 (0.289)	-0.316 (0.393)	-0.110 (0.336)	0.822* (0.435)	
Constant	3.414* (1.905)	5.833** (2.388)	5.593** (2.222)	-1.480 (3.082)	
Class share	0.354	0.209	0.255	0.044	0.138

* p<0.1, ** p<0.05, *** p<0.01, standard errors in parentheses

Similar to the Mixed Logit model, the WTP for each pear attribute was estimated for each consumer group using the same methodology, as detailed in Table 7. By integrating the findings from Tables 6, consumers can be categorized into five distinct groups based on their consumption characteristics: the low demand group, high-quality pursuit group, food safety preference group, pesticide reduction avoidance group, and biocontrol preference group. Specifically, consumers in the low demand group exhibit minimal WTP for reducing chemical pesticides and implementing biocontrol technologies. They also display a low inclination towards paying for enhanced vitamin C and fiber content in pear fruit and environmentally friendly production methods, signifying their lack of concern for these specific food attributes. The frequency of weekly exercise and personal monthly income significantly explain the membership of consumers in this subgroup, highlighting that low-income individuals with regular exercise habits are more likely to belong to this consumption category.

Table 7 WTP estimation of Latent Class model

WTP	Class1 Low-demand	Class2 High-quality Pursuit	Class3 Food safety preference	Class4 Pesticide reduction avoidance	Class5 BC preference
Functional attributes	2.530*** (0.442)	16.421*** (2.147)	2.345**(0.984)	11.304*** (2.606)	15.144** (6.756)
Chemical pesticide	0.172 (0.476)	5.224*** (1.550)	9.757*** (1.402)	-23.188*** (5.095)	1.826 (2.069)
Eco-friendly	1.037*** (0.399)	4.039*** (1.308)	7.683*** (1.071)	13.067*** (3.475)	6.695*** (1.243)
biocontrol	0.144 (0.378)	3.582*** (1.119)	3.288*** (0.887)	15.590*** (4.624)	18.708*** (6.703)

* p<0.1, ** p<0.05, *** p<0.01, standard errors in parentheses

6 Conclusions and discussion

6.1 Conclusions

The findings reveal a multi-dimensional trend in consumers' demand for fruit quality. Consumers exhibit a willingness to pay a premium for increased functional components in fruits, such as vitamin C and fiber content. They also show a willingness to pay extra for eco-friendly attributes and biocontrol methods. This suggests that consumers not only focus on the product's characteristics but also consider the impact of the food production process.

Moreover, consumers are willing to pay a certain price for reducing the application of chemical pesticides in food. However, their WTP for the safety attribute related to pesticide application is comparatively lower than for other quality attributes. This could be attributed to the perception that, although excessive pesticide use leads to uneconomical production at the producer level, consumers may not perceive the safety risks associated with chemical pesticides as strongly. Hence, they are less inclined to pay for this attribute compared to others.

Furthermore, the analysis of consumer preferences and willingness to pay for various quality attributes within the context of biocontrol control revealed interesting insights. Firstly, consumers show a preference for enhanced functional attributes achieved through biocontrol methods over unspecified methods, indicating a preference for "natural" production methods. Secondly, consumers are less willing to pay for food safety and eco-friendly attributes in the biocontrol context compared to unknown production methods. This suggests that consumers prioritize improving food safety and reducing environmental impact, regardless of the specific method used, especially for biocontrol measures. Consumers favor enhancing food's functional content through natural production methods like biocontrol.

Additionally, the study utilized the LC model to explore the heterogeneity in consumer preferences for product quality. The analysis uncovered significant heterogeneity in consumer preferences across various dimensions of pear fruit quality attributes, underscoring the importance of segmenting agricultural product quality attributes to align with consumer market segmentation trends.

6.2 Discussion

Building on the conclusions drawn, this study provides several key insights: first, consumers exhibit a multidimensional pattern in their food preferences. Beyond traditional food quality indicators, factors such as functional characteristics, food safety, environmental impact, and specific production methods have emerged as crucial determinants influencing consumer food choices. For producers, enhancing the quality of agricultural products to boost market value can be achieved by considering measures such as selecting specific crop varieties, employing biocontrol technologies, or improving agricultural production environments. Additionally, addressing the environmental impacts of agricultural production practices and safety concerns related to chemical inputs is essential to align agricultural products with consumer market demands.

Secondly, current agricultural production practices, including the use of natural enemies, microbial fungicides, and other biocontrol measures, play a significant role. These strategies not only affect the input-output dynamics in agricultural production but also help mitigate food safety risks and reduce adverse environmental impacts by substituting chemical pesticides. These attributes have evolved into critical benchmarks for consumer food choices. Our results indicate a high consumer WTP for pears with increased levels of vitamin C and fiber obtained through the "natural" production method of biocontrol. This suggests that farmers can enhance the value of agricultural products by adopting biocontrol methods. When selecting specific biocontrol practices, employing technologies that enhance functional content holds greater potential market value, provided that practical production circumstances are also considered.

Lastly, while the consumer market demonstrates a trend toward diversified food quality demands, it is challenging to transform food production on the supply side if consumer preferences cannot be translated into actual demand through market prices. The quality attributes of the food products discussed in this study are considered unobservable, making it difficult to assess, post-consumption, whether the food quality meets expectations, similar to characteristics of trust goods. Therefore, for food enterprises or the food industry, "visualizing" the inherent quality attributes of products through food labels, branding, or adding food descriptions is crucial for aligning food supply at the production end with food demand at the consumption end. Government entities, agricultural enterprises, industry associations, or other market participants need to focus on the "visualization" of the quality attributes of agricultural products with trust attributes, enhancing product differentiation, and establishing quality-price mechanisms that meet consumer demands. To address the heterogeneity in consumer preferences for food attributes, fruit marketing entities should further define market segmentation for food product and implement differentiated market strategies.