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Consumer preference and willingness to pay for low-residue vegetables: Evidence from discrete choice experiments in China

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Introduction: This study aims to investigate consumers' cognition, preference and willingness to pay (WTP) for celery with low pesticide residues, and to provide evidence from a consumer perspective for government food safety regulation.

Method: A survey was conducted on the population over the age of 18 in 6 provinces of Shanghai, Guangdong, Sichuan, Hunan, Hebei and Heilongjiang in China, in order to improve the representativeness of sample. The study carried out a survey of respondents' cognitive attitudes towards low-residue vegetables, and applied a discrete choice model (DCE) to simulate different scenarios of consumers buying vegetables. The DCE included residue level, appearance, taste, and price and finally constructed 24 choice sets. Respondents' preference for low-residue celery and WTP were analyzed using a mixed logit model.

Result: A total of 1292 respondents were surveyed. The model results showed that consumers had the highest positive preference for pesticide-free celery. For the Chinese consumers, price was the most important attribute, followed by the residue level, taste, and appearance. Consumer WTP for pesticide-free celery was11.17CNY/500g. Factors affecting consumer preferences were age, gender, income, education, whether they had children, or paid attention to pesticide residue in vegetables, and related reports of pesticide residue exceed the standard in vegetables.

Conclusion: Our study is more finely divided at the residue level, and the findings provide useful information for producers and policy makers.

KEYWORDS

willingness to pay, discrete choice experiment, consumer preference, organic food, low-pesticide residue vegetables, Chinese consumer

1. Introduction

Food safety has become a global public health problem. Globally, around 600 million people fall ill each year after eating contaminated food, resulting in 420,000 deaths and a loss of 33 million Disabilty Adjust Life Years (DALYs), according to the (World Health Organization, 2015). Between 2003 and 2017, China's National Foodborne Disease Outbreak Surveillance System reported a total of 19,517 food-borne disease outbreaks, resulting in 1,457 deaths. In the 13,307 incidents with known causes, 4.8% were related to pesticides (Li et al., 2020). In the analysis of the causes of pesticide poisoning in food-borne diseases, excessive pesticide residues accounted for about 35.59% (Zhuang et al., 2021). The food safety supervision and sampling inspection announcement issued by the China State Administration for Market Regulation in 2020 shows that, among the unqualified items detected, the pesticide and veterinary drug residue exceeding the standard limit, accounted for 35.31% of the total unqualified samples (State Administration for Market Regulation of the People's Republic of China, 2020). Among the sampling results in the first half of 2021, agricultural veterinary drug residue exceeding the standard value, accounted for 37.29% of the total unqualified samples (State Administration for Market Regulation of the People's Republic of China, 2021).

From an economic point of view, the occurrence of food safety problems is mainly due to market failure caused by information asymmetry and externalities, resulting in insufficient food safety and effective supply, excessive harmful substances in food, and excessive risks to human health. In this case, if the government formulates food safety regulations to reduce the level of food-borne health risks, public welfare can be improved.

The use of pesticides has greatly improved crop yields, but also has an adverse effect on the environment and human health (World Health Organization., 2002). Policymakers in various countries have also begun to formulate relevant food safety regulations to control the impact of pesticides on the environment and health, such as adjusting the limit of pesticide residues in food or restricting the use of certain pesticides in crops (Van Ravenswaay and Hoehn, 1991; Buzby et al., 1995). The new regulations will inevitably have an impact on the main players in the food chain. For example, the reduction of available pesticides may lead to a decline in crop yield or quality, which in turn affects producer profits and product prices. From the perspective of cost-benefit analysis, although regulation reduces food safety risks, it also has a negative impact on social welfare (Jones et al., 1999).

In the process of improving food safety levels, policymakers need to weigh the benefits and costs of food safety regulation to ensure that regulations maximize the net benefit of food safety, that is, making the marginal benefit of safer food equal the marginal cost of achieving food safety goals. Cost-benefit analysis is considered an indispensable tool in policy design and decision-making (OECD, 2006). A cost-benefit analysis reflects the costs and benefits of all beneficiaries and losers, and provides a rational model for determining the net benefit optimum. At the same time, the cost-benefit analysis focuses on consumer preferences and is relatively fair. Consumer willingness to pay (WTP) for lower pesticide residue levels can be used as an indicator of food safety needs (Fu et al., 1999). The monetary value of changes in pesticide residue levels can reflect the preferences and perceptions of those exposed to risk. The lack of directly observable prices requires the use of non-market techniques to monetize individual preferences (Bateman et al., 2002). Non-market assessment techniques can be classified as revealed preference (RP) or stated preference (SP) techniques. Revealed preferences are based on information about actual decisions in the real market to derive the monetary value of risk changes, whereas, stated preferences require respondents to make decisions in a hypothetical market (Tago et al., 2014). Identifying consumers' WTP for low-residue vegetables is critical for both vegetable producers and policy makers. For producers, it is necessary to learn whether consumers are willing to pay for low-residue vegetables, whether producers can obtain additional benefits, and if the benefits can offset the costs incurred. Establishing vegetable preferences help in obtaining valuable information in terms of policy formulation process and cost control, and based on it, reasonable and effective food safety policies can be formulated.

A large number of studies in different countries show that consumers are willing to pay a premium for low-residue or organic food (Cecchini et al., 2018), and the main factors that affect consumers' WTP were divided into demographic and socioeconomic factors, and risk perceptions (Haghiri et al., 2009; Suhaimi et al., 2021). Weaver et al. assessed consumer WTP for pesticide-free tomatoes. The results show that most respondents were willing to pay 10% more (Weaver et al., 1992). Other scholars have also conducted research on pesticide-free tomatoes in Turkey, Tanzania, and other countries. The results show that most consumers willing to pay a small premium for residue-free tomatoes. Factors such as gender and education affect the WTP (Sedef et al., 2001; Bayramoglu and Göktolga, 2009; Alphonce and Alfnes, 2012). Studies on organic apples, Japanese mustard, and eggs done in France, Japan, and Italy also show that consumers are willing to pay a premium for low-residue products (Stéphan et al., 2012; Seo et al., 2019; Yeh et al., 2020). Demographic factors such as age, gender, nationality, education, family size, and income, as well as environmental concerns and emphasis on health, are important factors affecting WTP (Stefano and Michele, 2000; Morteza et al., 2007; Haghiri et al., 2009; Haghjou et al., 2013; Muhammad et al., 2015).

Scholars in China analyzed consumers' WTP for meat and vegetables that were low-residue, organic, or traceable agricultural products, by using conditional value evaluation and choice experiment. The results show that most consumers are

willing to pay a certain price according to their preferences, and the premium for various products ranges from 42.11 to 335%. The main influencing factors were demographic factors, consumers' subjective knowledge, trust in government agencies, and awareness regarding the health and environmental impact of the use of pesticides (Dai et al., 2006; Zhou, 2006; Guo, 2013; Ge, 2018; Ma and Yao, 2018). At present, most of the studies on consumers' preference for low-residue vegetables in China are conducted in one city, which lacks overall representation.

Based on the above background, this study aims to evaluate Chinese consumers' cognition, preference and willingness to pay for low-residue vegetables. In this study, based on the per capita gross domestic product (GDP) level, we selected six provinces in China to conduct a survey, obtained consumers' concerns about pesticide residues in vegetables through a self-made questionnaire, and used discrete choice experiments to obtain consumer preferences and willingness to pay. Empirical analyses were conducted using mixed logistic models and explored preference heterogeneity among groups with different demographic characteristics. Information on consumer preferences and willingness to pay is crucial for analyzing the effects of policy implementation. This study estimates the benefits of food safety risk reduction, combined with the cost of regulation, to determine whether regulation can generate social benefits, thus providing a reference for government management decisions.

2. Materials and methods

2.1. Study design

According to the per capita GDP of each province in 2020 released by the National Bureau of Statistics of China, we divided the GDP per capita of 31 provinces in mainland China into three levels, high, middle and low, and considering the geographical location of the provinces, selected Shanghai, Guangdong, Sichuan, Hunan, Hebei and Heilongjiang for investigation. The geographical location and per capita GDP of the provinces are shown in Supplementary Table S1. The survey was officially conducted in July 2021. A self-designed questionnaire was used to collect data on Wenjuanxing, an online research platform. The questionnaire included three parts: basic personal information, cognitive situation and discrete choice experiment. Basic personal information includes demographic information and personal health status; cognition includes whether to pay attention to pesticide residues, sources of information, frequency of active acquisition, etc. In order to check the fluency and readability of the questionnaire, grasp the survey time, and improve the response efficiency of the respondents, a pre-survey was conducted before the formal experiment was carried out. The pre-survey was conducted by face-to-face survey. The respondents were instructed on site to complete the questionnaire, and feedback the problems encountered in questionnaire filling. The pre-survey was conducted in Harbin, Heilongjiang Province, with a sample size of about 15 people. In the formal survey, in order to improve the enthusiasm of the respondents, each respondent is given a reward of 5 yuan. In order to better control the quality of the questionnaires, the questionnaires whose filling time was too short were deleted, and the questionnaires were logically checked. Prior to data analysis, we removed respondents with obvious protest responses, that is, questionnaires in which all choose out-opt or one side of the alternative items (Sufyan et al., 2019b).

2.2. Choice sets design

There are two main reasons for taking celery as the research object in this study: First. Celery is commonly consumed by the chinese people. In recent years, in the sampling monitoring of commercially available celery, the detection rate of pesticides is about 70%, and the exceeding rate is between 16.4 and 33.3%. There are relatively serious pesticide residues (Wu et al., 2010; Fang et al., 2015; Xu et al., 2018; Qin et al., 2020; Zhang and Li, 2020). The main purpose of the research is to determine consumers' willingness to pay for celery with different pesticide residue levels, therefore, the pesticide residue level is included as the main attribute. The price attribute was included in the study as a tool to measure willingness to pay (Zhang and Jakku, 2020). At the same time, the taste (Malone and Lusk, 2017) and appearance (Alfnes et al., 2006) attributes that consumers are concerned about are included. Among these four attributes, the residual level and price can be quantified, so we divide the level more finely. The prices of common celery and organic celery in the market are confirmed as the upper and lower limits of price attributes. Taste and appearance are relatively subjective and difficult to quantify, so the taste attribute divided into three levels: superior, equal and inferior to ordinary celery. The appearance attribute are divided into three levels: marked, mild and scar-free (see Table 1).

After determining the attributes and levels, next step was to design the choice set. The choice and quantity were closely related to the number of attributes and levels. There were four attributes in this study. Two attributes were at five levels and two attributes were at three levels. If a full factorial design is used, $(5 \times 3 \times 3 \times 5)\ 2 = 50{,}625$ choice sets will be generated. Therefore, the D-efficiency program of stata16.0 is used to generate choice sets. Each choice set includes an out-opt. A total of 24 choice sets were generated, which were divided into four versions to reduce the respondent's response burden and improve response efficiency (Reed Johnson et al., 2013). Each version sets a repeated choice set based on six choice sets. An example of a choice set is given in Table 2.

2.3. Theoretical framework and data analysis

This study uses discrete choice experiments to simulate consumer purchases of vegetables. In recent years, discrete choice experiments have been widely used as an emerging preference measurement tool in the fields of food, environment, hygiene, and transportation (Flügel et al., 2015; Barrowclough and Alwang, 2018; Thøgersen et al., 2018; Livingstone et al., 2020; Phillips et al., 2021). Discrete choice applies to a range of choice scenarios, where an individual chooses one from a set of alternatives, and the alternative is represented by a set of attributes, thereby revealing the important attributes/levels that influence the individual's choice (Nakatani et al., 2014). The basis of the discrete choice model is the random utility theory and the theory of characteristic value. The theory of characteristic value shows that the utility consumers obtain from a product is a function of product attributes (Lancaster, 1966), and under budget constraints, consumers rationally choose products to maximize utility. U_{njt} represents the utility that the decision maker n obtains from the consumption of vegetable j under the choice scenario t, specified as a function of price P_{njt} and other non-monetary attributes x_{njt} (Hole and Kolstad, 2012). The utility model is as follows:

$$U_{\mathrm{njt}} = -\alpha_n p_{njt} + \beta'_n x_{njt} + e_{njt} \quad (1)$$

In the formula, α_n and β_n are random among the decision makers, assuming that e_{njt} is an independent identically distributed (IID) type I extreme value distribution (EV I) distribution. The variance of e_{njt} is different for different decision makers: $Var\left(e_{njt}\right) = k_n^2(\pi^2/6)$, where k_n is the scale parameter of decision maker n.

Dividing the utility function (1) by k_n does not affect the behavior (Train and Weeks, 2005), but produces a new error term, which obeys the IID extreme value distribution, and the variance is equal to $\frac{\pi^2}{6}$:

$$U_{njt} = -(\alpha_n/k_n)p_{njt} + (\beta_n/k_n)'x_{njt} + \varepsilon_{njt} \quad (2)$$

The utility coefficient is defined as $\lambda_n = \alpha_n/k_n$ and $c_n = \beta_n/k_n$, and the utility is written as:

$$U_{njt} = -\lambda_n p_{njt} + c_n x_{njt} + \varepsilon_{njt} \quad (3)$$

Equation (3) is called the utility model in the preference space. The willingness to pay for an attribute is the ratio of the attribute coefficient to the price coefficient: $w_n = c_n/\lambda_n$. Using this definition, the utility function can be rewritten as:

$$U_{njt} = -\lambda_n p_{njt} + (\lambda_n w_n)'x_{njt} + \varepsilon_{njt} \quad (4)$$

Equation (4) is called the utility model in the willingness to pay space. Under this parameterization, changes in willingness to pay (independent of scale) and changes in price coefficients (including scale) are distinguished.

In discrete choice experiments, consumers are usually faced with multiple combined scenarios with different attributes and are asked to make a choice among these scenarios. According

TABLE 1 Attributes and levels used in the discrete choice experiment (DCE).

Attributes	Levels
Pesticide residue level	80% of normal celery
	60% of normal celery
	40% of normal celery
	20% of normal celery
	No pesticide residues
Appearance	Marked mutilation or scarring
	Slight mutilation or scarring
	No mutilation or scarring
Taste	Not as good as normal celery
	Similar to normal celery
	Better than normal celery
Price	15CNY/500 g
	12CNY/500 g
	9CNY/500 g
	6CNY/500 g
	3CNY/500 g

TABLE 2 Example of discrete experiment choice set.

Attributes	Alternative1	Alternative2	Alternative3
Pesticide residue level	20% of normal celery	80% of normal celery	None of them
Appearance	Slight mutilation or scarring	No mutilation or scarring	
Taste	Not as good as normal celery	Better than normal celery	
Price	12CNY/500 g	3CNY/500 g	
Your choice	□	□	□

to the results of the choice, we can simulate and estimate the consumers' preference parameters for these characteristics or attributes by establishing a certain measurement model, thereby explaining the consumer's choice behavior. It is important to consider these individual preferences and heterogeneity in the modeling process. The mix logit model is one of the methods to explain the heterogeneity of the interviewees' preferences. Alternative specific constant (asc) terms are set to analyze intrinsic, property-independent preferences. We set the constant term for alternative1 and alternative2 to 1, and the out-opt to 0 (Si et al., 2019; Sufyan et al., 2019a). It allows the parameters to vary randomly among the individuals, and is characterized by the heterogeneity as a continuous function of the parameters (McFadden and Train, 2000). The probability that individual n chooses alternative j from the choice set sequence I is:

$$P_{nj} = \frac{\exp(\beta_s X'_{nj})}{\sum_{j=1}^{J} \exp(\beta_s X'_{nj})} \quad (5)$$

The program was developed by Hole in stata16.0 for data analysis (Hole, 2007). This study uses a mixed logit model to estimate the main effects, and an interaction term estimation model to assess whether there were potential differences in preferences among groups with different sociodemographic characteristics, including gender, age, income, education, degree, whether they had children, and the degree of concern about pesticide residue in vegetables. The interaction terms are fixed effect parameters, and the main attribute coefficients are random coefficients. For a list of variables, see Supplementary Tables S2, S3.

3. Results and discussion

3.1. Sample characters

A total of 1,307 respondents were investigated in this study, and 1,292 samples were finally retained after the questionnaire of obvious protest response and logic problem was deleted. 31.81% were registered in rural areas. The sample sizes of Shanghai, Guangdong, Hunan, Sichuan, Hebei and Heilongjiang were 239, 239, 204, 212, 203, and 195,, respectively. Women accounted for 48.76% of all respondents, the average age was 31.2 years, 79.95% had a job, 72.83% had a college degree or above, 62% were married, 81.27% had an average monthly household income of 5,000 yuan and above, and 81.42% of households spent 1,000 yuan and above on food every month. Most respondents believed that they were in good health. 61.38% of the respondents had children under 15. The basic information of the sample population is shown in Table 3.

3.2. Consumer cognition

The survey results showed that 80.19% of consumers were worried about pesticide residue in vegetables. Television, the Internet, and food safety agency publicity are the main channels through which consumers obtained information on pesticide residue in vegetables. Most consumers learn relevant information 1–3 times a week, 86.07% would screen the information, 79.72% would continue to pay attention to information, and 82.82% of consumers were concerned about reports of excessive pesticide residue in vegetables. 55.81% of the people strongly agreed or agreed that they could not identify the levels of pesticide residues in vegetables, and 41.56% of the people strongly agreed or agreed that they lacked the relevant knowledge about the health effects of pesticide residues. The main impact of these reports was reduced purchase or more cautious purchase (see Table 4).

The results of our survey showed that consumers are concerned about pesticide residues and lack of relevant knowledge and information. At the same time, studies have shown that some consumers do not understand the health hazards of pesticide residues and cannot identify the pesticide residue levels of vegetables sold in the market (Vidogbéna et al., 2015). Therefore, it's necessary to fully inform consumers the residue level through disclosing information or puting certification labels on low vegetables.

3.3. Preference weights and relative importance of attributes and levels

Table 5 reports the results of the mixed logit model in preference space. The coefficient of Mean asc is significantly positive, indicating that consumers are more inclined to choose low-residue vegetables than to maintain the status quo. The coefficient of SD asc is significant, indicating that there is significant heterogeneity in consumer preferences. Whether in urban or rural areas, the mean coefficients of all attributes are statistically significant and are expected signs, indicating that all attributes included in DCE have an impact on low-residue vegetable purchasing decisions. From the standard deviation of the regression coefficients, it can be seen that among urban and rural consumers, residue4, residue5, taste3 and appe3 have a significant impact on consumers' vegetable choices, and different respondents have different preferences for these attributes. Negative price coefficients indicate that both rural and urban consumers prefer lower-priced vegetables.

The preference weights are shown in Figure 1. The colored sphere represents the mean value of the preference coefficient, and the gray sphere represents the 95% confidence interval. In both urban or rural areas, consumers had the highest positive preference for celery without pesticide residues (Rural: $\beta = 2.27$,

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TABLE 3 Socio-demographic characteristics of the sample.

Variable	Characteristics	All ($n = 1292$)		Rural ($n = 411$)		Urban ($n = 881$)	
		N	%	N	%	N	%
Gender	Male	662	51.24	196	47.69	466	52.89
	Female	630	48.76	215	52.31	415	47.11
Age	18–29	609	47.14	255	62.04	354	40.18
	30–39	474	36.69	112	27.25	362	41.09
	40–49	148	11.46	34	8.27	114	12.94
	50–	61	4.72	10	2.43	51	5.78
Employment	Employed	1,045	80.88	293	71.29	752	85.36
	Unemployed	247	19.12	118	20.71	129	14.64
Education	Secondary School	25	1.93	12	2.92	13	1.48
	High School	119	9.21	61	14.84	58	6.58
	Vocational College	207	16.02	84	20.44	123	13.96
	Bachelor's Degree	814	63.00	226	54.99	588	66.74
	Master's Degree and Higher	127	9.83	28	6.81	99	11.24
Marital Status	Married	801	62.00	194	47.20	607	68.9
	Singe	473	36.61	210	51.09	263	29.85
	Divorce	16	1.24	5	1.22	11	1.25
	Widow	2	0.15	2	0.49	-	-
Household income (per month) (CNY)	3,000 or Less	60	4.64	32	7.79	28	3.18
	3,000–5,000	182	14.09	76	18.49	106	12.03
	5,000–10,000	362	28.02	142	34.55	220	24.97
	10,000–15,000	277	21.44	77	18.73	200	22.7
	15,000–20,000	235	18.19	50	12.17	185	21
	More than 20,000	176	13.62	34	8.27	142	16.12
Food expenditure (per month) (CNY)	500 or Less	35	2.71	18	4.38	17	1.93
	500–1,000	205	15.87	99	24.09	106	12.03
	1,000–2,000	378	29.26	121	29.44	257	29.17
	2,000–3,000	338	26.16	108	26.28	230	26.11
	3,000–4,000	165	12.77	35	8.52	130	14.76
	4,000–5,000	106	8.20	21	5.11	85	9.65
	More than 5,000	65	5.03	9	2.19	56	6.36
Family size	2 persons or less	134	10.37	48	11.68	86	9.76
	3–5 persons	1,088	84.21	332	80.78	756	85.81
	More than 6 persons	70	5.42	31	7.54	39	4.43
Child (age < 15)	Yes	793	61.38	229	55.72	564	64.02
	No	499	38.62	182	44.28	317	35.98
Health status	Very good	421	32.59	136	33.09	285	32.35
	Good	590	45.67	184	44.77	406	46.08
	General	263	20.36	84	20.44	179	20.32
	Poor	18	1.39	7	1.70	11	1.25

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TABLE 4 Consumers' cognition of vegetables with low residue.

Characteristics	All		Rural		Urban	
	N	%	N	%	N	%
Concerned about pesticide residues in vegetables						
Yes	1,036	80.19	324	79.00	712	80.82
No	256	19.81	87	21.00	169	19.18
Ways to obtain pesticide residues in vegetables						
Television	941	72.83	319	77.62	622	70.60
Magazine	406	31.42	137	33.33	269	30.53
Internet	1,134	87.77	354	86.13	780	88.54
Lecture	262	20.28	78	18.98	184	20.89
Food Safety Agencies Promote	811	62.77	266	64.72	545	61.86
Frequency of obtaining pesticide residue information						
Less	482	37.31	171	41.61	311	35.30
Once a week	367	28.41	105	25.55	262	29.74
2–3 times a week	340	26.32	106	25.79	234	26.56
4–5 times a week	62	4.80	13	3.16	49	5.56
Everyday	41	3.17	16	3.89	25	2.84
Whether to screen the information						
Yes	1,112	86.07	344	83.70	768	87.17
No	180	13.93	67	16.30	113	12.83
Continue to pay attention to the information						
Yes	1,030	79.72	324	78.83	706	80.14
No	262	20.28	87	21.17	175	19.86
Pay attention to pesticide residue reports						
Yes	1,070	82.82	339	82.48	731	82.97
No	222	17.18	72	17.52	150	17.03
How these reports affect you						
Do Not Affect	139	10.76	54	13.14	85	9.65
Reduce the Number of Purchases	583	45.12	216	52.55	367	41.66
Cautious to Buy	1,086	84.06	339	82.48	747	84.79
Buy a Substitute	516	39.94	169	41.12	347	39.39
Don't Buy	42	3.25	16	3.89	26	2.95
I can't identify the level of pesticide residue						
Couldn't agree more	250	19.35	83	20.19	167	18.96
Agree	471	36.46	155	37.71	316	35.87
General	377	29.18	118	28.71	259	29.4
Disagree	151	11.69	45	10.95	106	12.03
Strongly disagree	43	3.33	10	2.43	33	3.75

(Continued)

TABLE 4 (Continued)

Characteristics	All		Rural		Urban	
	N	%	N	%	N	%
Lack knowledge of the health effects of pesticide						
Couldn't agree more	139	10.76	49	11.92	90	10.22
Agree	398	30.80	127	30.9	271	30.76
General	347	26.86	121	29.44	226	25.65
Disagree	325	25.15	89	21.65	236	26.79
Strongly disagree	83	6.42	25	6.08	58	6.58

SE = 0.12, $p = 0.000$; Urban: $\beta = 2.31$, SE = 0.21, $p = 0.000$). The preference weight of cities is slightly higher than that of rural areas. Price is a negative preference, and the absolute value of the preference weight in the countryside is slightly higher than that in the city (Rural: $\beta = -0.28$, SE=0.02, $p = 0.000$; Urban: $\beta = -0.24$, SE=0.01, $p = 0.000$).

Figure 2 shows the relative importance scores of attributes of rural and urban consumers. The relative importance score of each attribute was determined by the ratio of the maximum utility to the total utility of the attribute. Among rural consumers, the relative importance score of price attributes was 83.15%, followed by residue attributes at 9.56%, taste attributes at 5.43%, and appearance attributes at 1.82%. The relative importance score of prices among urban consumers was 84.36%, followed by 9.01, 4.27, and 2.36% for residue, taste and appearance,, respectively.

In general, among the four attributes, the relative importance of price is the highest, and Chinese consumers' vegetable purchase preference is affected by consumption level. Consumers preferred low residue attributes over taste and appearance, and there were similarities in preferences between urban and rural residents. The highest positive preference for no pesticide residue in the preference weight also shows that reducing pesticide residue levels is more important to consumers relative to taste and appearance.

3.4. Preference heterogeneity

The heterogeneity analysis of the preferences in different regions is presented in Table 6. Among rural consumers, gender, income, education level, and concerns about pesticide residue in vegetables have an impact on purchasing decisions for low-residue vegetables. Compared with consumers who are not concerned about pesticide residue, concerned consumers place more importance on residue levels, but less on appearance. The higher the education level, the greater the emphasis on appearance. The higher the income level, the higher the emphasis on taste.

Age, gender, income, education level, whether the consumers had children, whether they paid attention to pesticide residue in vegetables, and whether they paid attention to reports of pesticide residue exceeding the standard in vegetables plays an important role in the urban consumers' decision to purchase low-residue vegetables. Compared with female consumers, male consumers are less concerned about residue levels and taste but are more concerned about price. Consumers with higher income place more emphasis on the residual levels. Consumers who paid attention to reports are more interested in residual levels and prices, as compared to those who do not. Older consumers are less concerned with appearance and taste, but are more concerned with price. Consumers who are concerned about pesticide residues in vegetables pay less attention to appearance.

In order to better analyze the heterogeneity of preferences among provinces, we added the province interaction term, and the specific results are shown in Supplementary Table S4. Among the interaction terms between province and each attribute level, only the interaction term between price attribute and province is significant, indicating that consumers in different provinces have different preferences for price attribute.

Heterogeneity analysis revealed the effects of demographic factors and risk concerns on preferences. Consistent with previous studies, our study confirmed that income level has a significant impact on consumers' vegetable purchasing decisions, and people with higher incomes tend to buy vegetables with lower pesticide residues (Dai et al., 2006; Haghjou et al., 2013; Muhammad et al., 2015). This may be due to a higher household income and higher affordability of consumers, the more aware they are of the potential health hazards of pesticide use (Haghiri et al., 2009). Consumers with higher risk concerns place more emphasis on the attribute of residue level, and conversely, they place less emphasis on appearance (Stefano and Michele, 2000). We also found that older consumers are less concerned with residue level, appearance, and taste, and are more concerned with price.

TABLE 5 Mixed logit model estimates result (main effects).

Attribute	Level	All			Rural			Urban		
		Coef.		SE	Coef.		SE	Coef.		SE
Mean										
asc		1.04	***	0.13	1.16	***	0.24	0.99	***	0.16
Pesticide residue level	residue2	0.69	***	0.10	0.67	***	0.18	0.70	***	0.11
	residue3	1.29	***	0.10	1.25	***	0.18	1.30	***	0.12
	residue4	1.97	***	0.10	2.03	***	0.19	1.95	***	0.12
	residue5	2.29	***	0.12	2.27	***	0.21	2.31	***	0.14
Appearance	appe2	0.33	***	0.05	0.32	***	0.10	0.34	***	0.06
	appe3	0.55	***	0.06	0.43	***	0.12	0.61	***	0.08
Taste	taste2	0.59	***	0.06	0.64	***	0.11	0.57	***	0.07
	taste3	1.15	***	0.07	1.29	***	0.14	1.09	***	0.09
Price	price_neg	−0.25	***	0.01	−0.28	***	0.02	−0.24	***	0.01
SD										
asc		1.82	***	0.12	−1.74	***	0.21	1.84	***	0.14
Pesticide residue level	residue2	0.44	*	0.18	0.80	***	0.22	0.14		0.52
	residue3	0.00		0.14	0.04		0.33	0.02		0.15
	residue4	0.84	***	0.11	0.75	***	0.23	0.87	***	0.13
	residue5	1.31	***	0.12	1.34	***	0.23	1.32	***	0.14
Appearance	appe2	0.03		0.39	0.30		0.29	0.04		0.28
	appe3	0.56	***	0.10	0.64	***	0.18	0.50	***	0.13
Taste	taste2	0.00		0.09	0.02		0.17	0.00		0.11
	taste3	0.73	***	0.09	0.81	***	0.16	0.70	***	0.11
Price	price_neg	0.26	***	0.02	0.29	***	0.05	0.25	***	0.03
Model Fit	AIC	13,574.59			4,305.17			9,295.04		
	BIC	13,735.67			4,443.34			9,448.47		

*$p < 0.05$, ***$p < 0.001$. AIC, Akaike information criterion; BIC, Bayesian information criterion; reference level: residul1,appe1,taste1.

3.5. Model estimates and WTP calculation

Table 7 shows the willingness to pay for each attribute level. The result of willingness to pay comes from a mix logit model with no interaction. Both urban and rural consumers have the highest WTP for celery without pesticide residue, with the prices 9.82CNY/500 g in rural areas and 11.72CNY/500 g in urban areas. The rural consumers' WTP for low-residue celery with pesticide residues of 60, 40, and 20% of normal celery is 3.43, 5.73, and 9.23 CNY/500 g,, respectively, the WTP for taste attribute is 2.65 and 5.46CNY/500 g,, respectively, the WTP for appearance attribute is 2.23 and 2.78CNY/500 g,, respectively. The urban consumers' WTP for low-residue celery with pesticide residues 60, 40, and 20 of ordinary celery is 3.97, 6.95, and 10.32 CNY/500 g, respectively, the WTP for taste attribute is 2.88 and 5.23 CNY/500 g, respectively, the WTP for appearance attribute is 2.32 and 3.64 CNY/500 g, respectively.

The results of WTP analysis showed that, consumers' WTP for pesticide-free celery is slightly higher than that of low-residue celery with 20% residues of ordinary celery, and much higher than that of low-residue celery with residue levels of 40% and 60% of ordinary celery. When the pesticide residue level is high, the difference of consumers' WTP between different pesticide residue levels was large. The difference was smaller when pesticide residue levels were relatively low. That is, when consumers perceive low residue level and low food safety risk, they are not willing to pay more money to further improve food safety level. It is acceptable for all consumers to pay a higher price to meet their own needs, there is a potential demand for higher

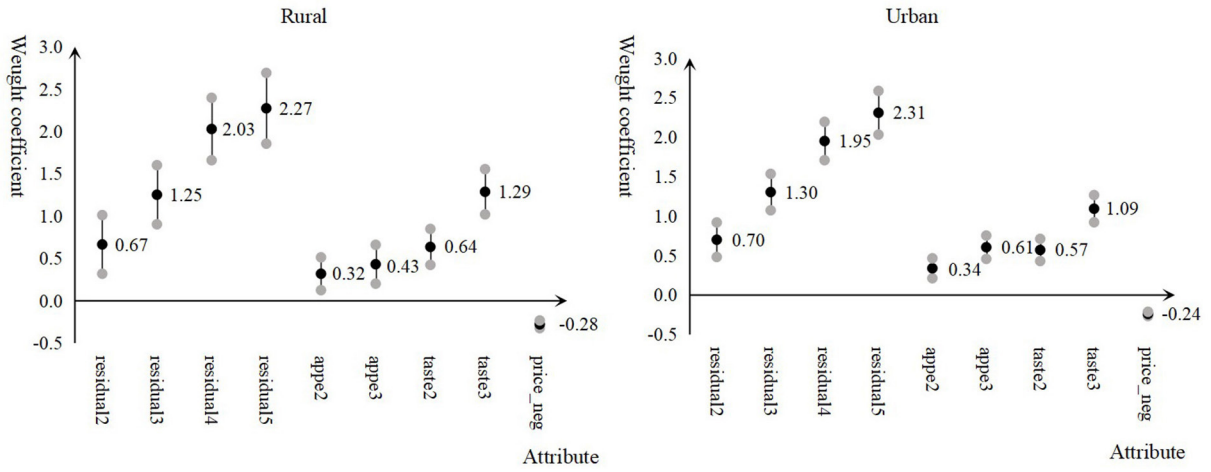

FIGURE 1
Rural and urban consumer preference weights with a 95% CI.

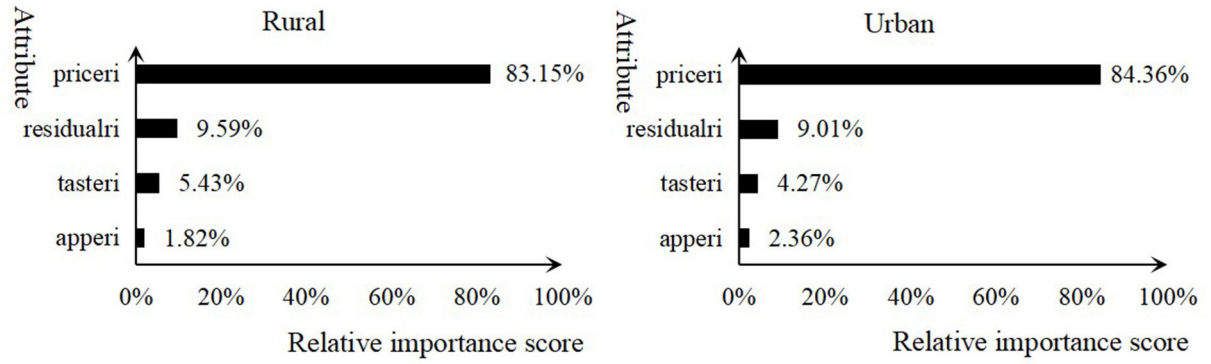

FIGURE 2
Rural and urban consumer relative importance score of the attributes.

levels of food safety regulations, and consumers want to obtain less residual food. The low-residue vegetable market has great potential for development in China (Certification Accreditation Administration of the People's Republic of China, 2019).

The analysis results from the urban and rural subgroups show that urban and rural consumers have significant differences in basic information such as age, education level, marriage, and average monthly household income, and these differences are also reflected in consumers' WTP. Rural consumers pay a premium of about 327% for pesticide-free celery and urban consumers about 390%. The WTP of urban consumers for each residue level is higher than rural consumers, and rural consumers are willing to pay less money to improve food safety when pesticide residue levels are low. In the two attributes of taste and appearance, both urban and rural consumers are willing to pay for celery with a better taste; urban consumers' WTP for perfect appearance is 3.636CNY/500 g (a premium of 121%), while rural consumers are not willing to pay a premium for that.

Based on data from six provinces, this study analyzed Chinese consumers' concern about pesticide residues in vegetables, and evaluated Chinese consumers' preference and WTP for low-residue vegetables using discrete choice experiment. The results of WTP can be used to indirectly measure the net benefit of consumers avoiding important sources of health risks as a result of improved food safety. Compared with previous studies on Chinese consumers, the data in this study are more representative. In previous studies

TABLE 6 Results of the preference heterogeneity analysis.

Attribute	Level	All				Rural				Urabn			
		Mean		95%CI		Mean		95%CI		Mean		95%CI	
asc		1.09	***	0.82	1.36	1.05	***	0.73	1.38	1.16	***	0.68	1.64
Pesticide residual level	residual2	0.60		−0.31	1.50	0.12		−1.44	1.68	0.82		−0.39	2.03
	residual3	0.64		−0.23	1.50	−0.38		−1.87	1.12	1.06		−0.08	2.21
	residual4	1.06	*	0.18	1.93	0.86		−0.63	2.34	1.06		−0.10	2.22
	residual5	1.69	**	0.60	2.79	2.14	*	0.26	4.02	1.41		−0.03	2.84
Appearance	appe2	0.75	*	0.16	1.34	−0.17		−1.21	0.88	1.28	***	0.49	2.06
	appe3	0.18		−0.48	0.83	−0.58		−1.74	0.59	0.67		−0.19	1.52
Taste	taste2	0.58		−0.03	1.19	−0.40		−1.46	0.65	0.91	*	0.10	1.72
	taste3	1.56	***	0.83	2.29	0.28		−1.03	1.59	1.97	***	1.03	2.92
Price	price_neg	−0.73	***	−0.92	−0.54	−0.86	***	−1.22	−0.49	−0.65	***	−0.88	−0.43
Interaction: demographic attributes*attibute													
attention*residual2	0.46	*	0.03	0.89	0.59		−0.19	1.36	0.36		−0.18	0.89	
age*residual2		−0.22	*	−0.40	−0.04	−0.08		−0.45	0.29	−0.26	*	−0.47	−0.05
age*residual4		−0.19	*	−0.37	−0.01	−0.17		−0.54	0.20	−0.18		−0.39	0.03
attention[a]*residual4		0.68	***	0.26	1.10	1.04	**	0.33	1.76	0.49		−0.04	1.01
gender*residual5		−0.52	**	−0.90	−0.14	−0.52		−1.21	0.17	−0.51	*	−0.97	−0.04
income*residual5		0.18	*	0.03	0.33	0.05		−0.23	0.33	0.22	*	0.04	0.40
attention*residual5		0.64	*	0.11	1.17	0.85		−0.05	1.75	0.52		−0.14	1.18
risk[b]*residual5		0.54		−0.01	1.10	0.06		−0.92	1.03	0.80	*	0.11	1.49
age*appearance2		−0.12	*	−0.24	0.00	−0.07		−0.33	0.20	−0.16	*	−0.30	−0.02
child*appearance2		−0.25	*	−0.46	−0.03	−0.08		−0.48	0.32	−0.32	*	−0.58	−0.05
attention*appearance2		−0.31	*	−0.59	−0.02	−0.51	*	−1.00	−0.01	−0.21		−0.56	0.15
age*appearance3		−0.14	*	−0.27	−0.01	−0.01		−0.29	0.27	−0.20	**	−0.35	−0.05
education*appearance3		0.15	*	0.00	0.29	0.25	*	0.01	0.50	0.09		−0.09	0.27
attention*appearance3		−0.43	**	−0.74	−0.12	−0.44		−0.99	0.12	−0.44	*	−0.83	−0.06
gender*taste2		0.01		−0.20	0.21	0.38	*	0.00	0.76	−0.16		−0.41	0.10
gender*taste3		−0.19		−0.44	0.07	0.12		−0.35	0.59	−0.32	*	−0.63	−0.02
age*taste3		−0.22	**	−0.37	−0.07	−0.23		−0.56	0.10	−0.21	*	−0.38	−0.04
income*taste3		0.09		−0.01	0.19	0.27	**	0.07	0.47	0.04		−0.08	0.15
gender*price		0.07	***	0.04	0.11	0.05		−0.01	0.11	0.09	***	0.04	0.13
age*price		0.03	**	0.01	0.05	0.04		0.00	0.08	0.03	*	0.01	0.05
education*price		0.02		0.00	0.04	0.00		−0.03	0.03	0.03	*	0.00	0.05
attention*price		0.08	***	0.03	0.13	0.07		−0.02	0.15	0.09	**	0.03	0.15
risk*price		0.08	**	0.03	0.13	0.08		−0.01	0.17	0.08	*	0.01	0.14
Model fit		AIC	13443.75	4318.9	9221.11								
	BIC	14112.26	4892.34	9857.84									

*p < 0.05, **p < 0.01, ***p < 0.001. AIC, Akaike information criterion; BIC, Bayesian information criterion. Reference level: residul1,appe1,taste1. [a]attention(Have you ever been concerned about pesticide residues in vegetables?); [b]risk (Are you concerned about reports of excessive pesticide residues in vegetables?). For conciseness, only the significant interaction terms at the 5% level are presented in table.

on consumers' WTP for low-residue foods, the residue-related attributes are usually set as whether organic or different certification labels, and the residue attributes are not subdivided into different levels (Sakagami and Haas, 2012; Wang et al., 2019; Carzedda et al., 2021; Van Loo et al., 2021). In actual food safety regulation, there is

TABLE 7 Mixed logit model in WTP space.

Attribute	Level	All				Rural				Urban			
		Coef.		SE	95%CI	Coef.		SE	95%CI	Coef.		SE	95%CI
Mean													
asc		3.68	***	0.68	2.34,5.01	3.57	***	1.06	1.49	3.77	***	0.87	2.06,5.48
Pesticide residue level	residue2	3.92	***	0.40	3.14, 4.70	3.43	***	0.73	2.01, 4.86	3.97	***	0.50	2.99, 4.96
	residue3	6.60	***	0.42	5.78, 7.42	5.73	***	0.72	4.32, 7.14	6.95	***	0.52	5.94, 7.97
	residue4	10.02	***	0.48	9.08, 10.97	9.23	***	0.79	7.67, 10.78	10.32	***	0.60	9.15, 11.49
	residue5	11.11	***	0.48	10.16, 12.05	9.82	***	0.75	8.34, 11.29	11.72	***	0.61	10.52, 12.93
Appearance	appe2	2.31	***	0.25	1.81, 2.81	2.23	***	0.42	1.41, 3.05	2.32	***	0.32	1.69, 2.95
	appe3	3.36	***	0.29	2.80, 3.93	2.78	***	0.50	1.80, 3.77	3.64	***	0.36	2.93, 4.34
Taste	taste2	2.81	***	0.27	2.29, 3.33	2.65	***	0.43	1.82, 3.49	2.88	***	0.34	2.21, 3.54
	taste3	5.31	***	0.31	4.71, 5.91	5.46	***	0.49	4.51, 6.42	5.25	***	0.39	4.49, 6.01
Price	price_neg	−1.58	***	0.05	−1.68, −11.48	−1.43	***	0.10	−1.62, −1.24	−1.64	***	0.06	−1.76, −1.52
asc		10.14	***	0.57	9.03,11.26	8.57	***	0.89	5.65	10.90	***	0.76	9.41,12.39
Pesticide residue level	residue2	−0.40		1.21	−2.78, −1.98	2.47	*	1.09	0.34, 4.60	0.00		0.97	1.89, 1.90
	residue3	−0.12		0.58	−1.24, −1.01	0.30		1.16	1.97, 2.58	0.03		0.71	1.35, 1.42
	residue4	5.03	***	0.46	4.12, 5.94	4.91	***	0.84	3.25, 6.56	−5.00	***	0.57	−6.12, −3.88
	residue5	6.47	***	0.53	5.42, 7.51	5.95	***	0.93	4.12, 7.77	6.62	***	0.68	5.30, 7.95
Appearance	appe2	−0.61		1.04	−2.64, −1.43	−1.22		1.45	−4.06, −1.61	−0.60		1.31	−3.16, −1.96
	appe3	−1.31		0.92	−3.10, −0.49	−1.64		1.48	−4.55, −1.26	−1.29		0.88	−3.03, −0.44
Taste	taste2	0.02		0.40	0.77, 0.81	−0.02		0.70	−1.39, −1.35	0.06		0.50	0.93, 1.04
	taste3	3.64	***	0.38	2.88, 4.39	3.58	***	0.81	1.99, 5.16	3.76	***	0.49	2.81, 4.72
Price	price_neg	0.65	***	0.07	0.51, 0.80	0.69	***	0.15	0.40, 0.98	0.63	***	0.09	0.46, 0.81
Model fit	AIC	13,878.60				4,412.24				9,493.12			
	BIC	14,039.69				4,550.42				9,646.55			

*$p < 0.05$, ***$p < 0.001$. AIC, Akaike information criterion; BIC, Bayesian information criterion; reference level: residul1,appe1,taste1.

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not a single "yes" or "no" issue. In this study, residue attributes are divided into five levels, which can provide more detailed information for food safety regulation evaluation and decision-making.

This study had certain limitations. First, DCE is a declarative preference, and the choice of scenario is based on assumptions, which does not necessarily reflect the consumer choices in real scenarios. Based on literature research and pre-survey, we screen the important attributes that affect consumer choice and set up a more realistic choice scenario. Second, due to the complexity of real market decision-making, the attributes in the research cannot contain all the attributes contained in the commodity in reality, therefore, the four main attributes of residue level, appearance taste and price are included in this study.

4. Conclusion

Consumer preference is an important market information andis crucial for the government to formulate relevant regulatory policies. Previous studies have shown that consumers are willing to pay a premium for residue-free or organic vegetables. This study further refined the residue levels and analyzed the willingness to pay of consumers with different residue levels. The results show that consumers have a strong positive preference and higher willingness to pay for low-residue vegetables. This indicates that consumers are willing to pay a certain cost for safe vegetables with less residue, and there is a potential demand for higher food safety levels. It can also provide market incentives for producers to improve their production methods and provide better and safer food, thereby influencing the development of relevant markets. And when the residue level is 60%-40% of common vegetables, consumers are willing to pay a relatively high premium to reduce the residue level. When the residue level is 20% of common vegetables, that is, the food safety risk is relatively low, consumers are willing to pay a relatively low premium to further improve the food safety level. Our results can provide data support for the cost-benefit analysis of the revision of pesticide residue standard system.

The results of heterogeneity analysis showed that demographic factors such as gender, age and income, and whether to pay attention to pesticide residues and reports of pesticide residues exceeding the standard in vegetables have a significant impact on Chinese consumers' preference for low-residue vegetable attributes, which suggests that we can develop market segments based on demographic characteristics to better promote the development of organic vegetable market.

Finally, we suggest that future research should analyze the consistency between real market data and hypothetical markets. Applying willingness-to-pay data to a cost-benefit analysis of food safety regulation revisions, conduct ex ante and ex post regulatory impact assessments, to estimate welfare changes under different regulatory scenarios and provide decision support for the development and adjustment of food safety regulations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

Conceptualization: JW, LZ, ZN, WW, GL, WF, XZ, and JT. Data curation: LZ and ZN. Formal analysis: JW. Investigation, project administration, and writing—original draft: JW, ZN, and WW. Methodology, supervision, and writing—review and editing: XZ and JT. Validation: LZ. Visualization: WW and WF. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.1019372/full#supplementary-material

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