Studies on Chinese consumers' willingness to pay for plant-based milk and its influencing factors based on CVM

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Abstract

Plant-based milk has developed rapidly due to its rich source of raw materials, unique taste and environmental friendliness. To explore consumers' willingness to pay for plant-based milk, we used the double boundary dichotomy of contingent valuation method (CVM) to make maximum likelihood estimation, analyzed the relationship between the purchase price and purchase intention variables, and discussed the influence of three main influencing factors: sensory characteristics, purchase price and ecological welfare on consumers' willingness to pay. The estimation results showed that: The main attributes affecting consumers' willingness to pay for plant-based milk in the future were purchase price and ecological welfare. What's more, the average of the overall willingness to pay of the surveyed group was about RMB ￥6.07 per 250ml, which could provide reference for enterprise pricing. We focused on promoting green consumption, ecological environmental protection, and market development, to explore effective strategies to catch the opportunities of sustainable agriculture development.

Keywords: consumer behavior, willingness to pay, contingent valuation method, plant-based milk, sustainable agriculture

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Introduction

In the face of environmental degradation, climate change, and resulting crises, it is increasingly urgent to control the greenhouse gas (GHG) emissions and establish a sustainable food production and consumption system in the world. The occurrence of plant-based products is consistent with the awareness of environment protection and ecological sustainability, for the plant-based foods had a lower life-cycle carbon footprint (CF) than animal-based foods in general (Xu and Lan, 2015), and researchers have found that global GHG emissions from animal-based foods are twice those of plant-based foods (Xu et al., 2021). Take milk as an example, one liter of milk produces an average of 3.2kg CO2 equivalent, while soymilk produces only 1kg CO2 equivalent, which is much lower than that of milk. And the production and processing of soybean milk occupy less land than that of milk (Poore and Nemecek, 2019). Apart from soymilk, there are other kinds of plant-based milk alternatives becoming popular for their common benefits of fewer carbon emissions and animal welfare. More generally, plant-based milk is becoming a better choice for people who are lactose intolerant or are allergic to milk proteins, for it is lactose-free, cholesterol-free, and low in calories. This kind of plant-based diets with low GHG emissions are often described as sustainable (Van Eenennaam and Werth, 2021), while diet-related GHG emissions mainly come from animal-sourced foods (Guyot et al., 2021; Saget et al., 2021).

From a scientific perspective, these plant-based milk are fluids that result from the breakdown (size reduction) of plant material (cereals, pseudo-cereals, legumes oil seeds, nuts) extracted in water, and further homogenization of such fluids results in particle size distribution in the range of 5-20μm which imitates cow's milk in appearance and consistency (Swati et al., 2016). The market for plant-based milk alternatives is projected to grow at a CAGR of 15 % from 2013 to 2018 (Markets and Markets 2013) and is expected to reach a value of $14 billion. It caters to the current consumer demand for a healthy low-fat diet and will have a huge market prospect in the future. The development of plant-based milk adapts to the consumption demand of continuous iteration and upgrading. According to the report on the Innovation Trend of 2020 Plant-based Protein Beverage released by Tmall Innovation Center (TMIC), the growth rate of China's plant-based protein beverage market in 2020 is as high as 800%, accounting for 15.5% of the growth contribution in the market. It has become a high-speed engine driving the growth of the beverage market only after drinking water and tea drinks.

Under the background of the brand layout of a large number of plant-based milk

products at home and abroad in the global market, plant-based milk, which belongs to Chinese traditional drinking habits, will attract consumers through what attributes, what factors will affect consumers' purchase behavior, and what prospect plant-based milk consumption will have in China. This series of problems is very worthy of study. The bilateral dichotomy based on Contingent Valuation Method (CVM) measured consumers' willingness to pay for plant-based milk, analyzed the overall level of willingness to pay as well as the factors affecting the attribute preference, and explained which attributes of consumer preference products can affect their willingness to pay for plant-based milk, to put forward targeted suggestions on promoting sustainable consumption, ecological environmental protection and market supervision.

Literature Review

Plant-based milk market development

In the earlier period, the academic researches on plant-based milk mostly focused on the technology research and nutritional evaluation committed to improving the sensory characteristics to make it more acceptable to consumers (Zhao et al., 2020; Wang, 2019), particularly making efforts to increase the shelf life, emulsion stability, nutritional completeness, and sensory acceptability of the final product (Swati, 2016). McClements et al. (2019) reviewed the current understanding of the development of plant-based milk, introduced the physical and chemical basis of the functional characteristics of plant-based milk, and compared the sensory properties and digestion process between cow milk with plant-based milk. Aydar et al. (2020) reviewed the new and conventional methods of plant-based milk production so far, the raw materials include almonds, cashews, coconuts, hazelnuts, peanuts, sesame, soybeans, tiger nuts, oats, rice, marijuana, and walnuts. These studies mentioned the consumption data and market prospect of plant-based milk, but there is little research from the perspective of consumer preference and purchase behavior.

With the popularity of plant-based products in the world, more and more articles discussed the nondairy plant-based alternatives consumption market in the background of the sales decline of milk. McCarthy et al. (2017) analyzed the reasons for the decline in milk consumption and the objective factors for consumers to choose plant-based milk from the perspective of consumer preference. The foothold of the research is to improve the market attraction of liquid milk, such as developing lactose-free milk. However, such studies have not stopped the consumption boom of plant-based milk. The Chicago market research Firm Mintel (2020) issued the American Milk and Non-Dairy Milk Report in October 2019,

which showed that the sales of milk have decreased by 22% since 2014-2019, reflecting the depressed state of the American dairy industry. Similarly, Hawkes (2019) showed the downward market trend of the California milk industry as of June 1, 2019, and then discussed the international competition and the industry growth of plant-based milk, making an expected judgment on the sales of plant-based milk. Huerga (2017), Harris (2018) began to study the policy issues of plant-based milk from the perspective of ethics and standards. Wei (2019) combed the plant-based milk products launched by major food enterprises, summarized the growing market share and investment tendency of plant-based milk, calling it "potential stock of market segmentation", and said that the development prospect of plant-based milk needed to be observed plus the competition in plant-based milk market was still going on. Clay et al. (2020) critically viewed the marketing boom of plant-based milk and put forward the vision that the consumption of plant-based milk can become purer.

Preference and attributes on plant-based milk

Prytulska et al. (2021) studied consumer preference for plant-based milk on cognition from the perspective of nutrition. They concluded that consumers had a different understanding of the nutritional value of plant-based milk versus traditional milk, and the main reason for the rapid popularity of plant-based alternatives is its environmental friendliness as well as animal welfare in the production process compared with animal-based foods. Subsequently, Yang and Dharmasena (2021) created a multidimensional hedonic attribute space according to the qualitative information of different types of plant-based milk or conventional milk available to consumers and studied the substitution elasticity of different kinds of plant-based milk.

From the perspective of the environment, it' essential to reduce the consumption of animal protein which can greatly reduce the impact of diet on the environment (Tukker et al., 2011). However, most consumers have not been aware of the great impact of animal protein on the environment (Hartmann and Siegrist, 2017). The results of various studies showed that consumers had a bias in estimating the impact of food on the environment (Lea and Worsley, 2008; Tobler et al., 2011). Many studies generally found that the adverse effects of meat or dairy products on carbon emission were underestimated (de Boer et al., 2014; Tobler et al., 2011). Therefore, consumers may not realize the great importance to reduce animal protein intake and form a sustainable diet. And some researches (Van Loo et al., 2014; Van Loo et al., 2020) also have shown that various sustainability certifications and claims for food products that focus on environmental or ethical benefits will empower consumers to make informed

purchasing decisions that take environmental and ethical considerations into account. To sum up, plant-based milk is in the stage of market layout and has not formed a brand competition pattern (Li and Hou, 2021), but with the improvement of people's awareness of health, carbon emission reduction, and animal welfare protection, plant-based milk will have great market potential and development prospects. It is necessary to break the inherent thinking mode and realize differentiated competition based on meeting the needs of consumers.

WTP based on CVM

Contingent Valuation Method (CVM) is often used in cost-benefit assessment and environmental impact assessment (Venkatachalam, 2004), deriving its theoretical basis from welfare economics(Gelo and Turpie, 2021). It can estimate and allocate the value of non-market resources, such as renewable energy, public space, and sustainable development (Wiser and Ryan, 2007; Bowman et al., 2009). Although these resources have produced utility, there is no exact market price for some parts of these resources. For example, renewable energy can reduce man-made climate change or save fossil fuels for future generations, but it's difficult to measure. Thus, through CVM, it can be possible to estimate the market price of a stated preference. Its basic mechanism is to ask people whether they are willing to pay for maintaining a certain environmental feature or whether they are willing to accept compensation for their losses (Bishop et al., 1989).

Numerous researches on measuring willingness to pay (WTP) based on CVM focuses on the value assessment in the field of ecological environment (Li et al., 2020; Li, 2018; Xiao and Yang, 2017), historical collection (Hamideh et al., 2013) and tourism resources (Xiao et al., 2021). What's more, CVM can also be used to measure the properties of food, such as dairy products, genetically modified food, organic food, or other kinds of food. Lu et al. (2015) measured consumers' willingness to pay for agricultural products with eco-friendly attributes and analyzed their influencing factors; Wang and Liu (2015) used CVM design to obtain consumers' willingness to pay for organic food and built a model to explain the influencing factors of consumers' willingness to pay for organic food. Yang (2016) used three quality certifications as pollution-free, green, and organic certification to concretize the concept of safety, and calculated consumers' WTP for the safety of milk. Wu et al. (2016) used the questionnaire based on the CVM method to understand consumers' attention to genetically modified food to varying degrees, and concluded that economic factors accounted for the main factor affecting the purchase of genetically modified food. Liu (2017) constructed the model of consumer choice behaviors and the survival analysis model for genetically modified

food, using the two boundary Contingent Valuation Method. The results showed that age, education level, individual annual income, safety awareness, information of genetically modified food channels, and understanding of them had a significant impact on consumer choice behaviors. Nevertheless, CVM also has some defects in measuring willingness to pay. Xuan and Cui (2005) pointed out that consumers may have a possibility to overestimate or underestimate willingness to pay to take eco-label food as an example. There was no restriction on the amount of consumption during the survey, resulting in differences in the effectiveness of respondents. Zhang (2012) also investigated the context-dependent effects of WTP for ecosystem restoration of the urban river and proved the existence of scope insensitivity, embedding reflect, sequencing effects, and part-whole effect of WTP. These findings are consistent with underlying economic theory, so deviation caused by the phenomenon should be considered when results from a CVM study are adopted in survey analysis．

From the perspective of WTP, the current measurement of WTP for food mostly focuses on the label nature of food, measuring consumers' WTP for a specific feature. The method is accurate and appropriate, but it lacks certain practical significance. Most of the foods studied by CVM are slightly targeted. To make full use of the CVM method in food, it is necessary to find products that are more in line with its essence. In terms of the variable setting of influencing factors, most domestic scholars still stay in the discussion of individual characteristics, such as gender, income, education level, etc., while many foreign researchers believe that individual characteristics are not as important as values or attitudes in influencing consumer behavior. McCarty et al. (1994) studied two values that affect consumer behavior, namely hedonism and a sense of security. Empirical research shows that consumers who identify with a sense of security and compassion are more likely to become environmental consumers (Laroche et al., 1996). And it needs to introduce other more explanatory variables to deal with the possible deviation of CVM and adopt proper programs to solve the possible errors in the investigation process, to ensure the validity of the method and the accuracy of the research data.

Analytical framework

The double boundary dichotomy method is used to measure the WTP for plant-based milk. The estimation principle of the double boundary dichotomy method is CVM. Assuming that the utility of consumers choosing plant-based milk can be expressed as U1, and the utility of choosing other protein drinks can be expressed as U0, e follows the Weibull distribution,

then:

$$U_1 = \alpha_1 + \beta'_1 X + \lambda_1 BID + \varepsilon_1 \qquad （1，2）$$

$$U_0 = \alpha_0 + \beta'_0 X + \varepsilon_0$$

X represents the key explanatory factors that affect consumer utility, including basic measurable variables such as consumer demographic characteristics, preference for value attributes of milk, and factors that may be correlated, such as lactose intolerance and vegetarianism.

BID is used to indicate how much more consumers are willing to pay for plant-based milk compared to other protein drinks, i.e., paying a premium. The average WTP is calculated as follows, and E (X) is the mean value of all variables in the model.

$$\alpha_1 + \beta'_1 X + \lambda_1 BID + \varepsilon_1 = \alpha_0 + \beta'_0 X + \varepsilon_0$$

$$E(\varepsilon_1) = E(\varepsilon_0)$$

$$E(WTP) = E(BID) = -\frac{\alpha^* + \beta^{*\prime} E(X)}{\lambda^*} \qquad （3，4，5）$$

The CVM questionnaire in this paper applies the most effective double boundary dichotomy method at present, which is developed based on the single boundary calculation method according to the random utility theory, determines the WTP interval of a single sample through a random problem and an advanced problem, and further determines the overall WTP distribution and mean value according to the law of large numbers and probability distribution hypothesis, It is different from the previous payment card, open and single boundary dichotomy. It can obtain more payment intention information through two inquiries, so as to obtain the real payment intention of consumers to the greatest extent. Double boundary dichotomy has some advantages in science and accuracy, but it can not estimate the WTP sequence of samples.

Let's define y_i^1 and y_i^2 as binary variables in response to two closed questions, then the probability of an individual answering "yes" to the first question and "no" to the second question can be expressed as

$$Pr(y_i^1 = 1, y_i^2 = 0 | z_i) = Pr(y, n) \qquad （6）$$

z_i represents the respondent, y_i^1 and y_i^2 represent the answers to the two questions, and we have assumptions:

$$WTP_i(z_i, u_i) = z_i'\beta + u_i, \quad u_i \sim N(0, \sigma^2) \qquad (7)$$

m_1, m_2 sets the price bid for two problems, then there are four probabilities. Using maximum likelihood estimation, in order to calculate parameters, the function to be maximized is:

$$\sum_{i=1}^{N}\left[d_i^{yn}\ln\left(\Phi\left(z_i'\frac{\beta}{\sigma} - \frac{m_1}{\sigma}\right) - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{m_2}{\sigma}\right)\right) + d_i^{yy}\ln\left(\Phi\left(z_i'\frac{\beta}{\sigma} - \frac{m_2}{\sigma}\right)\right) + \right.$$

$$\left. d_i^{ny}\ln\left(\Phi\left(z_i'\frac{\beta}{\sigma} - \frac{m_2}{\sigma}\right) - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{m_1}{\sigma}\right)\right) + d_i^{nn}\ln\left(1 - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{m_2}{\sigma}\right)\right)\right] \qquad (8)$$

Among them, d_i^{yn}, d_i^{yy}, d_i^{ny}, d_i^{nn} are index variables with a value of 1 or 0 according to the relevant situation of each individual, that is, a given individual only contributes to the logarithm of the likelihood function in one of its four parts. The resulting parameter $\hat{\beta}$、$\hat{\sigma}$ are used to estimate the WTP:

$$E(WTP) = z_i'\hat{\beta} \qquad (9)$$

In order to estimate consumers' WTP for plant-based milk, the questionnaire is designed in the form of attribute preference. Four initial prices are set according to the average unit price of existing plant-based milk products by the market research, which appear randomly in the first inquiry. The second inquiry was conducted according to the consumers' first answer. If the answer is "yes", then ask them a higher price again, otherwise, ask for a lower price again. According to the pre research on the types and prices of products in plant-based milk market, taking RMB ¥ 7.45 as the average price, the price setting of the double boundary dichotomy method is shown in the Table 1.

Survey

Survey instrument and procedure

The questionnaire was divided into four parts: firstly, it explained the basic information of plant-based milk and its ecological value of low-carbon and environmental protection. Secondly, it inquired about consumers' preference for the attributes of plant-based milk products from the three dimensions of the purchase price, sensory characteristics, and ecological welfare. In the empirical analysis stage, the variables were selected for regression analysis. Thirdly, we used the double boundary dichotomy to ask consumers' willingness to pay. Fourthly, we collected the demographic characteristics of consumers and the background information related to relevant living habits as control variables.

Sample source

We mainly distributed electronic questionnaires to consumers in Beijing, Tianjin, and Hebei, and the respondents answered the online questionnaires through mobile phones or computers. These survey regions are important economic growth areas in China, and the target groups of the survey are urban consumers with different levels of economic development. 300 questionnaires were distributed respectively in the three regions. After sample validity screening, 819 valid questionnaires were retained, with an effective rate of 91%, including 275 in Beijing and 258 in Tianjin, 286 in other regions of Hebei. In the statistics of 819 valid questionnaires, women accounted for 59.46%, and the total proportion of people with a college degree or above accounted for 89.86%. The age of the subjects was mainly between 20-40 years old, which was basically in line with reality. The sample was extensive and representative.

Descriptive statistics of data

When using the double boundary dichotomy to ask the WTP, the higher the first price randomly appears, the fewer people answer "yes", which was in line with the assumption of consumer rationality, but the reduction range gradually decreases, which was in line with the law of diminishing marginal effect. According to the results of the second inquiry based on the answer, it could be seen from table 1 that when gave consumers who answered "yes" for the first time a higher price, nearly 60% or higher of the samples were still willing to pay; Consumers who answered "no" for the first time got a second lower price, and 70% - 90% of the samples were still unwilling to pay a lower price. It can be seen that the overall WTP and acceptance of plant-based milk show a form of polarization in the sample.

Empirical Results

Variable assignment

The variables of the dual boundary dichotomous WTP function model were set as follows (shown in Table 2): firstly, consumers' WTP for plant-based milk was taken as a measure of the explained variables. Secondly, the core independent variables selected in this study represented consumers' value attribute preferences for milk in different dimensions, including purchase price, sensory characteristics, and ecological welfare, which were measured by a Likert five-point scale. In this paper, the basic demographic characteristics variables of gender, age, education level, residence type, and income level were selected as part of the control variables. In addition, the "vegetarian or not", "lactose intolerant", "three

high" disease history "and related types of occupations that may have an impact on the study were selected as part of the control variables. A number kinds of programs were adopted to reduce the endogenous problems in econometric research as much as possible to accurately estimate the impact of core variables on dependent variables.

Analysis of influencing factors

The double boundary dichotomy method uses the maximum likelihood estimation based on the Contingent Valuation Method (CVM) and takes the maximization of consumers' personal utility as the principle. It can simultaneously study the impact of other influencing factors at the level of consumers' WTP, and conduct regression analysis on the role of key explanatory variables by establishing a double boundary dichotomy WTP function model. The results are shown in Table 3:

According to the estimation results, the influence coefficient of sensory characteristics of plant-based milk was negative, but not significant, indicating that consumers who valued the sensory characteristics of products were reluctant to pay higher prices for plant-based milk. The reason may be that the taste of plant-based milk is relatively novel and there is a gap with the public taste, resulting in that some consumers who are used to drinking milk may not be able to adapt in a short time. The parameter estimation result of the purchase price was negative and significant, that was, consumers who paid more attention to the price were unwilling to pay a higher price for plant-based milk. The reason may be that under a certain consumption frequency of plant-based milk, the price of plant-based milk in the market generally shows an upward trend, increasing consumers' expected cost, a decrease in expected utility, and a certain negative impact on consumers' willingness to pay. In addition, in this model, consumers' preference for ecological welfare attributes had a significant positive impact on WTP, which showed that consumers recognized the ecological friendliness of plant-based milk to a certain extent.

In terms of individual socioeconomic attributes, other factors are implicating the consumers' WTP. The regression results of gender, education level, engaged in related occupations (medical, health, environmental protection, etc.), and purchase status of relatives and friends are very significant, in which gender and education level are negatively correlated with willingness to pay, indicating that women have slightly higher willingness to pay than men. Female consumers generally have higher requirements for low fat and low-calorie food and may be responsible for the entire family's food and beverage life, so they will tend to spend more money to choose plant-based food. What's more, consumers with higher

education may have a greater understanding of the productive processing as well as the nutritional composition of plant-based milk, as similar or alternative products to milk, thus they are not willing to pay a higher premium for plant-based milk. There are two aspects significantly positively correlated with willingness to pay, that is, engagement in related occupations and purchase status of relatives and friends. It indicated that the consumers engaged in medical, health, environmental protection, or other related occupations may have a higher willingness to pay than others, for they pay more attention to carbon emission, animal welfare, or medical health. Furthermore, the purchase of family and friends will have a peer effect, and affect consumers' purchase willingness. Family and friends may recommend the sensory characteristics or nutrition value of plant-based milk to consumers, help consumers understand the plant-based products, and improve their needs and willingness to pay.

Estimation of WTP

In the research design, this paper investigated and estimated consumers' WTP for plant-based milk by using the double boundary dichotomy method. Through random inquiry within a certain price range, the interval distribution of consumers' WTP was obtained according to the answer of "yes" or "no", and the distribution of overall WTP was obtained according to the maximum likelihood estimation. The mean value represented the overall average WTP of the investigated samples was RMB ￥ 6.069, and the standard deviation was 1.486, the maximum was 1.379, and the minimum was 10.519. The estimated results showed that in Figure 2.

According to the estimation results of this paper, the average value of the overall WTP for plant-based milk of the surveyed consumers was about RMB ￥ 6.07 per 250ml, which was close to the price level of domestic high-quality milk and imported milk with the same specifications in the market, lower than the market price of imported plant-based milk and higher than the price level of traditional plant-based milk in China. Compared with the average market price of RMB ￥ 7.45 obtained from our market pre survey, there is some gap between the average willingness to pay for vegetable milk calculated in this study. Therefore, reasonably adjusting the production cost and market price will certainly help the enterprise profit growth and plant-based food industry development.

Conclusion

The development of food segmentation and innovative categories are now regarded as important growth points by food giants (Grunert and Klaus, 2019). Although mass food is still the category supporting the main income and profit, the innovative type that can meet the needs of segmented consumers is the real factor driving the growth of enterprises in the future (Zorrilla, 2022). Plant-based milk symbolizes an enormous expansion prospective for the health food segmentation market. Due to the benefits associated with plant-based milk alternatives as detailed above, taste and nutrition can be essential in cultivating consumers with the habit of drinking plant-based milk on a wide scale. As an emerging category, the core technology of plant-based milk production is not as mature as the traditional milk with a history of decades, and many manufacturers are still in the exploratory stage. The immature process also leads to the problems of heavy fishiness and astringency, easy stratification, and so on. Many consumers do not fully adapt to the taste of plant-based milk. To meet the consumer's acceptability, it needs to be widely investigated through the development of advanced processing, technological interventions to improve the sensory characteristics, for developing a nutritionally complete beverage with high overall acceptability.

Furthermore, the main adverse factor affecting consumers' willingness to pay is the purchase price of plant-based milk, but there is a gap between consumers' willingness to pay for plant-based milk and the actual market price. The average price of plant-based milk on the market generally reaches more than RMB ￥ 7 per 250ml, higher than the willingness to pay of consumers in this study, reflecting that plant-based milk has the consumption characteristics of "high-grade products" to some extent. The reason behind this may be that the plant-based milk industry has not formed large-scale production, and the cost of transportation, storage, loss, and other back-end links in the industrial chain is high. Due to the dual factors of refrigeration and plant-based, the price of plant-based milk is generally high. Cost reduction to achieve mass production is essential to the supply chain of plant milk.

As a substitute for animal-based milk, plant-based milk can not compete with it in nutrition, milk flavor, or consumption habits, but it still has great potential to win a place in the beverage market with its unique advantages. As we expounded, producing the same weight of protein, plant-based milk has higher conversion efficiency, which can reduce the GHG emissions (Kustar and Patino-Echeverri, 2021), and it can also reduce the occupation of land resources and protect biodiversity. We found that consumers' preference for ecological welfare attributes of products can increase their willingness to pay for plant-based milk. It is

very important to strengthen the popularization and education of knowledge of plant-based milk for the development of the industry.

Production and consumption practices that reduce the environmental burden of eating and drinking and promote global sustainability are of paramount interest (Jaeger and Giacalone, 2021) and it is of the essence to build a healthy vegetarian environment. Reducing animal protein intake as well as increasing the choice of plant protein substitutes can reduce food's environmental impacts and avoid irreversible biodiversity loss (Penafiel et al., 2011; Cusworth et al., 2021). Thus, plant-based milk alternatives will continue to be a major research area in the low-carbon economy development category and promote sustainable agriculture development in Asia. Sustainable information intervention and broadcasting will play an important role in enabling consumers to cultivate sustainable consumption behavior. Communication could occur through a combination of carbon footprint labels (Edenbrandt and Lagerkvist, 2021), environmental taxes, or subsidies designed to reflect environmental costs in product prices (Springmann, 2016), and broader education on the true cost of food, to provide holistic evidence on the potential contribution of plant-based milk to environmentally-sustainable nutritional density.

Conclusion

Using the double boundary dichotomy of the Contingent Valuation Method, We took plant-based milk as the research object, made a maximum likelihood estimation of consumers' WTP and analyzed the relationship between variables, and then obtained the cognition and willingness to pay of consumers in northern China. The estimation results showed that: (1) The main attributes significantly affecting consumers' WTP for plant-based milk in the future were purchase price and ecological welfare. Fitting expectations, consumers who paid more attention to the price were unwilling to pay a higher price for plant-based milk, and consumers who recognized the ecological friendliness of plant-based milk to a certain extent would be more willing to pay. (2) The average overall willingness to pay of the surveyed group was about RMB ￥ 6.07 per 250ml, much lower than the average market price, and it can be used as a reference for market pricing. Reasonably adjusting the production cost and market price of plant-based milk will help industry sustainable development. Plus, it's necessary to point out that the low-carbon advantages of plant-based milk for consumers to promote the purchase. The promotion of plant-based diet can comply with the development of sustainable agriculture, which is not only in line with the dietary structure of Asians dominated by plant food and ensure human dietary health, but also help to save environment

resources, help the implementation of double carbon policy, and promote the sustainable development of agri-food system.

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References

Aydar, E. F. , Tutuncu, S. , Ozcelik, B. 2020. Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. J. Func. Foods 70, 103975.

Bishop, R.C., Mitchell, R.C., Carson, R.T. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Contingent Valuation Method 72(1):153-163.

Bowman, Troy, Jan T., and J. Colletti. 2009. Valuation of Open Space and Conservation Features in Residential Subdivisions. J. Environ. Manag. 321–30.

Clay, N., Sexton, A.E., Garnett, T., et al. 2020. Palatable disruption: the politics of plant milk. Agri. Hum. Val. 37（4）, 945–962.

Cusworth, G., GarnettT, Lorimer, J. 2021. Legume dreams: The contested futures of sustainable plant-based food systems in Europe. Global Environ. Change. 69, 102321.

de Boer, J., Schösler, H., Aiking, H. 2014. 'Meatless days' or 'less but better'? Exploring strategies to adapt Western meat consumption to health and sustainability challenges. Appetite 76, 120–128.

Edenbrandt A.K. and Lagerkvist, C.-J. 2021. Is food labelling effective in reducing climate impact by encouraging the substitution of protein sources? Food Policy 101, 102097.

Grunert, Klaus, G. 2019. International segmentation in the food domain: Issues and approaches. Food Res. Inter. 115, 311-318.

Hamideh, K.A., Vahid, K.A., Ali, S.S. 2013. Estimating the Willingness to Pay of Visitors of Shahre Sukhte Historical Collection, Using Conditional Valuation Method (CVM). Tour. Manage. Stud. 7(20):167-184.

Harris. L. 2018. Move Over Cow's Milk: Why the FDA Should Amend Their Guidelines to Include for Plant-Based Alternatives to Conventional Animal-Based Foods. Northern Illinois University Law Review 39 (2) : 301-329.

Hartmann, C., Siegrist, M. 2017. Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. Trends in Food Science Technology 61, 11–25.

Hawkes, L. 2019. As Calif, dairy falters, plant-based milk acres grow. Western Farm Press 41 (10) : 20.

Huerga, N.R. 2017. The CJEU confirms firms that plant-Based products cannot use the term 'milk' because of the rules of protection of the dairy market. but what about consumer interest?   Revista de Bioeticay Derecho 41: 197-208.

Jaeger, S.R., Giacalone, D.2021. Barriers to consumption of plant-based beverages: A comparison of product users and non-users on emotional, conceptual, situational,

conative and psychographic variables. Food Research International. 144, 110363.

Kesse-Guyot, E., Fouillet, H., Baudry, J., et al. 2021. Halving food-related greenhouse gas emissions can be achieved by redistributing meat consumption: Progressive optimization results of the NutriNet-Sante cohort. Science of the total environment 789.

Kustar A., Patino-Echeverri, D.. 2021. A Review of Environmental Life Cycle Assessments of Diets: Plant-Based Solutions Are Truly Sustainable, even in the Form of Fast Foods. Sustainability 13, 9926.

Laroche, M., Toffoli, R., Kim, C., et al. 1996. The influence of culture on pro-environmental knowledge, attitudes, and behaviors: a Canadian perspective. Advances in Consumer Research. Provo：Association for Consumer Research 23(1):196-202.

Lea, E., Worsley, A.2008. Australian consumers' food-related environmental beliefs and behaviours. Appetite 50, 207–214.

Li, Y.Z, Zhao, M.Y, Zhong, H.S., et al. 2020. Study on willingness to pay for urban green ecosystem recreation services and its influencing factors based on CVM: A case study of Wuchang District. Journal of Hubei University: Natural Science 42(1):7.

Li, Y., Hou, Y. 2021. The new track of the plant based dairy market. Dairy and Human (02): 22-29. (in Chinese)

Li, Z.T, Hu, B. 2018. Perceived health risk, environmental knowledge, and contingent valuation for improving air quality: new evidence from the Jinchuan mining area in China. Economics and Human Biology 31:54-68.

M. Springmann et al., Nature Climate Change 7, 69–74 (2016).

Markets and Markets (2013) Dairy alternative (beverage) market by type (Soy, almond, rice), formulation (plain, flavored, sweetened, unsweetened), channel (supermarket, health store, pharmacy, convenience store) & geography—global trends &forecast to 2018.

McCarthy, K.S., Parker, M., Ameerally, A., et al. 2017. Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk? Journal of Dairy Science 100 (8) : 6125-6138.

McCarty, J.A., Shrum, L.J. 1994. The recycling of solid wastes: personal values, value orientations, and attitudes about recycling as antecedents of recycling behavior. Journal of Business Research 30 (1):53-62.

McClements, D. J., Newman, E. and McClements, I. F. 2019. Plant‐based Milks: A Review of the Science Underpinning Their Design, Fabrication, and Performance. Comprehensive Reviews in Food Science and Food Safety 18: 2047-2067.

Prytulska, N., Motuzka, I., Koshelnyk, A. et al. 2021.Consumer preferences on the market of plant-based milk analogues. Potravinarstvo 15: 131-142.

Penafiel, D., Lachat, C., Espinel, R., et al. 2011. A Systematic Review on the Contributions of Edible Plant and Animal Biodiversity to Human Diets. Ecohealth 8:381-399.

Poore, J., Nemecek, T. 2018. Reducing food's environmental impacts through producers and consumers. Science 360 (6392): 987-992.

Sethi, S., Tyagi, S.K., Anurag, R.K. 2016.Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology 53(9):3408-3423.

Tobler, C., Visschers, V. H. M., Siegrist, M. 2011. Eating green. Consumers' willingness to

adopt ecological food consumption behaviors. Appetite 57 (3) , 674-682.

Tukker, A., Goldbohm, R. A., de Koning, A., et al. 2011. Environmental impacts of changes to healthier diets in Europe. Ecological Economics 70 (10) , 1776-1788.

Van Loo, E.J., Caputo, V., Nayga, R.M., Verbeke, W., 2014. Consumers' valuation of sustainability labels on meat. Food Policy 49, 137-150.

Van Loo, E.J., Caputo, V., Lusk, J.L., 2020. Consumer preferences for farm-raised meat, lab-grown meat, and plant-based alternatives: does information or brand matter? Food Policy 95.

Van Eenennaam, A..L, Werth, S.J.2021. Animal board invited review: Animal agriculture and alternative meats - learning from past science communication failures. Animal 15.

Venkatachalam, L. 2004. The Contingent Valuation Method: A Review. Environmental Impact Assessment Review 24: 89-124.

Wang, J., Liu, P.C. 2015. Research on willingness to pay for organic food based on CVM design: A case study of Wuhan consumers. Hubei agricultural sciences 54(02): 490-496.

Wang, W. 2019. Discussion on the application of Perilla in plant milk. Southern agricultural machinery 50 (05): 126.(in Chinese)

Wei, X. 2019. Vegetable milk: a potential stock in the market segment?. Agriculture Economics, (06): 38-41.(in Chinese)

Wiser, Ryan, H. 2007. Using Contingent Valuation to Explore Willingness to Pay for Renewable Energy: A Comparison of Collective and Voluntary Payment Vehicles. Ecological Economics 62: 419–32.

Xiao, J.H., Cheng, W.H., Zhao, Y. Z., et al. 2021. Study on the embedding effect of non-use evaluation of tourism resources in Archipelagoes: A Case study of Zhoushan Islands. Tourism Tribune 36(7):17.

Xiao, J.W., Yang, Y.M. 2017. An empirical study on WTP of residents' willingness to pay for ecological compensation in Xiangjiang River Basin of Hunan Province: Based on CVM conditional value Method. Journal of Central South University of Forestry and Technology 37(08):139-144.

Xu, X, Lan, Y. 2016. A comparative study on carbon footprints between plant-and animal-based foods in China. Journal of Cleaner Production 112: 2581-2592.

Xu, X.M., Sharma P. Shu S.J.. 2021. Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. Nature food 2:724.

Xuan, Y.N., Cui, C.X. 2005. Eco-label Food: Why Consumers Pay more than stated Willingness to pay -- And Analysis of the defects of CVM. Journal of Agrotechnical Economics (5):2-5.

Yang, T., Dharmasena, S.U.S. 2021 Consumer Demand for Plant-Based Milk Alternative Beverages: Hedonic Metric Augmented Barten's Synthetic Model. Foods 10 (2) : 265.

Yang, X. 2016. An empirical study on consumers' willingness to pay for dairy food safety -- a case study of Hangzhou city. Modern Economic Information (23) : 475-476.

Zhang, Y.F. 2012. An empirical study on content dependence of willingness to pay questionnaire in CVM study: A case study of CVM assessment of urban river ecological restoration in Shanghai. China Population, Resources and Environment 22(06): 170-176.

Zhao, D., Sun, H., Luo, B.J., et al. 2020. Development of oat walnut milk. Food industry

technology 41 (18): 187-192.(in Chinese)

Zorrilla, S.E. 2022. Innovative Food Processing Technologies: A Comprehensive Review. Journal of Food Engineering 317.

Tables

Table 1

Statistics of willingness to pay for plant-based milk

First inquiry of WTP (RMB ¥)	Classification indicators	Sample size (person)	Percentage (%)	Second inquiry of WTP (RMB ¥)	Classification indicators	Sample size (person)	Percentage (%)
7	Yes	85	41.26	8	Yes	50	58.82
					No	35	41.18
	No	121	58.74	6	Yes	27	22.31
					No	94	77.69
8	Yes	72	36.73	9	Yes	49	68.06
					No	23	31.94
	No	124	63.27	7	Yes	17	13.71
					No	107	86.29
9	Yes	62	31.47	10	Yes	35	56.45
					No	27	43.55
	No	135	68.53	8	Yes	13	9.63
					No	122	90.37
10	Yes	61	27.73	11	Yes	35	57.38
					No	26	42.62
	No	159	72.27	9	Yes	21	13.21
					No	138	86.79

Table 2

Variable assignment

| Type	Symbol	Variable meaning	Variable assignment	Average	S.E.
Dependent variable	WTP	Willingness to pay	Bid: No= 0, Yes= 1；Bid2: No= 0, Yes= 1	0.322	0.401
Independent variables	PRI	Purchase price of plant-based milk	Don't pay attention to it at all=1; Pay less attention to=2; General = 3; Attach importance to =4; Attach great importance to =5	3.98	0.93
	CHAR	Taste, appearance, smell and other sensory characteristic		3.79	0.98
	ECO	ecological welfare		3.81	1.10
Control variables	GEN	Gender	Woman= 0; Man= 1	0.41**	0.49
	AGE	Age	Actual value	32.45	11.21
	EDU	Education level	Primary school and below=1；Junior middle school=2；High school (including technical secondary school, vocational high school, etc.)=3；University (undergraduate, junior college)=4；Graduate and above=5	4.20***	0.73
	INC	Average individual monthly income	Under RMB 1000=1；RMB 1000-3500=2；RMB 3500-6000=3；RMB 6000-8000=4；RMB 8000-10000=5；RMB 10000-20000=6；More than RMB 20000=8	3.19	1.63
	VEG	Being vegetarian or not	No= 0; Yes= 1	0.07	0.26
	MED	Having "three-high" medical history or not	No= 0; Yes= 1	0.09	0.29
	LAC	Lactose intolerance or not	No= 0; Yes= 1	0.09	0.29
	RES	Residence type	Rural area= 0；Urban area= 1	0.92	0.27
	JOB	Engaged in medical, health, environmental protection or related occupations or not	No= 0; Yes= 1	0.11**	0.32
	KNOW	Knowledge of plant-based milk	Not at all=1；Know a little=2；Better understanding=3；Very well=4	1.91	0.67
	FRI	Purchase status of relatives and friends	Rarely find them buying=1；Occasionally buy=2；Find that they often buy=3	1.80***	0.59
	ADV	Advertisements	Haven't seen=1；Occasionally see=2；Often see=3	1.90**	0.59

Table 3

Estimation results of willingness to pay function model

Variables	Coefficient
CHAR	-0.131（0.211）
PRI	-1.042（0.212）***
ECO	0.495（0.177）***
GEN	-0.569（0.303）*
AGE	-0.0176（0.0149）
EDU	-0.876（0.218）***
INC	0.0796（0.0958）
VEG	0.499（0.563）
MED	0.527（0.525）
LAC	0.197（0.522）
RES	0.473（0.552）
JOB	1.252（0.456）***
KNOW	-0.00705（0.240）
FRI	0.556（0.286）*
ADV	-0.366（0.288）

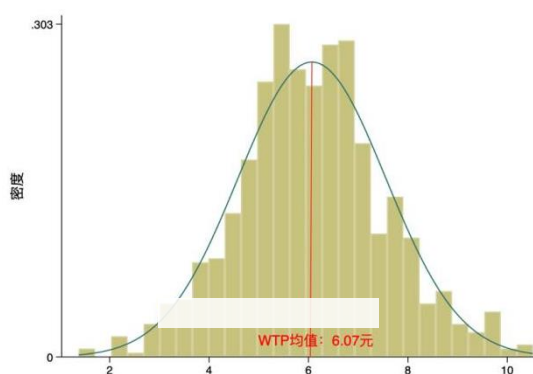Notes:

Standard deviation in parentheses; *** $p<0.01$, **$p<0.05$, *$p<0.10$

Figures
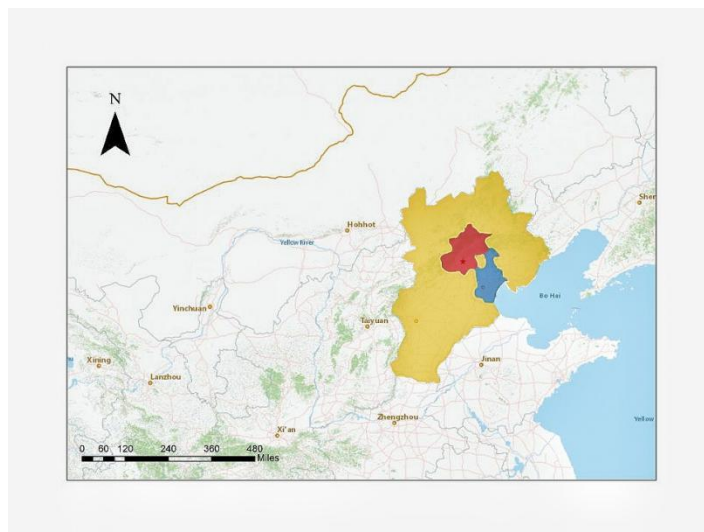
Fig.1 Beijing-Tianjin-Hebei research region

Fig.2 Distribution of consumers' willingness to pay