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Effects of the COVID-19 pandemic on urban residents' consumption behavior of forest food—an empirical study of 6,946 urban residents

Shiyu Liu, Dan He* and Ke Chen*

College of Economic and Management, Shenyang Agricultural University, Shenyang, Liaoning, China

Forest food, which possesses enormous potential, has emerged as a significant and promising food source under the all-encompassing approach to food. The sudden outbreak of the COVID-19 pandemic in 2019 has enhanced health cognition among residents, impacting household food consumption patterns. In this study, we analyzed data from 6,946 urban households in 14 cities of Liaoning Province to examine the consumption behavior of urban households regarding 4 categories of forest food (forest nuts, forest fruits and vegetables, forest drinks, and forest medicines) before and after the COVID-19 pandemic. Various empirical methods were employed, including the Contingent Valuation Method (CVM), Ordinal Logit Model, Mediation Effect Model, and Moderation Effect Model. The results revealed that the COVID-19 pandemic positively impacted the "willingness-behavior" consumption behavior of urban residents toward forest food. Health cognition played a positive mediating role in influencing residents' willingness to pay (WTP) for forest food during the pandemic. *Per capita* income had a negative moderating effect on the actual purchasing behavior of urban residents toward forest food. Furthermore, differences were observed in the consumption behavior of forest food among residents in cities with different levels of pandemic severity.

KEYWORDS

COVID-19 pandemic, forest food, consumption behavior, urban residents, health cognition

1 Introduction

As living standards continually improve, a transformation is happening in the general public's food consumption habits. People are now focusing on eating well, nutritiously, and balanced meals, rather than just eating enough, reflecting the increasing demand for both quantity and quality in food. To meet these changing needs, the Chinese government has proposed "people's food needs are more diversified, which requires changing concepts, establishing a big agricultural concept, a big food concept, that is a concept of all-encompassing approach to food, and seeking heat and protein from cultivated land, grasslands, forests, oceans, plants, animals and microorganisms, and developing food resources in an all-round and multi-channel way." This approach aligns with the growing consumer demand for diverse food options (Fan and Zhang, 2023), promotes improvements in people's nutritional structure, and enhances the national understanding of nutrition and health (Qing et al., 2023).

There is great potential for sourcing food from forests under the all-encompassing approach to food, which is seen as the future of food development. Forest products have become significant economic crops (Huang et al., 2022), ensuring a safe supply of basic food and essential nutrients, and offering opportunities for healthy and natural food options (Chamberlain et al., 2020). Compared to the traditional grain-centric approach, the all-encompassing food approach prioritizes the diversity and health properties of residents' diets (Long and Fan, 2023). Establishing an all-encompassing approach to food helps maintain food security from a broader perspective, emphasizing the significant role of food production from forests, grasslands, and river–lake-sea systems in securing China's food supply. This approach facilitates the transformation and upgrading of food security in terms of both quantity and quality.

The unexpected outbreak of COVID-19 in 2019 caused changes in family food consumption patterns (Eftimov et al., 2020; Ferreira Rodrigues et al., 2021; Filimonau et al., 2022). Consumer consciousness becoming more rational, and health cognition rapidly awakening. Therefore, in-depth exploration of the impact mechanism of the epidemic on the forest food consumption behavior of urban residents and clarification of the decision-making logic of consumer behavior are of great practical significance for optimizing and improving consumer forest food consumption behavior, stimulating and releasing consumer forest food consumption demand, enhancing the health awareness of urban residents in the field of food consumption, and promoting the healthy and rapid development of forest food market.

China, the European Union, and the United States are the most significant global markets for forest foods. In 2020, China's forest food market accounted for 29.18%[1] of the global market share. The prospects for the future development of China's forest food market are promising. The Northeast state-owned forest region, one of China's three major state-owned forest regions, covers more than 50% of China's state-owned forest area and is the primary source of forest foods, accounting for over 98% of the production in state-owned forest regions (Huang et al., 2022). Liaoning, the political, economic, and cultural center of Northeast China, serves as a unique case for this study. Based on the micro-level survey data from 6,946 urban households in 14 cities in Liaoning Province, this study explores the impact mechanisms of the COVID-19 pandemic on the consumption behavior of urban residents toward forest foods. This investigation will help analyze the impact path of the pandemic on forest food consumption under the mediating effect of health cognition and provide policy references to enhance residents' consumption of healthy foods and increase their resilience to risks.

Based on this, this paper proposes the following research objectives:

(1) The Conditional value assessment method (CVM) was used to measure the willingness of urban residents to pay for forest food before the COVID-19 outbreak.

(2) To explore the differences in urban residents' consumption behaviors of different kinds of forest food, this paper divided forest food into four categories: forest nuts, forest fruits and vegetables, forest

drinks and forest drugs, based on the Chinese classification standards of forest food (Liu et al., 2022) and the actual situation of Liaoning Province.

(3) The ordered Logit model was used to measure the impact of COVID-19 on the consumption behavior of urban residents in two stages: willingness to pay and actual purchasing behavior for forest food.

(4) The mediation effect model was used to explore the indirect impact of COVID-19 on urban residents' willingness to pay for forest food through the improvement of health awareness. The moderating effect model was used to explore the role of *per capita* income in the impact of the epidemic on the actual purchase behavior of forest food by urban residents.

2 Literature review

2.1 Forest food related research

Research on forest food began in the early 20th century, and forest food mainly includes nuts, fruits, edible fungi, vegetables, starch, bird's nest, oil, etc. (FAO, 1995). In 2015, China Forestry Development Promotion Association made a clear definition of forest food: "Forest food is a variety of food produced and processed by plants, microorganisms and animals growing in the forest ecological environment." Forest foods are closely related to the food security needs of the population, providing opportunities to expand the food system and transition to a bioeconomy (Chamberlain et al., 2020). Forest foods can improve the dietary quality and nutrition of consumers (Tata et al., 2019; Albrecht and Wiek, 2021), contributing to the diversity of human diets (Hall et al., 2019; Rasmussen et al., 2020). Moreover, forest foods also have a close relationship with the food security needs of the global population (Karki et al., 2018). They could remain essential to household strategies to eradicate hunger and achieve balanced nutrition, with many untapped potentials in reducing global hunger (FAO, 2015). It is estimated that forest foods contribute to the diet of approximately one billion people living in forest areas (FAO, 2020), with European households consuming an average of about 60 kilograms of forest foods each year (Lovrić et al., 2020). The development of forest foods can enhance both the economic benefits of forestry and socio-economic benefits. It plays a critical role in transforming and developing forestry and ensuring food security, which is significant for diversifying food sources, promoting balanced nutrition, and strengthening the national physique (Yang, 2022).

2.2 The impact of COVID-19 on food consumption

The unexpected outbreak of COVID-19 in 2019 impacted various aspects of the economic system (Tang et al., 2020) and rural development (Wei and Lu, 2020), causing changes in family food consumption patterns (Eftimov et al., 2020; Ferreira Rodrigues et al., 2021; Filimonau et al., 2022). In the short term, consumption patterns have shifted, and the consumption level of some groups has declined (Zang et al., 2020).

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1   The data on the market share of China's forest food market in 2020 is sourced from the Huaon Industry Research Institute (www.huaon.com).

However, in the long term, the trend of consumption upgrading in China remains unchanged, with consumption methods becoming more diversified, consumer consciousness becoming more rational, and health cognition rapidly awakening. Consumers are constantly changing their food purchasing behavior to reduce health risks (Hesham et al., 2021), with the pandemic having a limited impact on consumption (Guan, 2020; Zhu, 2020). COVID-19 has made the public realize, to a certain extent, the importance of healthy eating in preventing diseases and ensuring health, leading to a pursuit of safe and healthy foods. With the backdrop of the pandemic, consumer health consciousness continues to rise, and health needs are continually refined (CBN Data, 2020). Post-pandemic, 74% of Chinese prioritize "health," "diversity," and "balance" when choosing their diets, and healthy eating habits are becoming a consumer trend in China's food industry (KANTAR TNS, 2020). Forest foods, possessing both the attributes of necessary living goods found in agricultural products and the high added-value attributes of mid-to-high-end consumer goods, are healthier than ordinary agricultural products (Chamberlain et al., 2020; Nurhasan et al., 2022). Consumers focused on health consciousness and sustainable development tend to purchase forest foods (Chamberlain et al., 2020). Therefore, promoting consumer behavior toward forest foods not only aligns with the social environment of a commonly raised health cognition and the era background of an all-encompassing approach to food, but also stimulates the optimization of forest food market resource allocation, which is of great significance to the economic recovery in the post-pandemic period.

Substantial research has been conducted on the impact of the pandemic on food consumption in European countries such as Italy (Di Renzo et al., 2020; Fanelli, 2021; Caso et al., 2022), Spain (Batlle-Bayer et al., 2020), Poland (Sidor and Rzymski, 2020), Turkey (Kaya et al., 2021), and in American countries like Brazil (Ferreira Rodrigues et al., 2021; Manica-Cattani et al., 2022), United States (Chenarides et al., 2021; Parekh et al., 2021), as well as Asian nations such as Qatar (Ben Hassen et al., 2020), Japan (Qian et al., 2020), India (Jaacks et al., 2021), Iran (Mohajeri et al., 2021) and Bangladesh (Akter et al., 2022). All these provide important basis for this paper. Scholars in China primarily analyze the impact of the pandemic on the development of social consumption (Liu et al., 2022; Zhou et al., 2022), but the actual survey data of urban residents are seldom used to carry out research at the microscopic level. The COVID-19 pandemic has a serious impact on urban residents' health awareness of food consumption, family income and other aspects, so the research on the impact of this major public health event on urban residents' forest food consumption behavior should be paid attention to by the academic community.

3 Theory and hypothesis

In recent years, the acceptance of healthy foods among the general population has increased significantly (Nguyen et al., 2019), and individuals commonly opt to increase their health investments to enhance their resilience against unexpected public health incidents. Existing research shows that the COVID-19 pandemic has played a critical role in reshaping household lifestyles, food consumption, and dietary habits (Akbarzadeh et al., 2021; Kartari et al., 2021), adding to the uncertainty regarding the health of urban residents. Our study employs the indifference curve analysis to evaluate the impact of the

pandemic on the consumption behavior of forest food among urban residents.

3.1 The impact of the pandemic on forest food consumption behavior among urban residents

Globally, forest food is generally considered to comprise fruits, vegetables, meats, and nuts (Rowland et al., 2017). In alignment with the Chinese classification standards of forest food (Liu et al., 2022), this study categorizes forest food into 4 groups: forest nuts, forest fruits and vegetables, forest drinks, and forest medicinal products (Figure 1).

Before the outbreak of COVID-19, the budget line for urban household income was Y_1, and the indifference curve was L_1. The point of consumption equilibrium for urban residents was point A, where the two lines intersected. Following the sudden outbreak of the pandemic, urban residents became more focused on their personal and family health. The enhanced awareness and understanding of health influenced their consumption preferences, causing a lean toward consuming green, healthy food to boost their immunity. Existing research suggested that forest foods are healthier than ordinary agricultural products (Chamberlain et al., 2020; Nurhasan et al., 2022). Urban residents' consumption behavior of forest food was reflected in two aspects: First, when faced with other medicines or health products that achieve similar effects or satisfy the same needs, they preferred to purchase forest food such as forest nuts or forest drinks. Second, due to forest food's irreplaceable health and nutritional value, they still tended to purchase forest fruits, vegetables, and medicinal products, even when prices increase within acceptable ranges. Consumers were willing to pay a premium for forest food mainly because of the health safety brought about by its high quality (Sidali and Schulze, 2010; Hemmerling et al., 2013). When faced with serious public health events, consumers tended to buy healthier food
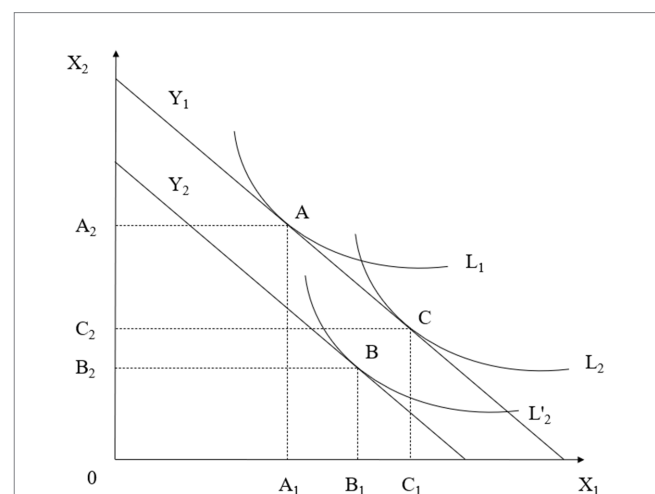

FIGURE 1
Indifference curve analysis of forest food consumption behavior among urban residents. X_1 represents the consumption of forest food, while X_2 represents the consumption of other substitutable foods.

at higher prices to meet their health needs. In this case, the health risk can outweigh the financial risk, and consumers' willingness to buy healthy food during the pandemic increases (Hesham et al., 2021).

Based on the above analysis, we proposed the following hypotheses:

H1a: The COVID-19 pandemic has increased urban residents' willingness to pay for forest food.

H1b: The COVID-19 pandemic has resulted in a higher rate of forest food purchases among urban residents.

3.2 Mediating role of health cognition

Economics typically suggests that changes in indifference curves result from changes in demand due to commodity price fluctuations. Considering that an individual's food environment affected their food patterns (Gustat et al., 2017), this article examined the relationship between changes in urban residents' health awareness during the pandemic and their demand for forest foods based on previous study (Zhou et al., 2022). After the outbreak, residents usually prioritized health when consuming food (Clark et al., 2020), and consumers who valued health consciousness and sustainability were inclined to buy forest foods (Chamberlain et al., 2020). According to Health Belief Model (HBM) and its application in the COVID-19 pandemic (Shahnazi et al., 2020), we inferred that, under the "background-perception-action" framework, the occurrence of the COVID-19 pandemic (background) led to an increase in urban residents' health cognition (perception), which increased demand for green, healthy forest foods (action). Consequently, the shape and position of the indifference curve changed, shifting to the right from L_1 to L_2. The intersection with the urban residents' family income budget line Y_1 was the new consumption equilibrium point C. At this point, the increase in urban residents' forest food consumption was A_1C_1.

Based on this analysis, we proposed the following hypotheses:

H2a: The COVID-19 pandemic positively influences urban residents' health cognition.

H2b: Health cognition positively mediates the impact of the pandemic on urban residents' willingness to pay for forest foods.

3.3 Moderating role of *per capita* income

In many developing countries, the outbreak and spread of the pandemic have primarily hindered economic development (Tadesse and Muluye, 2020). This economic downturn further escalated most urban households' concerns about financial status, job security, and future uncertainties (Kerr et al., 2021), intensified economic pressure (Carroll et al., 2020), reduced household income (Qian and Fan, 2020), and potentially weakened purchasing power for food (Hirvonen et al., 2021). As a result, the urban residents' family income budget line dropped from Y_1 to Y_2. Considering that forest foods were largely normal goods, the intersection with indifference curve L'_2, which corresponded to Y_2, was the new consumption equilibrium point B. Household income was a critical factor affecting consumption, and income uncertainty due to the pandemic could lead to an increase in household savings and a decrease

in consumption (Immordino et al., 2022). This budgetary constraint fundamentally suppressed the impact of the pandemic on food consumption behavior (Sharma et al., 2020). At this point, urban residents' decreased forest food consumption was B_1C_1.

Based on this analysis, we proposed the following hypothesis:

H3: *Per capita* income negatively moderates the impact of the pandemic on urban residents' forest food purchases.

Therefore, the ultimate increased in urban residents' consumption of forest foods after the pandemic was A_1B_1, the difference between the increase in A_1C_1 and the decrease in B_1C_1. In this study, we established a framework to analyze the influence of the COVID-19 pandemic on forest food consumption behavior among urban residents (Figure 2).

4 Materials and methods

4.1 Area selection and data sources

As of the end of 2022, China's forest area amounted to 231 million hectares, with a forest coverage rate of 24.02%. Forest food production and value were 6.786 million tons and 1.07 billion yuan, respectively.[2] The Northeast State-owned forest region was the primary source of China's forest food, contributing to more than 98% of total production (Huang et al., 2022). Liaoning, the political, economic, and cultural center of Northeast China, was selected for this study. From December 2022 to February 2023, a combined online and offline questionnaire survey was conducted among urban families in 14 cities in Liaoning Province. A total of 9,529 online questionnaires were collected.

Before answering the questionnaire, two screening questions were set: "During the 2020–2022 epidemic period, did you live in Liaoning Province for a long time (more than 6 months within a year)? "And" Are you a major consumer of food in your household, or are you familiar with household consumption?." If the respondents answer "no" to these two questions, this paper believes that such respondents do not know much about the consumption behavior of family forest food, and will be forced to end the questionnaire. Exclusion criteria included researchers who did not reside in Liaoning Province for a significant period during the epidemic and those who were unfamiliar with household consumption and forest foods. In the middle part of the questionnaire, a simple definition and classification of forest food are given, with the specific information as "forest food refers to all kinds of edible products that come from a good forest environment, follow the natural growth laws of animals and plants, have no synthetic additives, and have the characteristics of original ecology, no pollution, health and safety." According to the economic use of forest plant resources, forest food is divided into forest vegetables, forest food, forest oil, forest beverage, forest feed, forest medicine, forest honey source, forest spices and other, a total of 9 categories." After the basic information, there is also a selection question, asking the respondents to choose which one is not forest food from the four pictures. If the answer to this question is wrong,

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2   The data on China's forest area, forest coverage rate, forest food production, and output value in 2022 is sourced from the "China Forestry Statistical Yearbook 2022."
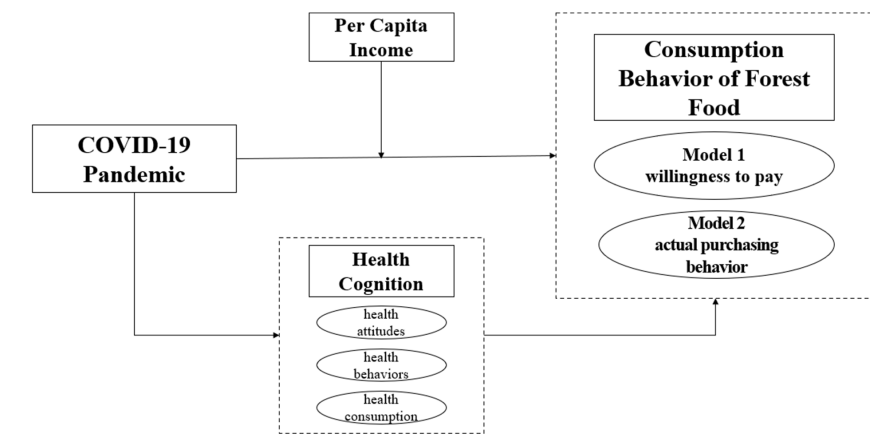
FIGURE 2
Mechanism of the impact of the COVID-19 pandemic on urban residents' forest food consumption behavior.
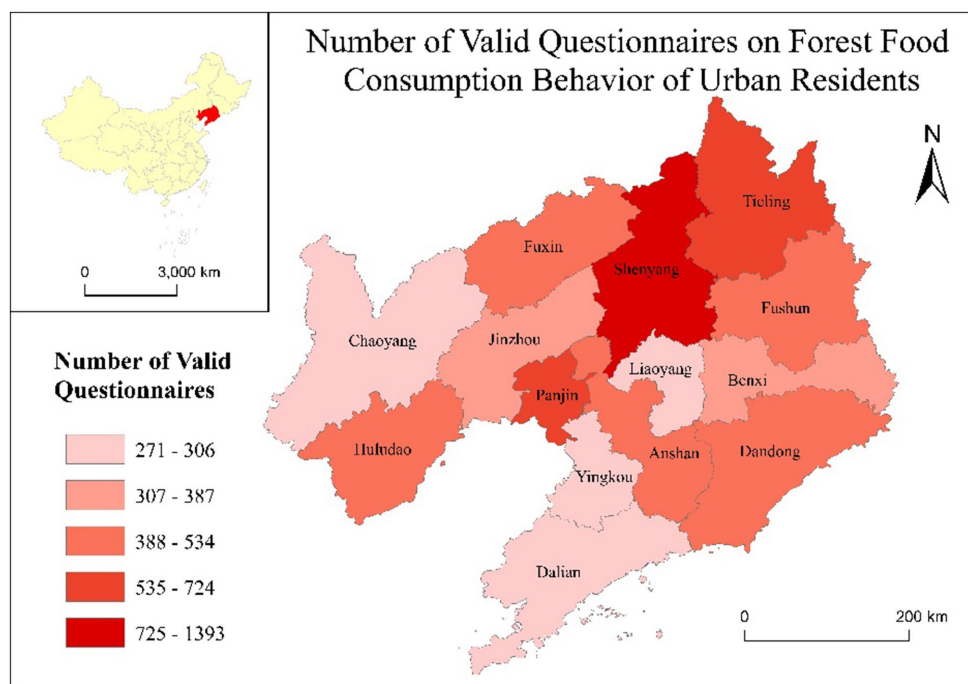

FIGURE 3
Number of valid questionnaires on forest food consumption behavior of urban residents.

the respondents are considered to have insufficient cognition of forest food and do not meet the requirements of this survey, and will be forced to finish the questionnaire.

After data cleaning for basic logic, 6,946 valid questionnaires were obtained, resulting in an effectiveness rate of 93.3% (Figure 3).

4.2 Variable selection

4.2.1 Independent variable: urban residents' forest food consumption behavior

The forest food consumption behavior of urban residents was examined in two stages: "willingness - action." Questions were posed

regarding 4 types of forest food: forest nuts, forest fruits and vegetables, forest drinks, and forest medicine. In the willingness to pay (WTP) stage, two phases were differentiated: during the COVID-19 pandemic from 2020 to 2022; after the issuance of "10 new measures" prevention and control optimization measures at the end of 2022.[3] Studies have shown that the retail price of forest food is generally 20–40% higher than that of ordinary food, and the price of forest food is 30% higher

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3 The specific measures to optimize the prevention and control of the COVID-19 pandemic, known as the "10 new measures," were introduced by the Joint Prevention and Control Mechanism of the State Council on 7 December 2022.

than that of ordinary agricultural products in China and 50% or more higher in Europe. At the same time, on the basis of green food, forest food has more stringent environmental requirements. Internationally, the price of green food is 150%–200% higher than that of similar ordinary food. In the first stage, WTP was measured by the amount of premium paid for forest food, with each category of forest food evaluated on an eight-point scale (no WTP = 0, supports equivalent = 1, (0, 10%] premium = 2, (10, 20%] premium = 3, (20, 30%] premium = 4, (30, 40%] premium = 5, (40, 50%] premium = 6, (50, 200%] premium = 7). In the second stage, respondents were asked whether their WTP increased after the pandemic, with responses evaluated on a seven-point scale, ranging from 1 (strongly disagree) to 7 (strongly agree).

In the actual purchasing behavior stage, forest food purchasing behavior was measured by the family's frequency of forest food purchases, covering two stages: during the pandemic from 2020 to 2022; before the pandemic from 2017 to 2019. In January 2023, the consumer questionnaire data collection of this paper was officially launched online; Prior to this, the research group conducted a pre-survey in Shenyang, Liaoning Province, in December 2022, collecting a total of 54 pre-survey questionnaires. In the process of pre-survey, the frequency and amount of actual purchases of forest food by urban residents were understood through interviews, and the consumption behavior of forest food by urban residents was subdivided into seven levels according to the actual situation of pre-survey. In the first stage, each type of forest food was evaluated on a seven-point scale (never buy = 1, once every 2 years = 2, once a year = 3, once every 6 months = 4, once every 3 months = 5, once a month = 6, multiple times a month = 7). In the second stage, respondents were asked whether the purchasing frequency changed compared to usual behavior before the pandemic, with answers evaluated on a seven-point scale ranging from 1 (greatly decreased) to 7 (greatly increased).

4.2.2 Core independent variable: COVID-19 pandemic

The impact of the pandemic from 2020 to 2022 was measured using 4 indicators: "impact of the pandemic on consumption expenditure," "improvement in diet consumption structure and habits due to the pandemic," "increased attention to the healthiness of diet consumption due to the pandemic," and "belief that forest food is green, healthy and worth purchasing due to the pandemic." These were evaluated on a 5-point scale (strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5). The time before the pandemic from 2017 to 2019 and after the announcement of the "10 new measures" pandemic control optimization measures at the end of 2022 was marked as a dummy variable "0."

4.2.3 Mediating variable: health cognition

Health cognition was measured through 7 indicators covering 3 dimensions: health attitudes, health behaviors, and health consumption. Health attitude indicators included "Do you consider nutritional health risk factors in your food consumption process?" and "Do you consider food and nutritional intake factors in your food consumption process?," evaluated on a five-point scale (very few = 1, few = 2, neutral = 3, many = 4, very many = 5). Health behavior indicators included "What changes have occurred in your average weekly exercise coefficient compared to before the pandemic?" and

"What changes have occurred in your exercise time per session compared to before the pandemic?," evaluated on a five-point scale (significantly reduced = 1, slightly reduced = 2, no change = 3, slightly increased = 4, significantly increased = 5). Health consumption indicators included "You actively seek and buy health-beneficial goods," "You actively consider health factors when making consumption decisions," and "You are willing to pay a higher price for healthier goods," evaluated on a five-point scale (strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5).

4.2.4 Moderating variable: specific amount of *per capita* income

The study used the average monthly income per person (yuan/person) of family members living together for a long time during the pandemic from 2020 to 2020 as a moderating variable in the mechanism of the pandemic's impact on urban residents' actual purchasing behavior of forest food.

4.2.5 Control variables

Control variables were considered from three levels: (1) Individual Characteristic Level: gender, age, occupation, level of education, and marital status; (2) Family Characteristic Level: family income, number of elderly in the family, number of children in the family, health status of the elderly in the family, health status of the children in the family, residential community grade; (3) Information Stimulus Level: number of WeChat friends, level of attention to the pandemic, where the level of attention to the pandemic was measured by the frequency of actively searching for and viewing information related to the pandemic and food consumption, and the frequency of discussing pandemic and food consumption-related situations with people around them.

4.3 Model selection

4.3.1 Contingent valuation method

The CVM is an approach that simulates a market via scenario description and determines the maximum WTP for a specific product by guiding consumers through a series of questions. The process involved reinforcing information, describing the purchasing scenario and product, and guiding respondents to provide answers regarding their WTP. The formula used to calculate consumers' WTP was as follows:

$$E\left(WTP\right) = \sum_{i=1}^{n} A_i * P_i \qquad (1)$$

Here, $E\left(WTP\right)$ denotes the expected value of WTP, A_i denotes the willingness-to-pay premium level i chosen by the sample consumers, P_i represents the probability of a consumer choosing A_i.

4.3.2 Benchmark regression model

In this study, we decomposed consumer behavior into two stages: "intention - action." We empirically examined the impact of the COVID-19 pandemic on both stages of consumer behavior toward forest food products. Since the variables characterizing forest food consumption behavior were all multi-ordered categorical variables,

we utilized the ordered Logit model for the benchmark regression estimation. The specific model settings were as follows:

$$Willingness_{it} = \alpha_0 + \alpha_1 X_{it} + \sum \beta_j C_{jit} + \delta_i + \mu_t + \varepsilon_{it} \quad (2)$$

$$Purchase_{it} = \alpha_0 + \alpha_1 X_{it} + \sum \beta_j C_{jit} + \delta_i + \mu_t + \varepsilon_{it} \quad (3)$$

4.3.3 Mediating effect model

To examine the mediating effect of health cognition on the impact of the pandemic on urban residents' WTP for forest food products, we draw upon the mediating effect model proposed by Wen et al. (2004). Based on the benchmark regression (2), we constructed a stepwise regression model 4–5:

$$health_{it} = \alpha_0 + \alpha_1 X_{it} + \sum \beta_j C_{jit} + \delta_i + \mu_t + \varepsilon_{it} \quad (4)$$

$$Willingness_{it} = \alpha_0 + \alpha_1 X_{it} + \alpha_2 health_{it} \\ + \sum \beta_j C_{jit} + \delta_i + \mu_t + \varepsilon_{it} \quad (5)$$

4.3.4 Moderating effect model

To examine the moderating effect of *per capita* income on the relationship between the pandemic and urban residents' actual purchase behavior of forest food products, regression Models 6–7 were constructed. *Per capita* income, the COVID-19 pandemic, and the interaction term of *per capita* income were added to the benchmark regression Model 3.

$$Purchase_{it} = \alpha_0 + \alpha_1 X_{it} + \alpha_2 \ln pci_{it} + \sum \beta_j C_{jit} + \delta_i + \mu_t + \varepsilon_{it} \quad (6)$$

$$Purchase_{it} = \alpha_0 + \alpha_1 X_{it} + +\alpha_2 \ln pci_{it} + \alpha_3 X_{it} * \ln pci_{it} \\ + \sum \beta_j C_{jit} + \xi_i + \mu_t + \varepsilon_{it} \quad (7)$$

In this model, the core explanatory variable X_{it} represents the COVID-19 pandemic in city i at time period t. The independent variable, consumers' consumption behavior of forest foods, is divided into two stages:$Willingness_{it}$, the WTP in city i at time period t, and$Purchase_{it}$, the actual purchase behavior in city i at time period t. The mediating variable $health_{it}$ represents the health cognition of urban residents in city i at time period t. The moderating variable $lnpci_{it}$ refers to the specific amount of *per capita* income in city i at time period t. $X_{it} * lnpci_{it}$ is the interaction term between the pandemic and *per capita* income. $\sum \beta_j C_{jit}$ represents the control variables. $\alpha_0, \alpha_1, \alpha_2, \alpha_3, \beta_j$ are coefficients to be estimated, while ξ_i, μ_t and ε_{it} are the city fixed effects, time period fixed effects, and random error terms, respectively.

5 Empirical results

5.1 Demographic characteristics

The survey respondents showed a balanced gender distribution, with slightly more females (53.38%), indicating their significant role in family consumption. The majority of consumers were young (52.75%) and middle-aged (46.44%), making them the primary

consumers within their families. Families with 3–4 members (63.26%) were the most prevalent demographic (Table 1).

Due to the length of the article, this study only presented the Pearson correlation coefficients for variables related to the impact of the pandemic on the "intention-behavior" consumption behavior of urban residents regarding forest nuts (Tables 2, 3).

5.2 Reliability and validity analysis

In the survey process, COVID-19 and health cognition measurements were performed using a Likert scale. Therefore, Cronbach's alpha method was used for reliability testing, where a coefficient greater than 0.7 indicated that the data passed the reliability test. The KMO sample measure and Bartlett's sphericity test were also used for validity testing, with a KMO value greater than 0.8 indicating that the data passed the validity test. A reliability and validity analysis was conducted on the variables set in this study using SPSS 27.0 software. The α coefficients for the variables were found to be 0.947 and 0.891, both exceeding the recommended threshold of 0.7. The KMO value was 0.875, indicating good sampling adequacy, and Bartlett's sphericity test resulted in a significant value of 226164.876 and a value of p of 0.00, confirming the reliability and validity of the survey data (Table 4).

5.3 Baseline model regression analysis

A Logit regression analysis and multi-collinearity testing were conducted on the explanatory variables using Stata 17.0 software. The results revealed VIF values ranging from 1 to 1.5, indicating that the model fitting results were reliable.

Table 5 presented the regression results for Model 1 and Model 2, which examined the impact of the core explanatory variable, COVID-19, on the willingness of urban residents to pay for forest foods. The coefficients for forest nuts, forest fruits and vegetables, forest drinks, and forest medicine were all positive and significant at the 1% level (forest nuts 0.628***, forest fruits and vegetables 0.743***, forest drinks 0.751***, forest medicine 0.856***). This finding supported research hypothesis H1a, indicating that COVID-19 has significantly increased the willingness of urban residents to pay for forest foods.

Table 6 presented the results for Model 3 and Model 4, which analyzed the impact of COVID-19 on the actual purchasing behavior of urban residents toward forest foods. The estimated coefficients for forest nuts, forest fruits and vegetables, forest drinks, and forest medicine were positive and significant at the 1% level (forest nuts 0.197***, forest fruits and vegetables 0.197***, forest drinks 0.206***, forest medicine 0.125***). This result supported research hypothesis H1b, suggesting that COVID-19 has significantly promoted the actual purchasing behavior of urban residents toward forest foods.

5.4 Mediating effect analysis

Stepwise regression analysis was utilized to examine the mediating effect. Table 7 demonstrated that the addition of the mediating variable in Models 6–7 resulted in higher likelihood ratio chi-square (LR chi²) and coefficient of determination (Pseudo R²)

TABLE 1 Demographic characteristics.

Variable	Characteristics	Frequency (n)	Percentage (%)	Mean	Standard deviation	Range
Gender	1. Male	3,238	46.62			
	2. Women	3,708	53.38			
Age	16–40 years	3,664	52.75	40.084	10.033	16–84
	41–65 years	3,226	46.44			
	65 years and over	56	0.81			
Educational level	1. Primary education	288	4.14			
	2. Secondary education	1,287	18.53			
	3. Higher education	4,761	68.53			
	4. Postgraduate education	610	8.80			
Occupation	1. Leaders in state organs, party mass organizations, enterprises and public institutions	621	8.94			
	2. Professionals and technicians	1,361	19.59			
	3. Civil servants, office workers, and related personnel	575	8.28			
	4. Self-employed individuals	179	2.58			
	5. General employees in enterprises and institutions	3,053	43.95			
	6. Private business owners	129	1.86			
	7. Freelancers	431	6.20			
	8. Current students	347	5.00			
	9. Individuals without a fixed occupation	250	3.60			
Marital status	1. Married	5,561	80.06			
	2. Unmarried	1,083	15.59			
	3. Divorced	254	3.66			
	4. Widowhood	48	0.69			
Number of family members	1–2 persons	1,472	21.19			
	3–4 persons	4,396	63.26			
	5 or more	1,080	15.55			
Number of WeChat friends	1. 0–100	1,550	22.32			
	2. 101–200	1,759	25.32			
	3. 201–500	2,333	33.59			
	4. 501–1,000	833	11.99			
	5. >1,001 yuan	471	6.78			
Average monthly household income	≤4,000 yuan	2,000	28.79	7713.062	6983.929	1,000–20,000
	4,001–8,000 yuan	2,606	37.52			
	8,001–12,000 yuan	1,447	20.83			
	≥12,001 yuan	893	12.86			
Impact of COVID-19 pandemic on family income	1. Increase in income	53	0.76			
	2. Largely unchanged	3,069	44.19			
	3. Decrease in income	3,824	55.05			
Grade of residential district	1. Low grade	2,655	38.22			
	2. Medium grade	4,012	57.76			
	3. High grade	279	4.02			
Current or past experience of being diagnosed as COVID-19	1. Yes	6,069	87.37			
	2. No	877	12.63			
Family members' current or past experience of being diagnosed as COVID-19	1. Yes	6,112	87.99			
	2. No	834	12.01			

compared to Model 5 without the mediating variable, indicating an improved model fit. The estimated coefficients for the core explanatory variable, COVID-19, and the mediating variable, health cognition, were positive and statistically significant at the 1% level. The results suggested a partial mediating effect and confirmed research hypotheses H2a and H2b.

Further research found that the coefficient of the COVID-19 variable dropped after the addition of the mediating variable. Specifically, the coefficient of the core explanatory variable for forest nuts dropped from 0.628*** to 0.372***, indicating a direct effect of 0.372 and a mediating effect of 0.256, accounting for 40.76% of the total effect. For forest fruits and vegetables, the coefficient dropped from

TABLE 2 Pearson's correlation coefficients for variables related to urban residents' willingness to pay for forest food (forest nuts).

	1	2	3	4	5	6	7	8	9	10	11	12
1. Willingness to pay for forest nuts	-											
2. COVID-19 pandemic	0.008	-										
3. Gender	−0.023***	−0.003	-									
4. Age	0.042***	−0.001	−0.044***	-								
5. Occupation	−0.054***	−0.008	0.090***	−0.234***	-							
6. Marital status	−0.005	0.000	0.025***	−0.297***	0.169***	-						
7. Household income	0.033***	0.004	−0.015*	−0.006	−0.122***	−0.054***	-					
8. Health status	0.152***	0.043***	−0.036***	−0.022***	−0.005	−0.043***	0.023***	. -				
9. Health status of the elderly at home	0.057***	0.013	−0.033***	0.033***	0.010	0.001	0.000	0.185***	-			
10. Health status of children at home	0.022***	0.014	0.025***	−0.062***	−0.017**	−0.218***	0.008	0.141***	0.155***	-		
11. Number of WeChat friends	0.039***	0.012	0.013	−0.185***	−0.111**	−0.008	0.186***	0.062***	−0.001	0.091***	-	
12. Level of concern about the epidemic	0.214***	0.109***	−0.015*	0.018**	−0.049***	−0.013	0.039***	0.200***	0.072***	0.022***	0.056***	-

*** statistically significant at 0.01 level (two-tail test); ** statistically significant at 0.05 level (two-tail test); * statistically significant at 0.1 level (two-tail test).

TABLE 3 Pearson's correlation coefficients for variables related to urban residents' actual purchasing behavior of forest food (forest nuts).

	1	2	3	4	5	6	7	8	9	10	11	12
1. Actual purchasing behavior of forest nuts	-											
2. COVID-19 pandemic	0.092***	-										
3. Gender	0.024***	−0.003	-									
4. Age	0.122***	−0.002	−0.044***	-								
5. Occupation	−0.098***	−0.009	0.090***	−0.234***	-							
6. Educational attainment	0.135***	0.011	0.066***	−0.203***	−0.304***	-						
7. Number of elderly people	−0.036***	0.002	−0.002	0.007	−0.005	−0.009	-					
8. Number of children	0.007	0.005	0.016*	−0.050***	−0.031***	0.011	0.187***	. -				
9. Household income	0.146***	0.005	−0.015*	−0.006	−0.122***	0.228***	−0.005	0.031***	-			
10. Grade of residential district	0.195***	0.016*	0.067***	0.017**	−0.159***	0.256**	−0.043***	0.042***	0.280***	-		
11. Number of WeChat friends	0.083***	0.015*	0.013	−0.185***	−0.111***	0.266***	0.019**	0.116***	0.186***	0.188***	-	
12. Level of concern about the epidemic	0.164***	0.144***	−0.015*	0.018**	−0.049***	0.037***	0.029***	0.014*	0.039***	0.056***	0.056***	-

*** statistically significant at 0.01 level (two-tail test); ** statistically significant at 0.05 level (two-tail test); * statistically significant at 0.1 level (two-tail test).

TABLE 4 Reliability and validity test.

Variables	Measurement items	Cronbach's alpha	KMO sampling adequacy	Bartlett's test of sphericity
COVID-19 pandemic	3	0.947		Approx. chi-square 226164.876
Health cognition	7	0.891	0.875	Degree of freedom 120
				Significance 0.000

0.743*** to 0.480***, indicating a direct effect of 0.480 and a mediating effect of 0.263, accounting for 35.40% of the total effect. For forest drinks, the coefficient dropped from 0.751*** to 0.503***, indicating a direct effect of 0.503 and a mediating effect of 0.248, accounting for 33.02% of the total effect. For forest medicine, the coefficient dropped from 0.856*** to 0.616***, indicating a direct effect of 0.616 and a mediating effect of 0.230, accounting for 26.87% of the total effect.

5.5 Moderating effect analysis

To explore whether *per capita* income plays a role in the effect of the pandemic on the actual purchasing behavior of urban residents toward forest foods, we added interaction terms to the regression using the hierarchical regression method to test whether *per capita*

income has a moderating effect. Since the selected moderating variable is a continuous variable, it was centralized before regression.

As shown in Table 8, the core explanatory variables of forest nuts, forest fruits and vegetables, and forest drinks were all significant, and the estimated coefficients were all positive (forest nuts 0.198***, forest fruits and vegetables 0.200***, forest drinks 0.208***). The estimated coefficients of the interaction terms between the pandemic and *per capita* income were all significantly negative (forest nuts −0.022*, forest fruits and vegetables −0.025**, forest drinks −0.019*); however, the interaction term was not significant for forest medicine (−0.002). The results showed that *per capita* income had a significant negative moderating effect on the relationship between the pandemic and the actual purchasing behavior of urban residents toward three types of forest foods, thereby validating research hypothesis H3 for forest nuts, forest fruits and vegetables, and forest drinks.

TABLE 5 Benchmark regression analysis of the impact of the COVID-19 pandemic on urban residents' willingness to pay for forest food.

Variables	Forest nuts		Forest fruit and vegetables		Forest drinks		Forest medicine	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
COVID-19 pandemic	0.877*** (0.034)	0.628*** (0.036)	0.978*** (0.034)	0.743*** (0.036)	0.994*** (0.033)	0.751*** (0.035)	1.093*** (0.034)	0.856*** (0.036)
Gender		−0.049 (0.031)		−0.051* (0.030)		0.003 (0.031)		−0.019 (0.031)
Age		0.007*** (0.002)		0.007*** (0.002)		0.008*** (0.002)		0.008*** (0.002)
Occupation		−0.019** (0.008)		−0.019** (0.008)		−0.015* (0.008)		−0.016** (0.008)
Marital status		0.082*** (0.030)		0.102*** (0.030)		0.056* (0.030)		0.099*** (0.030)
Household income		0.128*** (0.023)		0.131*** 0.022)		0.076*** (0.023)		0.092*** (0.023)
Health status		0.213*** (0.018)		0.201*** (0.018)		0.211*** (0.018)		0.197*** (0.018)
Health status of the elderly at home		0.019** (0.008)		0.022*** (0.007)		0.028*** (0.008)		0.031*** (0.008)
Health status of children at home		0.003 (0.007)		0.005 (0.007)		−0.002 (0.007)		0.000 (0.007)
Number of WeChat friends		0.033** (0.014)		0.043*** (0.014)		0.043*** (0.014)		0.040*** (0.014)
Level of concern about the epidemic		0.331*** (0.019)		0.319*** (0.019)		0.339*** (0.019)		0.326*** (0.019)
Regional fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
LR chi^2	780.29	1418.77	1285.88	1899.98	1019.93	1664.67	1183.77	1792.95
Pseudo R^2	0.0134	0.0244	0.0223	0.0329	0.0179	0.0292	0.0207	0.0314
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892	13,892	13,892

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

TABLE 6 Benchmark regression analysis of the impact of the COVID-19 pandemic on urban residents' actual purchasing behavior of forest food.

Variable name	Forest nuts		Forest fruit and vegetables		Forest drinks		Forest medicine	
	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4
COVID-19 pandemic	0.419*** (0.029)	0.197*** (0.033)	0.351*** (0.028)	0.197*** (0.033)	0.454*** (0.029)	0.206*** (0.033)	0.440*** (0.030)	0.125*** (0.035)
Gender		0.110*** (0.031)		0.255*** (0.031)		−0.019 (0.031)		−0.381*** (0.034)
Age		0.026*** (0.002)		0.012*** (0.002)		0.018*** (0.002)		0.018*** (0.002)
Occupation		0.020** (0.008)		0.026*** (0.008)		0.026*** (0.008)		−0.003 (0.009)
Educational level		0.255*** (0.028)		0.232*** (0.028)		0.090*** (0.028)		−0.196*** (0.030)
Number of elderly people		−0.052*** (0.013)		−0.091*** (0.013)		−0.046*** (0.013)		0.084*** (0.014)
Number of children		0.004 (0.023)		−0.000 (0.023)		−0.023 (0.023)		−0.102*** (0.025)
Household income		0.412*** (0.028)		0.326*** (0.027)		0.314*** (0.027)		0.192*** (0.030)
Grade of residential district		0.368*** (0.030)		0.282*** (0.030)		0.272*** (0.030)		0.104*** (0.033)
Number of WeChat friends		0.058*** (0.028)		0.031** (0.014)		0.061*** (0.014)		0.018 (0.015)
Level of concern about the epidemic		0.247*** (0.020)		0.165*** (0.020)		0.290*** (0.020)		0.412*** (0.022)
Regional fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
LR chi^2	531.06	1803.3	382.44	1186.21	464.46	1230.99	344.75	1156.64
Pseudo R^2	0.0107	0.0363	0.0073	0.0226	0.0094	0.0249	0.0089	0.0298
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892	13,892	13,892

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

TABLE 7 Stepwise regression results for the mediating effect.

(A)						
	Forest nuts			Forest fruit and vegetables		
Variables	Model 5	Model 6	Model 7	Model 5	Model 6	Model 7
	Willingness to pay	Health cognition	Willingness to pay	Willingness to pay	Health cognition	Willingness to pay
COVID-19 pandemic	0.628*** (0.036)	1.205*** (0.033)	0.372*** (0.037)	0.743*** (0.036)	1.205*** (0.033)	0.480*** (0.037)
Health cognition	-	-	0.771*** (0.027)	-	-	0.812*** (0.027)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
LR chi^2	1418.77	6897.02	2264.18	1899.98	6897.02	2828.61
Pseudo R^2	0.0244	0.0908	0.0390	0.0329	0.0908	0.0490
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

(B)						
	Forest drinks			Forest medicine		
Variables	Model 5	Model 6	Model 7	Model 5	Model 6	Model 7
	Willingness to pay	Health cognition	Willingness to pay	Willingness to pay	Health cognition	Willingness to pay
COVID-19 pandemic	0.751*** (0.035)	1.205*** (0.033)	0.503*** (0.037)	0.856*** (0.036)	1.205*** (0.033)	0.616*** (0.037)
Health cognition	-	-	0.766*** (0.027)	-	-	0.755*** (0.026)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
LR chi^2	1664.67	6897.02	2500.87	1792.95	6897.02	2615.24
Pseudo R^2	0.0292	0.0908	0.0438	0.0314	0.0908	0.0458
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

5.6 Robustness test

5.6.1 Changing regression model

To verify the robustness of the estimated results, we changed the model and employed OLS for regression. As shown in Table 9, Models 11 and 12–13 were robustness tests for Model 2 baseline regression and Model 6–7 mediation effect, respectively. The estimation results were consistent with the previous sections, with core explanatory variables and mediating variables being positively significant at a 1% level. It demonstrated that the model's estimation results were robust.

5.6.2 Altering core dependent variables

The core dependent variables in our study were replaced to test the robustness of the estimation results. According to existing research, the two dimensions of actual purchase behavior were frequency and amount. Therefore, the core dependent variable was replaced with the average annual expenditure on forest foods

by household. As Table 10 showed, Models 14 and 15–16 were robustness tests for Model 4 baseline regression and Models 9–10 moderating effect, respectively. The estimation results were generally consistent with the previous sections. The coefficients of the core explanatory variables were positively significant at a 1% level, while the coefficients of the interaction terms of the moderating variables ere negatively significant at 5% and 10% levels, suggesting that the estimation results of the model are robust.

5.7 Heterogeneity

From the first confirmed case of COVID-19 in Liaoning Province on 22 January 2020, to the introduction of the "10 new measures" prevention and control optimization measures on 7 December 2022, the severity of the pandemic has varied across different cities in Liaoning Province over the span of almost 2 years. We compiled data

TABLE 8 Stepwise regression results for the moderating effect.

(A)						
Variables	Forest nuts			Forest fruit and vegetables		
	Model 8	Model 9	Model 10	Model 8	Model 9	Model 10
COVID-19 pandemic	0.197*** (0.033)	0.198*** (0.033)	0.198*** (0.033)	0.197*** (0.033)	0.199*** (0.033)	0.200*** (0.033)
Specific amount of *per capita* income (center)	-	−0.129*** (0.046)	−0.130*** (0.046)	-	−0.232*** (0.046)	−0.232*** (0.046)
COVID-19 pandemic* Specific amount of *per capita* income (center)	-	-	−0.022* (0.012)	-	-	−0.025** (0.011)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
LR chi^2	1803.30	1811.06	1814.78	1186.21	1211.10	1216.00
Pseudo R^2	0.0363	0.0365	0.0365	0.0226	0.0230	0.0231
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

(B)						
Variables	Forest drinks			Forest medicine		
	Model 8	Model 9	Model 10	Model 8	Model 9	Model 10
COVID-19 pandemic	0.206*** (0.033)	0.208*** (0.033)	0.208*** (0.033)	0.125*** (0.035)	0.126*** (0.035)	0.126*** (0.035)
Specific amount of *per capita* income (center)	-	−0.211*** (0.046)	−0.212*** (0.046)	-	−0.172*** (0.050)	−0.172*** (0.050)
COVID-19 pandemic* Specific amount of *per capita* income (center)	-	-	−0.019* (0.012)	-	-	−0.002 (0.012)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
LR chi^2	1230.99	1251.70	1254.44	1156.64	1168.33	1168.35
Pseudo R^2	0.0249	0.0253	0.0253	0.0298	0.0301	0.0302
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

for the "accumulative number of locally confirmed cases"[4] and "cumulative days with new local cases and asymptomatic local infections"[5] for the 14 cities in Liaoning Province. Based on this data, Dalian, Shenyang, Huludao, Yingkou, and Tieling were categorized as "cities with severe epidemics"; Dandong, Fushun, Chaoyang, and Anshan were classified as "cities with moderate epidemics"; and Jinzhou, Panjin, Benxi, Fuxin, and Liaoyang were defined as "cities with light epidemics."

We further investigated the objective severity of the pandemic's impact on the variations in the actual purchasing behavior of urban residents toward forest foods. As shown in Table 11, after conducting an intergroup test, the results indicated significant disparities in the actual purchasing behavior of urban residents toward various types of forest foods across cities with different severities of the pandemic. Specifically, (1) in cities with severe epidemics, consumers had the highest actual purchase of forest nuts; (2) in cities with severe epidemics, consumers had the highest actual purchase of forest fruits and vegetables; (3) in cities with moderate epidemics, consumers had the highest actual purchase of forest drinks; (4) in cities with mild epidemics, consumers had the highest actual purchase of forest medicines.

6 Discussion and conclusion

This study utilized micro-survey data from 6,946 urban households across 14 cities in Liaoning Province. We employed CVM, Ordered Logit Model, Mediating Effect Model, and

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4 The data on the "cumulative number of locally confirmed cases" in 14 cities in Liaoning Province is sourced from the real-time epidemic big data report (https://voice.baidu.com/act/newpneumonia/newpneumonia/?from=osari_aladin_banner#tab4).

5 The data on the "cumulative number of days with new local cases and local asymptomatic infections" in 14 cities in Liaoning Province is sourced from the Health Commission of each city in Liaoning Province.

TABLE 9 Robustness tests for Benchmark regression and mediated effects changing models.

(A)						
	Forest nuts			Forest fruit and vegetables		
Variables	Model 11	Model 12	Model 13	Model 11	Model 12	Model 13
	Willingness to pay	Health cognition	Willingness to pay	Willingness to pay	Health cognition	Willingness to pay
COVID-19 pandemic	0.479*** (0.033)	0.374*** (0.010)	0.207*** (0.034)	0.528*** (0.033)	0.374*** (0.010)	0.244*** (0.034)
Health cognition	-	-	0.725*** (0.027)	-	-	0.761*** (0.028)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
R-squared	0.0845	0.3919	0.1284	0.1104	0.3919	0.1569
Adj R-squared	0.0828	0.3908	0.1268	0.1088	0.3908	0.1553
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

(B)						
	Forest drinks			Forest medicine		
Variables	Model 11	Model 12	Model 13	Model 11	Model 12	Model 13
	Willingness to pay	Health cognition	Willingness to pay	Willingness to pay	Health cognition	Willingness to pay
COVID-19 pandemic	0.582*** (0.033)	0.374*** (0.010)	0.312*** (0.034)	0.695*** (0.035)	0.374*** (0.010)	0.411*** (0.036)
Health cognition	-	-	0.722*** (0.028)	-	-	0.758*** (0.029)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
R-squared	0.0966	0.3919	0.1387	0.1046	0.3919	0.1464
Adj R-squared	0.0950	0.3908	0.1371	0.1030	0.3908	0.1448
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

Moderating Effect Model to empirically study the impact of the COVID-19 pandemic on the two-stage "intention-behavior" process of urban residents' consumption of forest foods. The study examined the mediating and moderating effects of health cognition and *per capita* income on the impact of the pandemic on urban residents' consumption behavior of forest foods. According to the results of empirical analysis, the research conclusions were drawn and discussed, and finally the policy implications for the development of forest food market were put forward.

6.1 Research conclusion

According to the empirical test results and the theoretical analysis framework established, this paper combs the logical mechanism of urban residents' formation of forest food consumption behavior, and the impact mechanism of health cognition and *per capita* income on the formation of urban residents' consumption behavior, and finally draws four conclusions.

1. The COVID-19 pandemic positively impacts urban residents' consumption of forest foods. By breaking down consumer behavior into "intention-behavior" stages, the empirical results indicated that the onset of the COVID-19 pandemic significantly promoted urban residents' WTP for forest foods and their actual purchasing behavior at a 1% level.
2. The Perception of Health Plays a Mediating Role in the Impact of the Pandemic on Urban Residents' WTP for Forest Foods. Our findings confirmed that health cognition played a positive mediating effect in the impact of the pandemic on urban residents' WTP for forest foods at a 1% level.
3. In the influence of the COVID-19 pandemic on urban residents' purchasing behavior of forest foods, specifically forest nuts, forest fruits and vegetables, and forest drinks, *per capita* income exhibited a significant negative moderating effect. *Per capita* income did not play a moderating role in the impact of the pandemic on urban residents' purchase behavior of forest medicines.

TABLE 10 Robustness tests for Benchmark regression and moderated effects changing variables.

(A)						
	Forest nuts			Forest fruit and vegetables		
Variables	Model 14	Model 15	Model 16	Model 14	Model 15	Model 16
COVID-19 pandemic	0.196*** (0.033)	0.197*** (0.033)	0.197*** (0.033)	0.171*** (0.033)	0.173*** (0.033)	0.174*** (0.033)
Specific amount of *per capita* income (center)	-	−0.188*** (0.048)	−0.188*** (0.048)	-	−0.246*** (0.047)	−0.247*** (0.047)
COVID-19 pandemic* Specific amount of *per capita* income (center)	-	-	−0.022* (0.012)	-	-	−0.025** (0.012)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
LR chi^2	2213.38	2228.98	2232.45	1888.62	1915.57	1920.05
Pseudo R^2	0.0487	0.0491	0.0491	0.0406	0.0413	0.0413
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

(B)						
	Forest drinks			Forest medicine		
Variables	Model 14	Model 15	Model 16	Model 14	Model 15	Model 16
COVID-19 pandemic	0.191*** (0.033)	0.192*** (0.033)	0.192*** (0.033)	0.130*** (0.035)	0.131*** (0.035)	0.131*** (0.035)
Specific amount of *per capita* income (center)	-	−0.217*** (0.048)	−0.217*** (0.048)	-	−0.186*** (0.051)	−0.186*** (0.051)
COVID-19 pandemic* Specific amount of *per capita* income (center)	-	-	−0.027** (0.012)	-	-	0.002 (0.013)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
LR chi^2	1745.86	1766.62	1770.63	1266.50	1280.14	1280.15
Pseudo R^2	0.0399	0.0403	0.0404	0.0330	0.0334	0.0334
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	13,892	13,892	13,892	13,892	13,892	13,892

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

4. Consumption Behavior of Forest Foods among Urban Residents Varies in Cities with Different Pandemic Severity. In cities with severe epidemics, consumers had the highest actual purchase of forest nuts and forest fruits and vegetables; in cities with moderate epidemics, consumers had the highest actual purchase of forest drinks; in cities with mild epidemics, consumers had the highest actual purchase of forest medicines.

6.2 Discussion

6.2.1 The COVID-19 pandemic positively impacts urban residents' consumption of forest foods

The pandemic has driven Chinese consumers' willingness toward green organic food (Ghufran et al., 2022). In the context of forest nuts, our conclusion was consistent with the findings from studies in Spain (Batlle-Bayer et al., 2020), Turkey (Kaya et al., 2021), Iran (Mohajeri et al., 2021), Brazil (Manica-Cattani et al., 2022), suggesting an increase or similarity in nut consumption due to increased anxiety and home time during the pandemic. Regarding forest fruits and vegetables, our findings were consistent with studies from Spain (Batlle-Bayer et al., 2020), Switzerland (Ammann et al., 2022), Iran (Mohajeri et al., 2021), and other countries (Lamy et al., 2022), but contradict those of some scholars, mainly because their studies mainly focus on specific groups such as farmers (Jaacks et al., 2021) and university students (Jehi et al., 2023). In terms of forest drinks, our conclusion aligned with the findings of scholars from Saudi Arabia (Abdullah Alotiby and Naif Al-Harbi, 2021), where consumers improved their immunity and health status through forest drinks like honey during the pandemic. In the case of forest medicines, our conclusions were consistent with existing research indicating that forest medicines such as ginseng and Ganoderma lucidum have potential preventive and therapeutic effects on the COVID-19 pandemic (Yi, 2022), and Chinese consumers choose forest medicines to cope with the pandemic (Zhang and Yi, 2021).

TABLE 11 Heterogeneity regression results of epidemic severity on urban residents' actual purchasing behavior of forest food.

(A)						
	Forest nuts			Forest fruit and vegetables		
	Model 17	Model 18	Model 19	Model 17	Model 18	Model 19
Variables	Cities with heavy epidemics	Cities with generalized epidemics	Cities with less severe epidemics	Cities with heavy epidemics	Cities with generalized epidemics	Cities with less severe epidemics
Core explanatory variables	0.246*** (0.051)	0.216*** (0.067)	0.112** (0.057)	0.222*** (0.050)	0.182*** (0.066)	0.182*** (0.057)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effects	NO	NO	NO	NO	NO	NO
Time fixed effects	YES	YES	YES	YES	YES	YES
LR chi²	778.80	457.02	407.65	448.21	304.82	260.26
Pseudo R²	0.0358	0.0373	0.0262	0.0203	0.0234	0.0159
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	6,108	3,456	4,328	6,108	3,456	4,328

(B)						
	Forest drinks			Forest medicine		
	Model 17	Model 18	Model 19	Model 17	Model 18	Model 19
Variables	Cities with heavy epidemics	Cities with generalized epidemics	Cities with less severe epidemics	Cities with heavy epidemics	Cities with generalized epidemics	Cities with less severe epidemics
Core explanatory variables	0.177*** (0.050)	0.232*** (0.067)	0.228*** (0.057)	0.099* (0.054)	0.137* (0.073)	0.138** (0.061)
Control variables	Control	Control	Control	Control	Control	Control
Regional fixed effects	NO	NO	NO	NO	NO	NO
Time fixed effects	YES	YES	YES	YES	YES	YES
LR chi²	527.34	351.98	244.78	493.99	326.87	310.62
Pseudo R²	0.0241	0.0289	0.0159	0.0292	0.0349	0.0250
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Sample size	6,108	3,456	4,328	6,108	3,456	4,328

*** statistically significant at the 1% level; ** statistically significant at the 5% level; * statistically significant at the 10% level. Standard errors are shown in parentheses.

6.2.2 Individual characteristics, family characteristics, and information stimulus influence urban residents' consumption of forest foods

At the individual characteristic level, the age of the respondents significantly and positively affected both stages of urban residents' consumption behavior, consistent with existing research findings (De Backer et al., 2020). As age increases, consumers paid more attention to their own and family's health management. Young and middle-aged consumers exhibited a higher level of awareness and recognition toward healthy green forest foods than younger individuals.

At the family characteristic level, family income significantly and positively influenced the WTP for forest foods. Higher-income families tended to opt for healthier consumption patterns in food choices, and their WTP for green and healthy forest foods was higher. Although forest foods were traditionally seen as an important food source for low-income groups (Schlesinger et al., 2015; Mollee et al., 2017), existing research shows that wealthier, higher-income consumers also held a positive attitude toward forest foods (Aworh, 2018; Garekae and Shackleton, 2020), and consumed more forest

foods (Darr et al., 2020). Therefore, the variables that represented the family's economic level, such as family income and the level of the residential community where the respondents lived, had a significant and positive impact on the influence of the pandemic on the two-stage consumption behavior of urban residents' forest foods at a 1% level.

At the information stimulus level, the number of WeChat friends and the level of attention to the pandemic are significantly and positively associated with both stages of urban residents' consumption behavior. Consumers who had a broader understanding of the pandemic and forest foods, as well as access to more information, were more aware of the irreplaceable nutritional value of forest foods. Consequently, they demonstrated a higher WTP and engaged in a higher actual purchase behavior.

Notably, as WTP represented subjective consciousness and actual purchasing behavior reflects objective actions, adjustments were made in selecting control variables. The regression results revealed significant and positive relationships between respondents' health conditions, as well as the health status of elderly individuals in their homes, and urban residents' WTP for forest foods. A consumer's health condition greatly influenced

their food consumption choices and preferences, and the attention given to the health of elderly individuals by their children may also promote a family's WTP for high-quality forest foods. Moreover, the number of family members was found to have a significant and positive relationship with the actual purchasing behavior of urban residents for forest foods, while the number of elderly individuals and children in the household had a significant and negative relationship. As elderly individuals were typically not the primary purchasers in family consumption, the smaller the number of elderly individuals, the stronger the actual purchasing behavior of urban households for forest foods. Interestingly, the number of elderly individuals in the home positively impacted the actual purchasing behavior of urban residents for forest medicines. It suggested that, considering the health status of elderly individuals at home, urban households with more elderly individuals tended to purchase more nourishing forest medicines.

6.2.3 The perception of health plays a mediating role in the impact of the pandemic on urban residents' WTP for forest foods

The sudden onset of the COVID-19 pandemic has led to an overall increase in urban residents' health cognition. Correspondingly, consumers' WTP for healthy, eco-friendly forest foods has also risen in their everyday food choices. The COVID-19 pandemic has altered people's consumption habits (KANTAR TNS, 2020), with consumers showing more interest in food that contributes to maintaining good physical and mental health and higher demand and consumption (Molina-Montes et al., 2021). Our findings also confirmed that health cognition played a positive mediating effect in the impact of the pandemic on urban residents' WTP for forest foods at a 1% level. The impact of the COVID-19 pandemic on urban residents' WTP for forest foods was partially attributed to its influence on consumers' health cognition. Health is the primary factor in people's food choices (Meiselman, 2022). Although consensus has not been reached, numerous studies also showed that people's diets have become healthier during the pandemic (Scott and Ensaff, 2022), and consumers' WTP for healthy foods has increased (Hesham et al., 2021). In the process of food consumption, the importance of health was typically prioritized (Ben Hassen et al., 2020; Clark et al., 2020). Consumers who valued health cognition and sustainable development tended to purchase forest foods (Chamberlain et al., 2020).

6.2.4 *Per capita* income has a moderating effect on the impact of the pandemic on urban residents' actual purchase behavior of forest foods

In the influence of the COVID-19 pandemic on urban residents' purchasing behavior of forest foods, specifically forest nuts, forest fruits and vegetables, and forest drinks, *per capita* income exhibited a significant negative moderating effect. The economic recession caused by the pandemic has increased financial pressure (Carroll et al., 2020), reduced household income (Qian and Fan, 2020), and lowered purchasing power for food (Ben Hassen et al., 2020; Hirvonen et al., 2021), affecting food consumption (Ben Hassen et al., 2020).

Per capita income did not play a moderating role in the impact of the pandemic on urban residents' purchase behavior of forest medicines. From the consumer's perspective, expensive

forest medicines were typically consumed by high-income families, which represented a smaller proportion of society and are less affected by the pandemic (Carroll et al., 2020; Mandal et al., 2021). High-income families may have more ways to buffer economic shocks (Pfeffer et al., 2013) and are less likely to engage in panic buying during the pandemic (Kassas and Nayga, 2021), thus resulting in a non-significant moderating effect of *per capita* income on the impact of the pandemic on urban residents' actual purchase behavior of forest medicines. From the perspective of the commodities, forest medicines such as ginseng and Ganoderma lucidum are considered luxury goods, and they experience greater price fluctuations during the pandemic compared to other commodities. This abnormal price volatility may also contribute to the non-significant moderating effect of *per capita* income on the impact of the pandemic on urban residents' actual purchase behavior of forest medicines.

6.2.5 Consumption behavior of forest foods among urban residents varies in cities with different pandemic severity

In cities heavily impacted by the pandemic, residents spent more time at home due to strict movement restrictions. To cope with the psychological stress and pass the time (Torales et al., 2020; Fiorenzato et al., 2021), there was a growing demand for recreational foods like forest nuts (Carroll et al., 2020). In fact, the purchasing behavior for forest nuts was twice as high in heavily affected cities compared to mildly affected cities. Furthermore, urban residents tried to minimize visits to public shopping places for safety reasons (Ferreira Rodrigues et al., 2021; Hesham et al., 2021) and opted for stockpiling consumption (Fanelli, 2021). Forest fruits and vegetables, like mushrooms and wood ears, were preferred as they had a longer shelf life and were easier to preserve. Additionally, the increase in time spent at home during the pandemic led to a rise in homemade meals (Ferreira Rodrigues et al., 2021) and increased involvement in home cooking (Molina-Montes et al., 2021). As a result, the actual purchasing behavior for forest fruits and vegetables was highest in heavily affected cities. Residents in moderately affected cities showed the highest actual purchasing behavior for forest drinks. They recognized the health benefits of such drinks and did not underestimate their value like residents in mildly affected cities. Moreover, they did not face significant dining restrictions like those in heavily affected cities. Finally, residents in heavily affected cities faced a higher risk of falling ill and requiring medical assistance. On the other hand, residents in other cities chose to stockpile and purchase forest medicines as a precautionary measure after obtaining pandemic-related information. Therefore, the actual purchasing behavior for forest medicines was highest in mildly affected cities.

6.3 Limitations

Due to the sudden outbreak of the pandemic and the unplanned nature of the lockdowns, this study could not assess participants' consumption of forest foods before the pandemic. Therefore, it had to rely on their subjective recollection of changes in behavior. This kind of uncertainty will lead to the problems of such as omitted variables and recall bias.

To control the spread of the epidemic, China has adopted a strict lockdown policy. As a result, this paper could not obtain data through

field investigation, so the final formal investigation was completed through the online circle of friends. Although there are many inconveniences, the sample quality is still strictly controlled in the process of issuing questionnaires to make up for the defects in data acquisition in this paper.

6.4 Innovation

1. In recent years, most of the studies on forest food focus on the influencing factors, and there is a lack of empirical studies using micro-survey data. Based on the micro-survey data of 6,946 families in 14 cities of Liaoning Province, this paper uses the ordered Logit model, the intermediary effect model and the regulatory effect model to conduct further empirical research. In addition, the robustness test and heterogeneity analysis were used to expand it.

2. Most of the existing literatures studied the contribution of forest food in nutritional diet by studying the consumption differences between forest food and meat, fish and other foods. However, there are many kinds of forest food, and few literatures explored the differences in urban residents' willingness to pay for different kinds of forest food and their actual purchasing behaviors. Therefore, on the basis of existing research, forest food is divided into four categories: forest nuts, forest fruits and vegetables, forest drinks and forest drugs, and the differences of urban residents' consumption behaviors of different kinds of forest food are explored, respectively.

3. Healthy and green forest food consumption is an important part in the field of food consumption in the society where health awareness is generally enhanced. However, there are few studies on forest food consumption in China in recent years. The "all-encompassing approach to food "advocated by the Chinese government and the sudden COVID-19 epidemic in 2019 provide an important background for the study of forest food consumption. In this special context, this paper explores the mechanism of the epidemic on the forest food consumption behavior of urban residents, so as to provide a theoretical basis for the future development of forest food industry.

4. There have been scholars in the field of epidemic and food consumption related research, but the research on the internal mechanism of this process is relatively shallow. This paper uses the Health Belief Model (HBM) and the mediating variable— health cognition and the moderating variable—*per capita* income to analyze and confirm the mechanism transmission process between the COVID-19 epidemic and food consumption from theoretical and empirical perspectives, respectively.

7 Policy implications

7.1 Establish development plans, provide policy support

As a crucial food resource in the all-encompassing approach to food, forest foods have a wide market prospect and development value.

It is important to extend the industrial chain of forest foods and enhance their high added value. Therefore, the government should formulate development plans for forest foods, scientifically and rationally layout its development area and scale, provide funding subsidies and other policy support for the development of forest food enterprises. Furthermore, creating a good business platform and entrepreneurial atmosphere will facilitate the growth of forest food enterprises.

7.2 Expand food range, support resource utilization

Under the guiding principle of an all-encompassing approach to food, the government should broaden the scope of agricultural policies to include a wider range of food categories. Specifically, increased support for nutritionally-rich and healthy foods, such as forest nuts and forest fruits and vegetables, will help diversify the food supply and cater to the changing dietary preferences of the population. Additionally, the government should prioritize the development and utilization of various food resources, invest in infrastructure, and explore the untapped potential of food production resources, including those found in forests.

7.3 Innovative marketing strategies, ensure food safety

In the context of rapid economic development and growing awareness of ecological and green development principles, forest foods have emerged as safe and high-quality food options with significant economic, ecological, and social benefits. They hold immense potential in the food market. As such, businesses should recognize the crucial role of forest foods in ensuring food safety and use it as a key marketing strategy. This will stimulate consumer interest and encourage spontaneous purchasing behavior, while also fostering a sense of responsibility toward protecting forest ecology.

7.4 Enhance propaganda efforts, improve product recognition

Cognition is closely linked to willingness. However, the limited availability of information channels and the lack of consumer awareness pose significant challenges to the development of the forest food market. Therefore, businesses should adopt various communication strategies to educate consumers about forest foods. This should include highlighting the unique growing conditions, irreplaceable nutritional value, and environmentally-friendly production processes employed by companies, aiming to enhance consumer recognition of the distinctiveness and healthiness of forest foods.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

SL: Writing – original draft. DH: Writing – review & editing. KC: Writing – review & editing.

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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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