Research on Modular Wooden Tea Packaging Design Based on Kano-AHP-QFD

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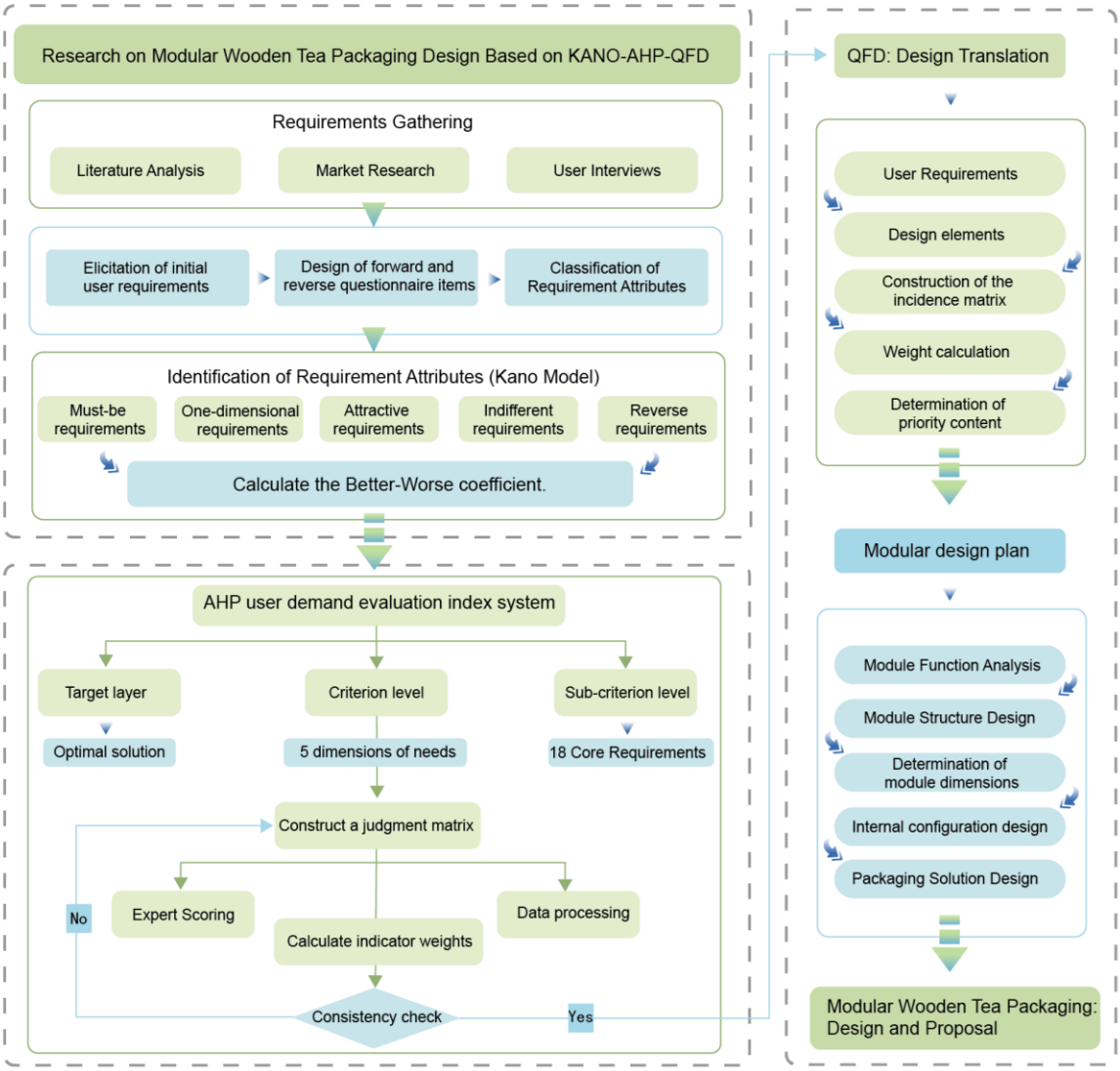
GRAPHICAL ABSTRACT



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Yue Yi [a,*] and Shanshan Huang [b]

As green consumption and the tea gift market continue to develop, tea packaging is shifting from basic protection toward improved user experience and sustainable use. To address the limited structural utilization and low modularity of existing wooden tea packaging, this study developed a user-needs-driven design approach integrating Kano, AHP, and QFD. User requirements were identified through questionnaires and interviews and classified using the Kano model. AHP was then applied to determine the priorities of requirements, and QFD was used to translate key requirements into design attributes. The results showed that independent module disassembly and reconfiguration, stable connections, adjustable internal space, and post-gifting conversion into everyday storage were high-priority requirements. QFD further identified the interlocking grid structure, multifunctional storage structure, structural stability design, modular dimensional adaptability, and lightweight material reduction as the five highest-ranked design attributes, with relative weights of 21.35, 16.67, 11.35, 11.31, and 10.67, respectively. Based on these findings, a modular wooden tea packaging solution with detachable, replaceable components was developed to enable flexible reconfiguration and functional extension. This study provides a systematic reference for user-needs-driven modular wooden packaging design.

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Keywords: Wooden packaging design; Modular design; Kano model; Analytic Hierarchy Process (AHP); Quality Function Deployment (QFD)

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INTRODUCTION

Against the growing momentum of the circular economy and sustainable consumption, packaging design is shifting from linear use-and-disposal models toward material reduction, reuse, disassembly, and recyclability (Zhu *et al.* 2022). Tea packaging must satisfy multiple requirements, including product protection, dimensional adaptability, ease of use, visual expression, and post-use management. Wood offers favorable structural strength, natural texture, and long-term durability, making it suitable for mid- to high-end tea packaging. However, conventional wooden tea gift boxes often rely on fixed structures and predetermined internal partitions, limiting dimensional adaptability, component reconfiguration, and post-use functionality. Modular design provides a potential solution by using relatively independent functional units and standardized interfaces to support component combination, disassembly, replacement, and reconfiguration, thereby improving adaptability and extending product service life (Sonego *et al.* 2018). Applying these principles to wooden tea packaging can therefore enhance spatial flexibility,

component reuse, and post-use value while maintaining the essential functions of product protection and gift-giving.

Existing studies have explored sustainable packaging, wooden packaging, modular design, and tea packaging from different perspectives. In sustainable packaging research, attention has focused mainly on material efficiency, logistics optimization, environmental assessment, and reverse-loop systems, while the relationship between packaging design and user behavior remains relatively underexplored (Silva and Pålsson 2022). In the field of wooden packaging, studies have further integrated life cycle assessment, life cycle costing, and circularity indicators to compare single-use wooden crates, corrugated cardboard boxes, and reusable plastic containers. These findings indicate that the renewability of a packaging material alone does not determine its overall sustainability performance (Rasines *et al.* 2024). Other studies have integrated regional cultural symbols, wood characteristics, and multi-criteria decision-making methods in Yunnan coffee packaging, providing a more systematic basis for evaluating wooden packaging and comparing cultural expression and visual appeal (Zhang and Jiang 2026). In modular design, shared components and expandable functions have been used to reduce complete product replacement and resource consumption (Mesa *et al.* 2021). In tea packaging research, Kansei engineering, the semantic differential method, and eye-tracking experiments have been applied to quantify consumers' perceptions of visual elements such as color, graphics, and composition (Wang *et al.* 2024).

Despite these advances in environmental assessment, material comparison, user perception, modular design, and requirement-based decision making, these research directions remain relatively fragmented. Based on the research gaps identified above, this study focuses on three core research questions. First, it seeks to identify the major user requirements for modular wooden tea packaging and to examine how different requirements affect user satisfaction. Second, it aims to determine the relative priorities of the core user requirements and further translate them into actionable design attributes. Third, it investigates how the prioritized user requirements and design attributes can be implemented in a specific modular wooden tea packaging solution and preliminarily evaluated by users and experts. On this basis, three corresponding research objectives were established: (i) to establish a user requirement framework for modular wooden tea packaging and apply the Kano model to classify requirement attributes and assess their effects on user satisfaction; (ii) to use AHP to calculate the weights of user requirements and determine their priorities; and (iii) to employ QFD to translate prioritized user requirements into key design attributes and develop a modular wooden tea packaging solution accordingly.

This study adopted a user-needs-oriented approach by integrating Kano, AHP, and QFD into modular wooden tea packaging design. First, user requirements were collected through a literature review, market research, and user interviews on component replaceability and maintainability. The collected information was screened, merged, and categorized into five requirement categories and 22 user requirement indicators. Based on these indicators, a paired functional and dysfunctional Kano questionnaire was developed. A total of 160 questionnaires were distributed online, mainly through the Wenjuanxing platform, with participants recruited from WeChat groups, tea consumer communities, and design-related professional networks. After data screening, 155 valid responses were retained. Questionnaires with unusually short completion times, extensive consecutive identical responses, missing key items, obvious response inconsistencies, or duplicate submissions were excluded. The Kano model was then used to classify requirement

attributes, and the Better and Worse coefficients were calculated to assess their effects on user satisfaction and dissatisfaction. Based on the Kano results, four Indifferent requirements were excluded, leaving 18 core user requirements for further analysis. An AHP evaluation was then conducted with 10 experts, including 3 packaging designers, 2 wood-processing professionals, 2 tea industry practitioners, and 3 product design researchers. Judgment matrices were constructed and subjected to consistency testing to determine the relative importance and priority of the 18 core user requirements. Subsequently, QFD was applied to translate and consolidate these requirements into 11 key design attributes and determine their priorities. Finally, a modular wooden tea packaging design solution was developed based on the integrated Kano–AHP–QFD results.

Literature Review

Modular packaging design

Driven by green and low-carbon development and sustainable consumption, packaging design is gradually shifting from single-use models toward material reduction, circularity, and more efficient resource utilization. Packaging appearance and environmental information can influence consumers' perceptions of sustainability and, in turn, their purchase intentions (Magnier and Schoormans 2015). These perceptions are also shaped by factors such as circular-economy attributes, the appearance of natural materials, and overall design features (Otto *et al.* 2021). Wood offers high toughness, low density, low thermal conductivity, and favorable mechanical properties, giving it considerable potential for packaging applications (Chutturi *et al.* 2023). Its hierarchical structure provides elasticity, compressibility, and structural recovery, supporting detachable, reconfigurable, and cushioning structures (Fu *et al.* 2025). However, hygroscopicity, swelling-induced deformation, and surface protection remain important considerations in wooden packaging design (Yu *et al.* 2020).

Research on packaging modularity is gradually shifting from fixed box structures toward systematic approaches based on functional decomposition, module configuration, and adaptation to multiple use scenarios. Standardized modular dimensions can improve the combination of packaging units, enhance pallet and transport-space utilization, and support handling, storage, and automated operations (Garcia-Arca *et al.* 2020). Replaceable modular inserts further allow the same outer packaging to accommodate products of different forms and dimensions and to be reconfigured for display functions, extending packaging modules beyond the outer box to inserts, handles, and display components (Pogacar and Gregor-Svetec 2025). Studies in other product domains also provide useful references for modular design. Functional decomposition into independently usable and reconfigurable units highlights the importance of functional independence, interface relationships, operational convenience, and adaptability across usage scenarios (Guo *et al.* 2026). Translating barriers encountered during use into structural and functional criteria further emphasizes the role of user behavior and usage contexts in module configuration (Yao *et al.* 2026). In wooden product design, modular structures composed of rotatable wooden components and connecting shafts demonstrate the potential of modular decomposition for functional reconfiguration and local replacement (Fan and Wang 2026). More broadly, the design of wooden modules and components requires the integrated consideration of user requirements, material-processing characteristics, structural configuration, and functional validation (Wu *et al.* 2026).

Overall, existing studies have advanced modular design through functional decomposition, module combination, product configuration, and design validation, providing a methodological basis for packaging structure development. However, research specifically addressing modular wooden tea packaging remains limited. In particular, insufficient attention has been paid to dimensional adaptability, internal spatial configuration, standardized connection mechanisms, sealing and protection, and post-use functional transformation. Existing studies have also rarely examined how these structural issues can be systematically linked to user requirements. Therefore, further research is needed to establish a user-needs-oriented basis for the structural configuration and functional extension of modular wooden tea packaging.

User-needs-oriented research in packaging design

Accurately identifying user requirements is essential for effective packaging design, and consumer perception research provides an important basis for optimizing packaging form, color, and information presentation. Packaging form can influence perceptions of brand positioning and product choice, with elongated forms more likely to be associated with premium brands (Chen *et al.* 2020). Packaging color can also affect consumers' evaluations of food pleasantness and attractiveness (van Esch *et al.* 2019). Hue and saturation may shape expectations of coffee sweetness, bitterness, aroma, roast level, and overall liking (Carvalho *et al.* 2025). In tea packaging design, user affective requirements can be organized through the affinity diagram method and further translated into design attributes using preference ranking and QFD, providing a systematic pathway from user requirements to packaging structure and form (Fang and Qu 2025).

User-needs-oriented design is shifting from isolated preference evaluation toward systematic processes integrating requirement identification, prioritization, and design translation. In smart packaging development, data-driven frameworks can integrate the needs of consumers, producers, and logistics stakeholders, and the QFD method can be used to link user requirements with engineering characteristics (Camilleri *et al.* 2025). Related product design studies have combined F-Kano for requirement classification, DEMATEL for relationship analysis, and QFD for functional translation, establishing a continuous pathway from requirement identification to design implementation (Wen *et al.* 2025). Other integrated approaches combining Kansei engineering, AHP, the coefficient of variation method, coupling coordination analysis, and GA-BP neural networks further reveal complex relationships between user perceptions and product form (Ren *et al.* 2026). Together, these studies highlight the complementary value of multiple methods in user requirement analysis and design translation.

Overall, existing studies have provided a solid methodological basis for consumer perception analysis, requirement classification, importance evaluation, and design attribute extraction. However, tea packaging research still focuses mainly on visual and perceptual aspects, with limited attention to modular configuration, connection mechanisms, dimensional adaptability, and post-use functional transformation. In addition, user-needs-oriented studies often address requirement identification, prioritization, and design translation as separate stages, resulting in an incomplete link between user research and design implementation. Although multi-method approaches have been applied in other product fields, their use in modular wooden packaging remains limited. Therefore, this study integrates Kano, AHP, and QFD methods to establish a continuous process from requirement classification and prioritization to design attribute translation and

implementation, thereby strengthening the connection between user requirements and the final design solution.

EXPERIMENTAL

Research Framework

This study developed a Kano–AHP–QFD-based framework for modular wooden tea packaging, covering user requirement identification, prioritization, design translation, and solution development. Kano was used to classify requirements according to their asymmetric effects on user satisfaction, AHP was used to quantify the relative importance of the retained core requirements, and QFD was used to translate prioritized requirements into actionable design attributes. Together, the three methods form a continuous process from requirement classification and prioritization to design translation and implementation, addressing the limitations of any single method. The research process consists of three stages: (1) user requirement elicitation and construction of the requirement framework; (2) identification of requirement attributes and determination of requirement priorities; and (3) extraction of design attributes and development of the final design solution (Fig. 1).

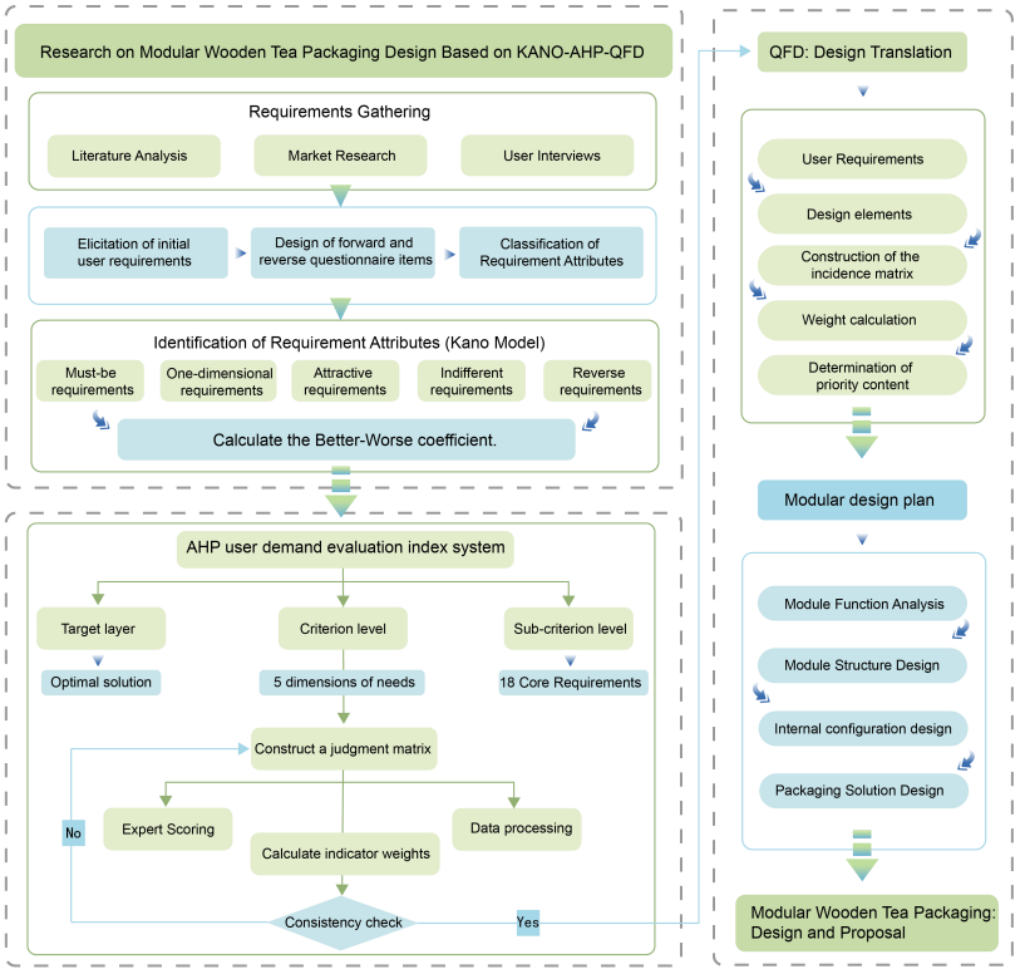

Fig. 1. Overall flow chart of the study

Relevant literature was reviewed, followed by semi-structured interviews with tea consumers, industry practitioners, wood-processing professionals, and packaging designers. The interviews focused on functional, structural, usability, visual, and extended-use requirements for wooden tea packaging. The collected information was then screened, merged, and refined, with redundant items removed, resulting in a structured user requirement framework for modular wooden tea packaging.

A paired functional and dysfunctional Kano questionnaire was developed based on the established user requirement indicators to classify requirement attributes. The Better and Worse coefficients were then calculated to evaluate the effects of requirement fulfillment and non-fulfillment on user satisfaction. Subsequently, AHP was used to construct a hierarchical structure and determine the relative weights of the requirements. By integrating the Kano classifications, Better–Worse coefficients, and AHP weights, the core user requirements requiring priority consideration in modular wooden tea packaging design were identified.

The prioritized user requirements were incorporated into the QFD House of Quality to analyze their relationships with specific design attributes and identify those requiring priority attention. Based on the QFD results, key principles for module definition, structural configuration, and detailed design were established, leading to the development of a modular wooden tea packaging solution.

Kano Model

The Kano model, proposed by Noriaki Kano in 1984 (Fig. 2), classifies user requirements into five categories—Must-be, One-dimensional, Attractive, Indifferent, and Reverse—by comparing users' responses to the presence and absence of specific product attributes. This classification helps distinguish fundamental requirements, performance-related requirements, and attractive requirements that may contribute to product differentiation and innovation (Huang and Cui 2026). In this study, the Kano model was applied to classify user requirements for modular wooden tea packaging and evaluate their effects on user satisfaction, thereby identifying fundamental requirements, priority improvement requirements, and latent requirements with the potential to enhance satisfaction.

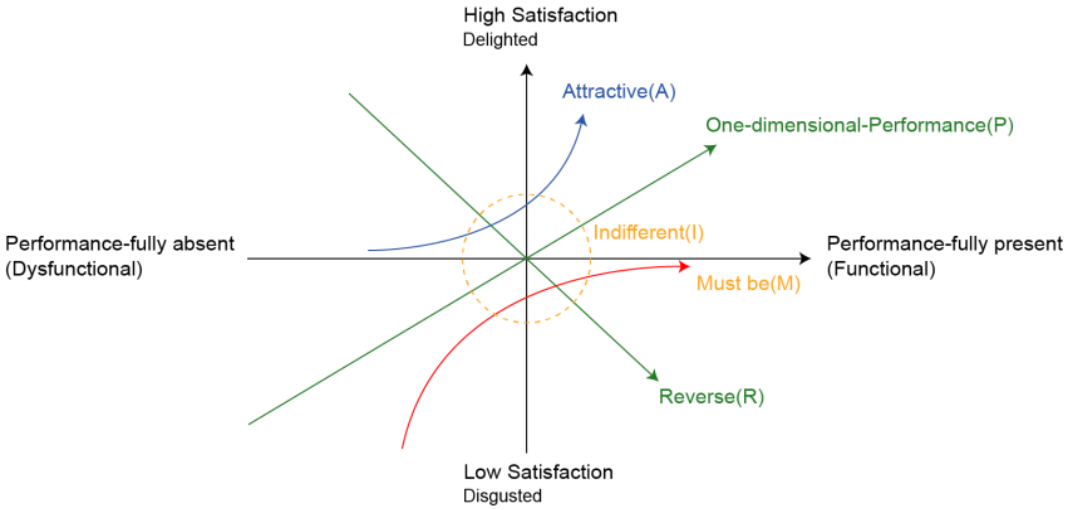

Fig. 2. Kano model

Based on the literature review, user interviews, and questionnaire results, the collected information was screened, merged, and synthesized into 22 user requirements across five dimensions.

For each requirement, paired functional and dysfunctional questions were used to collect user responses. The resulting response combinations were then mapped to the Kano evaluation matrix (Table 1) to determine the corresponding requirement category.

Table 1. Kano Evaluation Criteria

User Demand		Negative Question				
		Like	Expect	Neutral	Tolerate	Dislike
Positive Question	Like	Q	A	A	A	O
	Expect	R	I	I	I	M
	Neutral	R	I	I	I	M
	Tolerate	R	I	I	I	M
	Dislike	R	R	R	R	Q

Note: Must-be requirements (M), One-dimensional requirements (O), Attractive requirements(A), Indifferent requirements (I), Reverse requirements (R), Questionable results (Q)

Based on the distribution of the Kano requirement categories, the Better–Worse coefficients were calculated to quantify the effects of requirement fulfillment and non-fulfillment on user satisfaction. The Better coefficient indicates the extent to which fulfilling a requirement increases satisfaction, whereas the Worse coefficient reflects the extent to which its non-fulfillment increases dissatisfaction. The coefficients were calculated as follows,

$$Better = \frac{A+O}{A+O+M+I} \quad (1)$$

$$Worse = -\frac{O+M}{A+O+M+I} \quad (2)$$

where A is Attractive requirements, O is one-dimensional requirements, M is Must-be requirements, and I is Indifferent requirements.

Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a multi-criteria decision-making method that decomposes complex decision problems into hierarchical levels and determines factor weights through pairwise comparisons. Consistency testing is then used to assess the reliability of the judgments. In this study, AHP was applied to determine the relative importance and priority of user requirements for modular wooden tea packaging, providing a quantitative basis for subsequent design decisions (Wang *et al.* 2025).

Based on the preliminary user requirement investigation and Kano analysis, the user requirements for modular wooden tea packaging were organized into a three-level hierarchy comprising the goal level (A), criterion level (B), and indicator level (C).

An expert panel of ten members was invited to conduct pairwise comparisons of the user requirements within each hierarchical level. Each expert independently assessed

the relative importance of the requirement indicators based on professional experience and their understanding of the design requirements. The individual judgment matrices provided by the ten experts were aggregated element-wise using the geometric mean method to obtain a group judgment matrix. The aggregated judgment matrix was subsequently used for weight calculation and consistency testing. A 1–9 fundamental scale and its reciprocals were used to express the relative importance between pairs of user requirements (Table 2).

Table 2. 1–9 Scale for Pairwise Comparisons

Scale Value	Meaning
1	Two factors are equally important
3	Factor i is slightly more important than factor j
5	Factor i is significantly more important than factor j
7	Factor i is strongly more important than factor j
9	Factor i is absolutely more important than factor j
2, 4, 6, 8	Intermediate values between adjacent scale values

Based on the constructed judgment matrix, the geometric mean method was applied. For each row of the judgment matrix, the product of all matrix elements was calculated (Wang *et al.* 2025) as follows,

$$M_i = \prod_{j=1}^{m} b_{ij} \quad (i = 1, 2, \ldots, m) \tag{3}$$

where b_{ij} denotes the element in the ith row and jth column of the judgment matrix, and m represents the number of evaluation criteria.

The geometric mean of each row was calculated from the product of its elements and used as the initial, unnormalized weight of the corresponding user requirement, as follows,

$$a_i = \sqrt[m]{M_i} \quad (i = 1, 2, \ldots, m) \tag{4}$$

where m denotes the number of rows in the judgment matrix.

To obtain the relative weight of each user requirement, the geometric means calculated in the previous step were normalized as shown in Eq. 5.

$$w_i = \frac{a_a}{\sum_{i=1}^{m} a_i} \tag{5}$$

To assess the consistency of the judgment matrix, the maximum eigenvalue λ_{max}, was calculated based on the normalized weight vector (W_i) as follows,

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{B_{w_i}}{w_i} \tag{6}$$

where B_{wi} denotes the ith component of the product of the judgment matrix and the weight vector, and n represents the number of evaluation items.

To verify the consistency and reliability of the judgment matrix, a consistency test was conducted according to Eq. 7,

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{7}$$

where CI indicates the consistency index, λ_{max} denotes the maximum eigenvalue of the judgment matrix, and (n) denotes the order of the matrix.

Finally, the consistency ratio (*CR*) was calculated to determine whether the judgment matrix exhibited an acceptable level of consistency, as follows,

$$CR = \frac{CI}{RI} \tag{8}$$

where *RI* denotes the random consistency index, whose value is determined by the order *n* of the judgment matrix (Table 3), and *CR* denotes the consistency ratio. When ($CR<0.1$), the judgment matrix is considered to have an acceptable level of consistency. When ($CR\geq0.1$), the consistency of the judgments is considered insufficient, and the judgment matrix should be re-examined and adjusted until the consistency requirement is satisfied.

Table 3. Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.51	1.54

Quality Function Deployment

Quality Function Deployment (QFD) is a user-needs-oriented product development method that uses the House of Quality (HoQ) to establish relationships between user requirements and design characteristics. It enables user needs to be translated into actionable design attributes and helps identify those requiring priority optimization (Wang *et al.* 2024). In this study, a House of Quality (HoQ) matrix was constructed to analyze the relationships between core user requirements and corresponding design attributes, determine their priorities, and support design solution development (Fig. 3). The specific procedures were as follows:

To construct the decision matrix, the core user requirements and their integrated weights were incorporated into the left-hand section of the HoQ.

The core user requirements were translated into corresponding design attributes. Based on the predefined relationship-strength scale (Table 4), the relationships between user requirements and design attributes were quantitatively evaluated to construct the central matrix of the HoQ.

Table 4. Corresponding Valuation of User Needs and Design Indicators

Correlation Strength	Strong Correlation	Moderate Correlation	Weak Correlation	No Correlation
Symbol	●	◎	▲	
Score	5	3	1	0

Next, the interrelationships among design attributes were evaluated. In the roof section of the House of Quality, "+" and "–" were used to indicate positive and negative correlations, respectively, among the design attributes.

The absolute weight (W_j) and relative weight (W_k) of each design attribute were calculated as follows,

$$W_j = \sum_{i=1}^{q} W_i P_{ij} \tag{9}$$

$$W_k = \frac{W_j}{\sum_{i=1}^{q} W_j} \tag{10}$$

where W_j denotes the absolute weight of the design attribute, W_i denotes the integrated weight of the user requirement, P_{ij} denotes the relationship coefficient between the i^{th} user requirement and the j^{th} design attribute, and W_k denotes the relative weight of the design attribute.

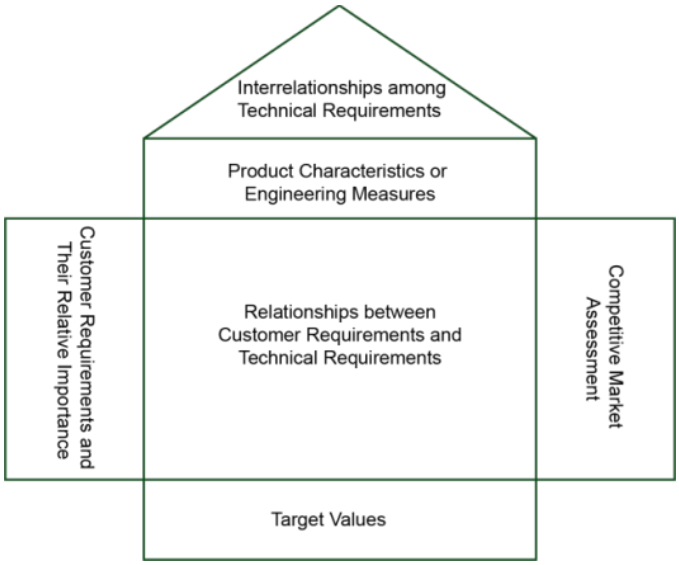

Fig. 3. House of quality

RESULTS AND DISCUSSION

User Requirement Elicitation

This study first conducted a literature review and market case analysis to identify requirements related to tea packaging, wooden packaging, modular packaging, and repeated use. The review focused on dimensional adaptability, module configuration, and wood-material characteristics. In parallel, ten representative wooden tea packaging products were analyzed to identify common limitations, including fixed structures, insufficient dimensional compatibility, difficulty in component replacement, and limited post-use functionality.

Based on the above analysis, semi-structured interviews were conducted with 20 consumers, five tea industry practitioners, six packaging designers, and two wood-processing professionals. Consumers provided information on product use, gift-giving, storage, and post-use needs; industry practitioners contributed packaging application perspectives; designers focused on structure, usability, and visual design; and wood-processing professionals provided input on material processing and structural implementation. Information from the literature review, market cases, and interviews was consolidated into concise requirement statements. Irrelevant, ambiguous, incomplete, and repetitive content was removed, while semantically similar requirements were merged and distinct requirements were retained. The resulting requirements were grouped into five dimensions—functional, structural, aesthetic, environmental, and reuse—and their wording was standardized. This process resulted in five primary dimensions and 22 secondary requirement indicators, which were used to develop the paired functional and dysfunctional Kano questionnaire (Table 5).

Table 5. Results of the Demand Analysis for Modular Tea Packaging

Dimension	Code	Initial User Requirement
Functional Requirements (A)	A1	The packaging provides effective sealing and moisture protection.
	A2	The wooden box provides good structural stability.
	A3	The tea packaging is easy to open and allows convenient access to and removal of the contents.
	A4	The packaging is convenient to carry and handle.
Structural Requirements (B)	B1	The internal space can be adjusted according to product dimensions.
	B2	Packaging modules can be independently disassembled and reconfigured.
	B3	The modules employ standardized and stable connection mechanisms.
	B4	The same packaging provides at least two opening methods.
Aesthetic Requirements (C)	C1	The packaging reflects the natural grain and texture of wood.
	C2	The packaging conveys a sense of quality and suitability for gift-giving.
	C3	The visual form reflects characteristics of tea culture.
	C4	The packaging allows personalized engraving or customized patterns.
	C5	The packaging incorporates engraving and elaborate decorative elements.
Environmental Requirements (D)	D1	The wooden material is safe and does not adversely affect tea quality.
	D2	Material use is reduced while maintaining adequate protective performance.
	D3	The combined use of wood and other materials is minimized.
	D4	Packaging components are easy to disassemble, sort, and recycle.
	D5	The packaging surface provides information on environmental concepts or circular-use guidance.
Reuse Requirements (E)	E1	After gift-giving, the packaging can be converted into an everyday storage product.
	E2	The packaging can be repeatedly refilled with tea.
	E3	The packaging can be disassembled during storage or transportation to reduce space occupation.
	E4	After use, the packaging can be converted into a desktop decorative object.

User Requirement Analysis Based on the Kano Model

To further identify the effects of different requirements on user satisfaction, a paired functional and dysfunctional Kano questionnaire was developed based on the 22 user requirements identified in the preceding stage. The functional questions were used to assess users' attitudes when a specific product attribute was present, whereas the dysfunctional questions assessed their attitudes when that attribute was absent (Table 6). Each question provided five response options: "Like," "Must-be," "Neutral," "Tolerate," and "Dislike," The questionnaire consisted of two sections: respondents' demographic information and requirement evaluation. The requirement evaluation section contained 22 pairs of functional and dysfunctional questions, comprising a total of 44 items.

Table 6. Kano Questionnaire Example

No.	Item	Like	Expect	Neutral	Tolerate	Dislike
1	Provides sealing and moisture protection.	○	○	○	○	○
2	Does not provide sealing and moisture protection.	○	○	○	○	○

Table 7. Results of the Questionnaire Survey Based on the Kano Model

Indicator	Requirement Category						Attribute	Better Coefficient	Worse Coefficient
	A	O	M	I	R	Q			
A1	22	37	67	23	6	0	M	0.399	−0.703
A2	18	43	65	21	8	0	M	0.418	−0.740
A3	25	65	38	20	7	0	O	0.621	−0.710
A4	30	60	33	27	5	0	O	0.608	−0.628
B1	29	64	37	19	6	0	O	0.641	−0.697
B2	29	62	36	20	8	0	O	0.628	−0.676
B3	22	35	69	20	9	0	M	0.393	−0.717
B4	25	22	17	85	6	0	I	0.318	−0.264
C1	30	60	34	23	7	1	O	0.621	−0.648
C2	28	61	31	28	7	0	O	0.610	−0.630
C3	31	60	32	24	6	2	O	0.628	−0.634
C4	66	36	18	31	4	0	A	0.689	−0.365
C5	23	18	15	97	2	0	I	0.275	−0.221
D1	18	35	70	24	8	0	M	0.361	−0.714
D2	28	64	32	23	8	0	O	0.634	−0.662
D3	25	55	40	29	6	0	O	0.548	−0.651
D4	66	40	14	30	5	0	A	0.726	−0.370
D5	24	22	17	84	8	0	I	0.322	−0.273
E1	67	35	18	28	7	0	A	0.699	−0.363
E2	29	61	35	21	9	0	O	0.621	−0.662
E3	61	40	21	29	4	0	A	0.687	−0.415
E4	24	20	16	91	4	0	I	0.299	-0.245

A total of 160 questionnaires were collected through online distribution, of which 155 were deemed valid. In all valid questionnaires, responses were provided for both the functional and dysfunctional questions corresponding to each requirement, with no missing or duplicate responses. After data collection, the functional and dysfunctional evaluations for each requirement were entered into the Kano evaluation matrix, and the requirement category was determined according to the combination of the two responses. The results showed that the user requirements for modular wooden tea packaging comprised four must-be requirements, ten one-dimensional requirements, four attractive requirements, and four indifferent requirements. Must-be requirements (A1, A2, B3, and D1) represent basic design constraints, as their absence may cause dissatisfaction. One-dimensional requirements (B1 and B2) should be prioritized for performance improvement, while Attractive requirements such as E1 can support functional innovation. Indifferent requirements have limited effects on satisfaction and were therefore not prioritized in subsequent analysis.

On this basis, the Better and Worse coefficients were calculated using Eqs. 1 and 2 to quantify the effects of requirement fulfillment and non-fulfillment on user satisfaction (Table 7). The Better coefficient ranges from 0 to 1; a higher value indicates greater sensitivity of user satisfaction to the fulfillment of the corresponding requirement and,

consequently, a higher priority for improvement. The Worse coefficient ranges from −1 to 0; a more negative value indicates greater sensitivity of user dissatisfaction to the non-fulfillment of the requirement and therefore greater priority. Based on the calculated coefficients and Kano requirement classifications, a four-quadrant scatter plot of user satisfaction was constructed to visualize the distribution of the requirements (Fig. 4).

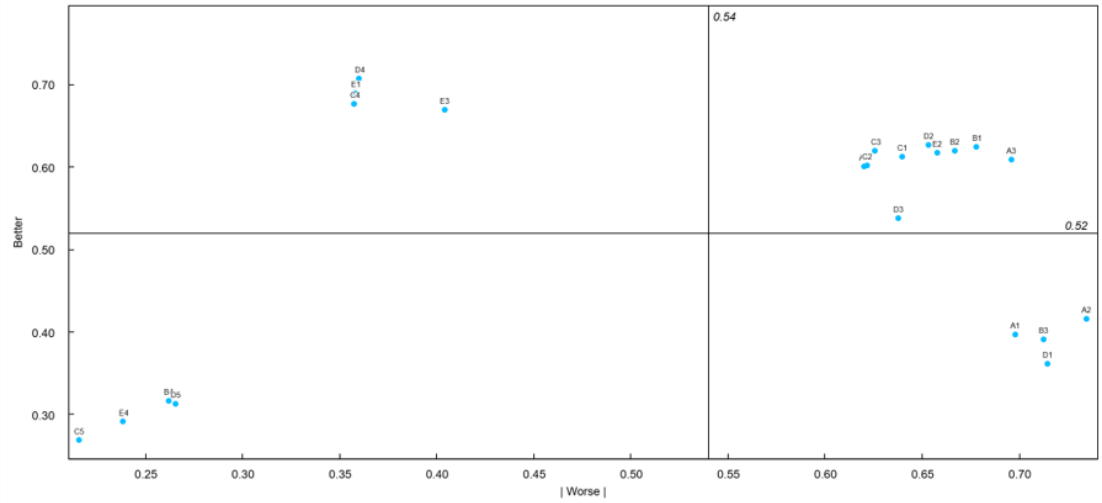

Fig. 4. Better-Worse coefficient diagram

Calculation of User Requirement Weights Using AHP

According to the Kano questionnaire analysis, the 22 initial user requirements were classified as Must-be requirements (M), One-dimensional requirements (O), Attractive requirements (A), and Indifferent requirements (I). Among them, four requirements—providing at least two opening methods within the same packaging (B4), incorporating engraving and elaborate decorative elements (C5), displaying environmental concepts or circular-use guidance on the packaging surface (D5), and converting the packaging into a desktop decorative object after use (E4)—were identified as Indifferent requirements. In the Kano model, Indifferent requirements are characterized by relatively limited changes in user satisfaction regardless of whether they are fulfilled. This classification was further supported by the Better–Worse analysis. Specifically, B4, C5, D5, and E4 exhibited the four lowest Better coefficients and the four Worse coefficients closest to zero among the 22 requirements, indicating that both their fulfillment and non-fulfillment had relatively limited effects on user satisfaction. Therefore, these four requirements were not retained as core requirements for subsequent priority weighting and QFD analysis. Their exclusion from the core analysis does not imply that they have no design value, but rather that they were not considered priority requirements in the present design framework. The remaining 18 Must-be, One-dimensional, and Attractive requirements were therefore defined as the core objectives for the design and evaluation of modular wooden tea packaging. Based on these requirements, an AHP hierarchical structure model was constructed (Fig. 5).

An expert evaluation panel comprising ten specialists from relevant fields was established, including three packaging designers, two wood-processing professionals, two tea industry practitioners, and three product design researchers. The experts had approximately 5 to 15 years of relevant research or professional experience, covering packaging structure and visual design, wood processing and structural manufacturing, tea product development and packaging applications, and product design and user research.

This multidisciplinary composition provided complementary perspectives for evaluating the priorities of user requirements. Using Saaty's 1–9 scale, the experts conducted pairwise comparisons of the requirement dimensions at the criterion level and the corresponding indicators within each dimension to construct the judgment matrices. The weights were then calculated using Eqs. 3 through 8, and consistency testing was performed to assess the reliability of the judgments. All matrices satisfied the consistency criterion (CR < 0.10), indicating acceptable internal consistency of the pairwise judgments. The resulting AHP analysis included the judgment matrices, weight calculations, and consistency test results (Tables 8 through 15).

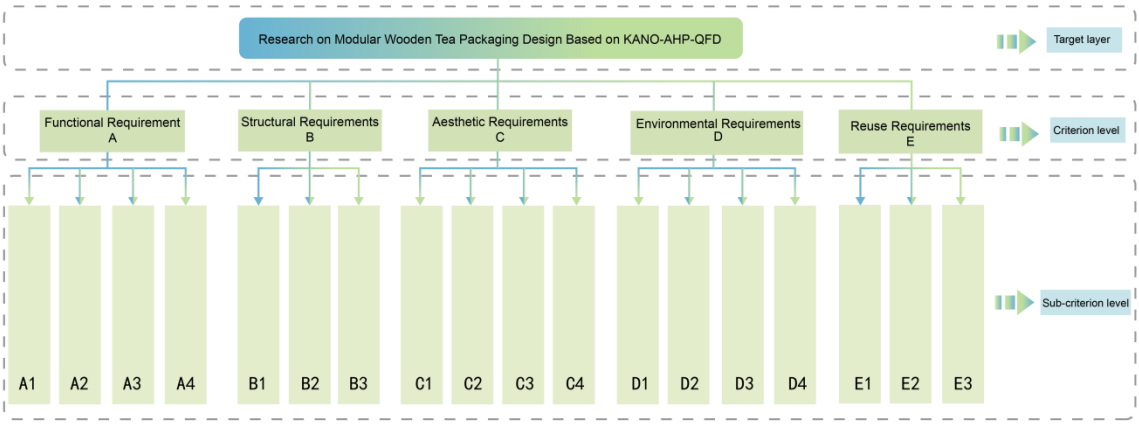

Fig. 5. A hierarchical model for modular tea packaging

Table 8. Evaluation Results of the Criterion-Level Judgment Matrix

Target layer	A	B	C	D	E
A	1	1	2.2826	1.3195	1.3887
B	1	1	2.6564	2.1946	1.4142
C	0.4381	0.3764	1	0.7231	0.6101
D	0.7579	0.4557	1.3830	1	0.6871
E	0.7201	0.7071	1.6391	1.4555	1

Table 9. Evaluation Results of the Functional Requirements Judgment Matrix (A)

A	A1	A2	A3	A4
A1	1	1.0184	1.4142	1.5115
A2	0.9819	1	1.3195	1.4310
A3	0.7071	0.7579	1	1.6075
A4	0.6616	0.6988	0.6221	1

Table 10. Evaluation Results of the Structural Requirements Judgment Matrix (B)

B	B1	B2	B3
B1	1	0.6494	0.9221
B2	1.5399	1	1.0292
B3	1.0845	0.9716	1

Table 11. Evaluation Results of the Aesthetic Requirements Judgment Matrix (C)

C	C1	C2	C3	C4
C1	1	0.9270	1.1822	1.3195
C2	1.0787	1	0.7117	1.4194
C3	0.8459	1.4051	1	1.9840
C4	0.7579	0.7045	0.5040	1

Table 12. Evaluation Results of the Environmental Requirements Judgment Matrix (D)

D	D1	D2	D3	D4
D1	1	1.0679	1.8951	1.3830
D2	0.9364	1	1.1487	1.3741
D3	0.5277	0.8706	1	0.6478
D4	0.7231	0.7277	1.5436	1

Table 13. Evaluation Results of the Reuse Requirements Judgment Matrix (E)

E	E1	E2	E3
E1	1	1.4402	1.0718
E2	0.6943	1	0.8934
E3	0.9330	1.1193	1

Table 14. Priority Ranking of Comprehensive Weights for Core Needs

Target layer	Dimension	Weight	Subcriterion Level	Weight	Integrated Weight	Rank
Modular Wooden Tea Packaging Design	Functional Requirements (A)	0.2518	A1	0.2979	0.0750	5
			A2	0.2862	0.0721	6
			A3	0.2363	0.0595	8
			A4	0.1796	0.0452	11
	Structural Requirements (B)	0.2884	B1	0.2785	0.0803	3
			B2	0.3853	0.1111	1
			B3	0.3362	0.0970	2
	Aesthetic Requirements (C)	0.1120	C1	0.2689	0.0301	15
			C2	0.2506	0.0281	16
			C3	0.3039	0.0340	14
			C4	0.1766	0.0198	18
	Environmental Requirements (D)	0.1513	D1	0.3167	0.0479	10
			D2	0.2700	0.0409	12
			D3	0.1809	0.0274	17
			D4	0.2325	0.0352	13
	Reuse Requirements (E)	0.1966	E1	0.3823	0.0752	4
			E2	0.2821	0.0555	9
			E3	0.3356	0.0660	7

Table 15. Consistency Test Results

Matrix Name		λ_{max}	CI	CR	Test Result
Criterion Level		5.0239	0.0060	0.0053	Passed
Sub-criterion Level	A	4.0204	0.0068	0.0076	Passed
	B	3.0115	0.0058	0.0111	Passed
	C	4.0421	0.0140	0.0158	Passed
	D	4.0366	0.0122	0.0137	Passed
	E	3.0037	0.0019	0.0036	Passed

Translation of Design Attributes for Modular Wooden Tea Packaging Based on QFD

This study aimed to integrate the results of user requirement analysis with modular design principles to develop a wooden tea packaging solution that combines functionality, cultural expression, and value for sustainable use. Based on the integrated weights of user requirements obtained through AHP, the relationships between user requirements and design attributes were further examined. An interdisciplinary expert panel of eight members from the fields of packaging design, industrial design, and wood processing analyzed and consolidated the 18 core user requirements. Through expert discussion, the user requirements were translated into 11 design attributes according to three consolidation criteria: similarity in functional requirements, relevance of design implementation pathways, and feasibility of structural application (Table 10).

Table 16. Conversion Mapping of User Quality Characteristics

Design Attribute Code	Design Attribute Name	Corresponding User Requirements	Basis for Translation
T1	Sealing and Moisture-Proof Design	A1	Tea Preservation
T2	Structural Stability Design	A2, B3	Structural Reinforcement
T3	User-Friendly Operation Design	A3, A4	Operational Optimization
T4	Modular Dimensional Adaptability	B1, E2	Spatial Adaptability
T5	Interlocking Grid Structure	A2, B1, B2, B3, D4, E3	Module Connection
T6	Wooden Aesthetic Design	C1, C2	Material Expression
T7	Gift-Oriented Cultural Visual Design	C2, C3	Cultural Communication
T8	Personalized Customization Design	C4	Personalized Expression
T9	Safe Single-Material Selection	D1, D3, D4	Safety and Environmental Sustainability
T10	Lightweight Material Reduction	A4, D2, D3, E3	Material Reduction Optimization
T11	Multifunctional Storage Structure	E1, E2	Functional Transformation

The user requirements, their corresponding weights, and the design attributes were entered into the appropriate sections of the House of Quality to analyze the strength of the relationships between individual user requirements and design attributes. Relationship strength was assessed according to predefined criteria, where 5 indicates a direct and substantial relationship, 3 a meaningful but non-dominant relationship, 1 an indirect or limited relationship, and 0 no substantive relationship. The resulting scores were then incorporated into the relationship matrix using the corresponding symbols. In the lower section of the House of Quality, the weights and ranking values of the design attributes were calculated using Eqs. (9) and (10). Finally, a QFD-based House of Quality (HoQ) matrix was established (Fig. 6). The HoQ analysis results showed that the Interlocking Grid

Structure (T5), Multifunctional Storage Structure (T11), Structural Stability Design (T2), Modular Dimensional Adaptability (T4), and Lightweight Material Reduction (T10) were the five highest-ranked design attributes, with relative weights of 21.35, 16.67, 11.35, 11.31, and 10.67, respectively. The top five design attributes accounted for 71.35% of the total relative weight, indicating a clear concentration of QFD priorities and providing a basis for identifying the core design attributes. Meanwhile, a relatively clear decline in weight was observed between the fifth-ranked Lightweight Material Reduction (T10, 10.67) and the sixth-ranked Safe Single-Material Selection (T9, 6.47). Therefore, this study identified the core design attributes by jointly considering the cumulative weight concentration and the weight differences in the ranking distribution. Based on these two criteria, the top five attributes were selected as the core design attributes for subsequent design development. The remaining six design attributes were not excluded. Rather, they were retained as supporting design attributes and appropriately incorporated into the final design solution.

	Weight	Quality characteristics										
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
A1	0.0750	●								△		
A2	0.0721		●			△						
A3	0.0595	△		●	△							△
A4	0.0452		△	●							○	
B1	0.0803				●	○						○
B2	0.1111		○		○	●					△	○
B3	0.0970	△	○			●						
C1	0.0301						●			△		
C2	0.0281						○	●				△
C3	0.0340						△	●	△			
C4	0.0198							△	●			
D1	0.0479	△					△			●		
D2	0.0409										●	
D3	0.0274									●	○	
D4	0.0352					○				○	○	
E1	0.0752					○		△				●
E2	0.0555			△	○	△						●
E3	0.0660				△	○					●	○
Importance	Absolute Weight	57.94	103.00	57.90	102.68	193.82	31.67	40.55	13.30	58.72	96.90	151.33
	Relative Weight	6.38	11.35	6.38	11.31	21.35	3.49	4.47	1.47	6.47	10.67	16.67
	Ranking	7	3	8	4	1	10	9	11	6	5	2

Fig. 6. Mapping model

Design Practice for Modular Wooden Tea Packaging

Based on the Kano–AHP–QFD analysis, the interlocking grid structure, multifunctional storage structure, structural stability design, modular dimensional adaptability, and lightweight material reduction were identified as the five highest-priority design attributes. These attributes were further linked to the corresponding high-priority user requirements and specific design measures. B2 and B3 were mainly associated with T5 and implemented through mortise-and-tenon snap-fit joints, wooden dowels, and positioning elements; B1 corresponded to T4 and was realized through adjustable partitions; and E1 corresponded to T11 and was implemented through reconfigurable internal modules for everyday storage. Supporting attributes such as wooden aesthetic

design and gift-oriented cultural visual design were also incorporated to improve the overall packaging solution.

In the design practice, the packaging combines a rounded-square box body with curved surrounding panels. The soft curved surfaces reduce the rigid appearance of conventional wooden boxes while preserving the natural qualities of wood and creating a simple and refined visual character (Fig. 7).

Fig. 7. Modular wooden packaging design for tea

This form responds to wooden aesthetic design and gift-oriented cultural visual design, strengthening the cultural and emotional expression of the packaging. Structurally, the packaging consists of standardized modules, including a top lid, surrounding panels, adjustable partitions, and a base plate, which are connected through standardized interfaces to support flexible assembly and reconfiguration. The segmented curved panels are secured using mortise-and-tenon snap-fit joints, wooden dowels, and positioning elements,

providing structural stability while facilitating component replacement and repeated assembly. Adjustable internal partitions form storage spaces of different sizes through interlocking connections, thereby allowing the layout to accommodate different tea-container dimensions and storage requirements. The detachable partitions and reconfigurable modules also extend the packaging beyond tea storage. After the tea has been consumed, the internal configuration can be adjusted to store jewelry, stationery, cosmetics, and other daily-use items, thereby increasing the long-term use value of the packaging.

An embedded base plate, modular positioning features, and multiple connection points were incorporated to support connection stability during disassembly and reassembly. Considering the high-priority design attributes identified through QFD, walnut was selected as the primary material based on its dimensional stability, processing adaptability, and visual characteristics. Its dimensional stability and machinability are suitable for the structural stability design (T2), modular dimensional adaptability (T4), and interlocking grid structure (T5) adopted in the proposed packaging. These material characteristics facilitate the fabrication of mortise-and-tenon snap-fit joints, wooden dowels, positioning elements, and adjustable partitions, while supporting the dimensional consistency required for modular assembly and reconfiguration. In addition, the natural grain and warm coloration of walnut contribute to wooden aesthetic expression and the visual quality expected in tea-gifting contexts. A wood-wax oil finish was applied to preserve the natural texture and tactile qualities of the material while enhancing surface protection.

Design Feedback and Evaluation

To conduct a preliminary evaluation of user acceptance and perceived design applicability of the proposed modular wooden tea packaging, a total of 30 participants were invited to evaluate the design solution, including 21 consumers, four packaging designers, three industrial designers, and two wood-processing professionals. The evaluation dimensions were established based on the preceding Kano–AHP–QFD analysis and the design objectives, comprising five dimensions: modular design, structural convenience, functional adaptability, wooden aesthetic expression, and sustainable use value. The evaluation questionnaire consisted of 14 items using a five-point Likert scale ranging from 1 (“very unacceptable”) to 5 (“very acceptable”). Reliability analysis showed acceptable internal consistency for the 14-item evaluation scale, with a Cronbach’s α of 0.761. The mean scores and standard deviations for the five evaluation dimensions are presented in Table 17, and the mean scores are visualized in the radar chart (Fig. 8). Sustainable use value received the highest mean score (4.27), followed by wooden aesthetic expression (4.20), while the remaining dimensions also scored 4.00 or higher. Overall, the results indicated generally favorable evaluations of the proposed design and provided preliminary support for its user acceptance and perceived design applicability.

Table 17. Descriptive Statistics of the Final Design Evaluation

Dimension	Modular Design	Functional Adaptability	Structural Convenience	Wood Aesthetic Expression	Sustainable Use Value
Mean	4.00	4.04	4.05	4.20	4.26
Std.	0.66	0.55	0.44	0.72	0.54

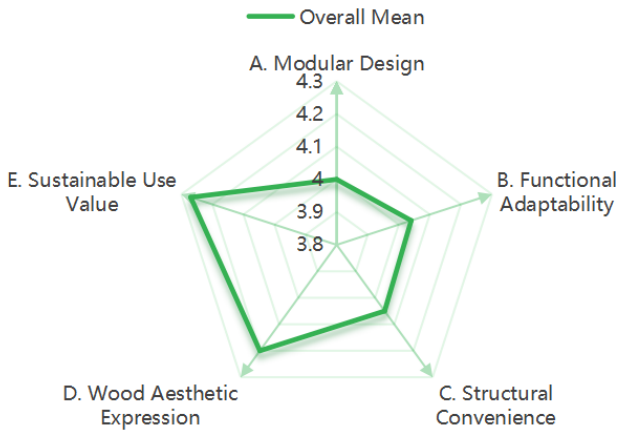

Fig. 8. User acceptance radar chart

Overall, this study integrated the Kano model, AHP, and QFD to establish a continuous process from user requirement identification and prioritization to design attribute translation. The results were then further applied to the design and evaluation of modular wooden tea packaging. Nevertheless, several limitations remain. The user sample was limited in size and diversity, particularly in age and consumption experience, which may have influenced the results. In addition, the study focused mainly on requirement analysis, design attribute extraction, and design solution development, with limited examination of manufacturing precision, structural durability, production cost, and long-term use performance. Further validation through physical prototyping and actual-use testing is therefore required.

Future research should expand the sample size and geographical coverage while improving the representation of different age groups, consumption experiences, and occupational backgrounds. Physical prototype testing, manufacturing validation, and long-term user feedback should also be incorporated to evaluate disassembly and reassembly efficiency, connection stability, spatial adaptability, and repeated-use performance. These investigations would provide further evidence of the feasibility and structural reliability of the design under actual production and long-term use conditions and assess its applicability across different storage scenarios.

CONCLUSIONS

1. This study established a user-needs-driven framework for modular wooden tea packaging by integrating Kano, analytic hierarchy process (AHP), and quality function deployment (QFD). The framework connects requirement classification, prioritization, design attribute translation, and design implementation, thereby providing a structured basis for translating user requirements into design decisions.
2. The results highlight modular reconfiguration, stable connections, dimensional adaptability, and post-use functional extension as major design priorities for modular wooden tea packaging. These requirements were translated into structural and functional design directions through QFD, supporting the development of detachable, adjustable, and multifunctional packaging components.
3. The design feedback and evaluation further supported the effectiveness of the proposed

approach. All five evaluation dimensions received mean scores above 4.0, indicating generally positive assessments of the modular wooden tea packaging design. High levels of recognition were observed for modular design, structural convenience, functional adaptability, wooden aesthetic expression, and sustainable use value. These results support the translation of the Kano–AHP–QFD analysis into design practice and indicate favorable user acceptance and perceived feasibility. The findings provide a useful reference for the further development of modular wooden tea packaging.

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Use of Generative AI

To ensure transparency in the research process, the authors declare that ChatGPT (OpenAI) was used primarily for English translation and language editing. The research design, data collection and analysis, design decision-making, and interpretation of the results and conclusions were conducted independently by the authors.

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