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Research on the Application and Evaluation of Mongolian Saddle Culture in Kumis Packaging Design Based on AIGC

ABSTRACT

This study explores the application of generative artificial intelligence technology in the design of cultural and creative products, using kumis packaging design as a case study. It establishes and validates a "human + AI" collaborative design framework oriented by user demands, driven by cultural resources, and supported by artificially intelligent technological tools. As an important part of ethnic cultural heritage, the Mongolian saddle, with its profound cultural connotations and unique visual characteristics, provides abundant inspiration for kumis packaging design. Through semi-structured interviews, this research identifies design requirement indicators for kumis packaging. The Analytic Hierarchy Process (AHP) is applied to construct a hierarchical model of requirements and calculate indicator weights to identify key design criteria. Subsequently, samples of Mongolian saddle cultural resources are collected, deconstructed, and categorized using an expert panel method, resulting in a structured image set. These elements are then translated into input prompts for AIGC tools to generate multiple kumis packaging designs rich in the cultural essence of the Mongolian saddle. The designs are scientifically evaluated using the Fuzzy Comprehensive Evaluation (FCE) method. The results indicate that the integration of AIGC technology not only enables the effective transformation and expression of cultural elements but also significantly enhances the efficiency and diversity of design generation. This validates the feasibility and practical value of AIGC as a "co-creator" in cultural and creative design. This study provides theoretical guidance and practical reference for the innovative integration of ethnic culture and modern design, expands the application scenarios of generative AI technology in cultural and creative design, and contributes to promoting cultural sustainability.

Introduction

Kumis, also known as mare's milk wine, is a traditional fermented beverage. Due to its effects of dispelling cold, relaxing tendons, promoting blood circulation, aiding digestion, and its variety of derivative flavors for consumption (Carrick, 1881), kumis is increasingly becoming a popular beverage among modern consumers, with its audience no longer limited to the Mongolian community (Maksyutov et al., 2013). With the growing consumer base of kumis, the design of kumis packaging has garnered widespread attention (Jiang and Wang, 2013). However, existing kumis packaging designs face pressing issues, such as insufficient cultural expression and a lack of distinctive ethnic cultural characteristics, which result in poor product differentiation and difficulty in meeting the demands of market competition (Yun, 2014; Wu and Jiang, 2025; Wang et al., 2025). Although designers have been paying attention to the use of ethnic elements in modern kumis packaging design, the widespread practice of blindly piling up traditional patterns without thoughtful integration is common (Bu and Chen, 2023). This approach often lacks overall design coherence and fails to fully reflect the unique and profound cultural characteristics of the Mongolian ethnic group (Zhao and Sahari, 2024). To address this issue, the approach proposed in this study integrates structured cultural resource analysis and deconstruction, expert-guided factor screening, and AIGC-based generation, thereby ensuring that traditional Mongolian cultural elements are not merely applied superficially but are systematically and coherently integrated into the packaging designs. The Chinese Mongolian ethnic group, known as the "people on horseback," has seen the art of Mongolian saddle-making included in the second batch of National Intangible Cultural Heritage lists due to its significant artistic, cultural, and practical value (China Intangible Cultural Heritage, 2008). Mongolian saddle culture, shaped over centuries by Mongolian craftsmanship, aesthetic evolution, social customs, and environmental adaptation, reflects not only the unique aesthetic preferences of the Mongolian people but also serves as a concentrated representation of the natural, social, and spiritual culture of Inner Mongolia (Zhao, 2017), holding immense cultural value. However, like many traditional cultural artifacts, Mongolian saddle culture faces the risk of gradual decline in modern times. The shift in nomadic customs, rapid urbanization, and weakened intergenerational knowledge transmission have posed significant challenges to the inheritance and creative transformation of saddle culture (Yembuu, 2021). Additionally, the commercial and design markets rarely integrate Mongolian saddle artistry into modern cultural and creative products, leading to a disconnect between this traditional cultural heritage and contemporary lifestyles and design practices (Wang and Hai, 2024). Achieving a balance between preserving its cultural significance and incorporating it into modern innovation is not only an urgent issue for Mongolian saddle culture but also a shared challenge for many other forms of intangible cultural heritage (Lu and Phanlukthao, 2024). While ethnological (Yan, 2023), archaeological (Bayarsaikhan et al., 2024), and material cultural (Cui and Zhao, 2022) research have contributed to the documentation and academic preservation of Mongolian saddle culture, there remains a significant research gap in dynamically revitalizing and creatively reapplying saddle culture through design-driven approaches (Yan, 2020). Therefore, this study attempts to explore the application of Mongolian saddle culture in kumis packaging design. The aim is to enhance the ethnic cultural characteristics in kumis packaging design and provide new pathways for the preservation and innovative application of Mongolian saddle culture.

In recent years, Artificial Intelligence Content Generation (AIGC) technology has emerged as a transformative tool in the creative industries (Ko et al., 2023). AIGC refers to the use of artificial intelligence to generate and create content, producing high-quality outputs based on user-input keywords or requirements (Wu et al., 2023), partially replacing or assisting human creativity (Yin et al., 2023). Tools like MidJourney and Stable Diffusion enable designers and researchers to input information such as product requirements, functional demands, and design constraints, guiding models to generate diverse creative design solutions (Lu et al., 2023). These tools' generative potential has opened new opportunities for the preservation of traditional crafts and the innovative development of cultural heritage (Li and Lin, 2021; Wei and Qingna, 2021). Currently, research on the application of AIGC in the creative design industry has become a hot topic in both academia and the design community, yielding some notable achievements. In the visual arts field, AIGC has been used to reinterpret classical painting styles (Guo et al., 2024) or create synthetic artworks that simulate traditional aesthetics (Zhang and Romainoor, 2023). For instance, Song et al. trained an AIGC model to redraw features of traditional ink paintings, generating Chinese aesthetic images through the input of "prompts" (Song et al., 2023). Similarly, Elgammal et al. demonstrated how Generative Adversarial Networks (GANs) could learn artistic styles and produce original works, paving new paths for computational creativity (Elgammal et al., 2017). In product design, AIGC has been applied at various stages of the design process, including creative exploration, design generation, assistance and suggestions, as well as evaluation and feedback (Wu et al., 2024). For example, Wang et al. developed a specialized database for Ming-style furniture based on the MidJourney platform. Their empirical study successfully reproduced the aesthetic characteristics of Ming-style furniture and revealed its deep cultural connotations (Wang et al., 2024). By leveraging AIGC technology, their research promoted the integration of traditional and modern furniture design. Xie et al. proposed a method for generating children's bed design renderings based on Control Net, enabling the generation of complete renderings from input sketches (Xie et al., 2024). McCormack et al. (2020) and Wu et al. (2021) explored the "Human-AI" co-creation model, where human designers guide AI tools to produce creative designs. These hybrid workflows improve efficiency while retaining creative capability. In the fields of intangible heritage and cultural creative design, research on AIGC applications is still in its infancy, but its potential is increasingly being recognized. In related practices, Liang (2024) trained models for textile patterns, ceramic designs, and furniture products, producing modern adaptations rooted in traditional culture. Zhang et al. (2024) utilized AIGC technology to design cultural and creative products themed around Nanjing's Republican-era architectural heritage, paving new paths for its preservation. Wu and Chang (2024) applied AI technology to adapt the Tujia Baishe Dance into design practices, showcasing the prospects of AI in the digital preservation of intangible cultural heritage. Liu et al. (2023) analyzed cultural symbols from semantic, morphological, and pragmatic perspectives using the MidJourney tool to generate creative outputs. Their study, based on Macao's Portuguese paving culture, produced cultural and creative products that integrate unique local cultural elements. The above literature provides insights into the innovative applications of AIGC in the field of cultural creative design. However, there is still a gap in the application research and practice of AIGC in cultural creative packaging design.

In addition, it is necessary to situate this study within the broader discourse of heritage and cultural studies. As Kirshenblatt-Gimblett (1995) argued, heritage is not simply inherited from the past but is actively produced as a form of metacultural production in response to present concerns. Wang and Adzharuddin (2025) introduce the notion of "synthetic authenticity" in AI-generated intangible cultural heritage, showing that audience trust hinges on traditional aesthetic cues and transparent AI disclosure. Meanwhile, Fu et al. (2025) examine how AI in digital preservation raises challenges of authenticity and ethical responsibility, particularly when AI-generated representations simplify or generalize cultural features. Similarly, He et al. (2025) reveals that when participants generate heritage-related visuals via AI, those unfamiliar with cultural context often produce outputs lacking nuance or depth. These works, together with Nazirah and Asliza (2024), who explore the risks of cultural appropriation and ethical issues in preserving global cultures through AI, underscore that Mongolian saddle culture is not merely an artifact of tradition but a dynamic cultural expression requiring thoughtful mediation in contemporary design practices. From a Science and Technology Studies (STS) perspective, Latour (2005) reminds us that technologies are never neutral tools but "actants" that co-shape cultural and social realities. Applying this view to design, the adoption of AI-generated content (AIGC) in kumis packaging raises questions about how technology reconfigures the relationship between designers, culture, and consumers. These theoretical perspectives provide a critical foundation for this research, ensuring that the integration of Mongolian saddle culture into kumis packaging design via AIGC is not only technically innovative but also socially and culturally responsible.

Against this background, this study aims to explore how AIGC technology serves as a mediated partner to empower the preservation of ethnic culture and the design of cultural and creative packaging. Using the application of Mongolian saddle culture in kumis packaging design as a case study, the research proposes a Human-AI collaborative design methodology and practical framework to bridge existing research gaps. It examines the potential of AIGC technology to optimize the design process of "cultural creative products rooted in ethnic culture," bringing new momentum to the development of regional ethnic cultures and providing new perspectives and methods for innovation in cultural creative product design. By doing so, this study contributes to the emerging intersection of artificial intelligence, cultural heritage, and creative design, aiming to support technological innovation and the sustainable inheritance and development of traditional cultural heritage.

Materials and Methods

The application and evaluation method of AIGC-based Mongolian saddle culture in kumis packaging design proposed in this study includes the following steps:

Step 1: Demand Collection and Analysis of Kumis Packaging Design.

To scientifically identify and prioritize the design requirements for kumis packaging, semi-structured interviews were conducted with cultural product design and marketing professionals, Mongolian cultural practitioners and researchers, and consumer representatives. Based on the interview data, using the Kawakita Jiro (KJ) method, also known as the affinity diagram method, a set of design requirement indicators was established. The Analytic Hierarchy Process (AHP) was then applied to construct a hierarchical model of design requirements and calculate indicator weights. This enabled the identification of requirements priorities in kumis packaging design. The Analytic Hierarchy Process (AHP), with its advantages of structural simplicity, strong operability, practicality, and systematic nature (Zhao et al., 2024), has been widely applied in decision-making analysis across multiple fields. This method transforms qualitative decision factors into quantifiable weights through pairwise comparisons (Zahedi, 1986), combined with a consistency check mechanism to reduce subjective bias and decision errors (Liu et al., 2024), thereby making the entire decision-making process more scientific, accurate, and intuitive (Yi et al., 2024). In addition, the AHP method is logically clear and procedurally straightforward, making it easy to understand, master, and apply even for non-professionals (Desai et al., 2021). With these advantages, the AHP method has been widely verified and applied in product design evaluation and decision-making studies (Sun et al., 2023; Xie et al., 2024), fully demonstrating its applicability and stability in this field. Although recent studies have introduced fuzzy extensions of AHP to further improve the precision in handling uncertainty and subjective judgment, this study aims to provide design practitioners with a design guidance method that is highly universal, easy to understand, and highly operable. Compared with Fuzzy AHP, conventional AHP has a more intuitive calculation process and higher transparency, simplicity, and repeatability (Zhu et al., 2021), making it easier for subsequent designers to understand and apply. Therefore, adopting the conventional AHP in this study helps ensure the scientific validity and effectiveness of the design guidance method while enhancing its usability, operability, and practical value.

Step 2: Data Collection of Mongolian Saddle Cultural Resources.

In order to apply Mongolian saddle culture to kumis packaging design, a comprehensive collection of cultural resources was undertaken. This study conducts a comprehensive collection and documentation of Mongolian saddle cultural resources samples through relevant books and materials review and field investigations in various museums, ethnic cultural centers, and traditional saddle workshops in Inner Mongolia.

Step 3: Deconstruction and Classification of Mongolian Saddle Cultural Elements.

Based on the collected Mongolian saddle samples, an expert panel discussion is held with three Mongolian saddle artisans and two Mongolian culture researchers/professors. Representative Mongolian saddles are selected as experimental samples, and their cultural elements are deconstructed and classified. These elements are then transformed into a structured set of cultural factors that served as the foundation for generating prompts in the AIGC process.

Step 4: AIGC-Based Design Generation.

Stable Diffusion was selected as the primary AIGC tool for this study due to its open-source accessibility, controllability, and capacity for custom fine-tuning, which are essential for reproducible academic research. Its ability to integrate cultural datasets and provide prompt-level control made it well suited for systematically embedding Mongolian cultural features into packaging design. Generative design was carried out using Stable Diffusion. The structured image set of Mongolian saddle culture and the analysis results of the design demand indicators for kumis packaging are translated into prompt input formats compatible with Stable Diffusion. By combining kumis packaging design descriptors (e.g., packaging form, material properties) with cultural factors (e.g., saddle motifs, symbolic patterns and colors), the prompts guided Stable Diffusion to generate diverse and culturally grounded Kumis packaging design concepts. To ensure reproducibility and transparency, representative prompt examples are provided in “Supplementary material”-"S1 File".

Step 5: Evaluation of Design Outputs.
The generated design solutions are evaluated comprehensively using the Fuzzy Comprehensive Evaluation (FCE) method (Chang, 2021). The evaluation results validate the potential of AIGC tools as co-creators in the design of ethnic cultural and creative products and help select the optimal solutions.

This proposed methodology demonstrates the application of AIGC in integrating Mongolian saddle culture into kumis packaging design and offers a systematic approach for evaluation. This study integrates user-centered evaluation methods with generative AI-assisted cultural design, forming a systematic human–AI collaborative cultural design framework that bridges traditional decision analysis and emerging AIGC-driven creativity. The overall design and evaluation process framework is illustrated in Figure 1.

Fig. 1 The application and evaluation process framework for AIGC-based Mongolian saddle culture in kumis packaging design

Results—Design Example of Kumis Packaging

Design Demands Collection and Analysis for Kumis Packaging

Selection of Participant Samples

To comprehensively gather design requirement indicators for kumis packaging, this study employs purposive sampling to select representative samples from respondents with relevant experience and diverse backgrounds. This ensures the breadth and depth of the research data. At the same time, gender diversity and balance were intentionally considered during the sampling process to ensure that the collected insights reflect the perspectives of both male and female participants, thereby minimizing potential gender-related biases in the results. The interview sample includes the following three groups, totaling 20 participants. The demographic details of the participants are as follows:

(1) 6 Design and Marketing Professionals (3 males and 3 females): including three packaging designers with over 10 years of experience and three sales professionals with years of experience in marketing kumis. The designers bring in-depth industry knowledge and expertise, offering insights into the feasibility, aesthetic appeal, and other aspects of packaging design from a professional perspective. Their input helps the study better understand and identify

consumers' requirements for kumis packaging. Meanwhile, the sales professionals provide insights into how packaging influences consumer behavior, such as strategies to enhance market competitiveness and brand value through design. They also share common customer feedback, preferences, and issues encountered during the sales process, as well as their observations of market trends related to kumis packaging. (2) 6 Mongolian Cultural Practitioners and Researchers (3 males and 3 females): including three experts in traditional Mongolian culture and three craft inheritors/practitioners from kumis production enterprises. These participants were selected for their profound understanding of Mongolian traditional culture. They provide professional guidance on the identification and integration of cultural symbols into packaging design, enabling researchers to blend cultural heritage with modern packaging solutions. (3) 8 consumer representatives who have had multiple experiences of purchasing kumis: ①4 Mongolian consumers (2 males and 2 females). They were selected from Mongolian consumers who live in Inner Mongolia. They are the traditional target users of kumis and can provide opinions from the perspective of cultural identity and usage habits. ②4 non-Mongolian consumers (2 males and 2 females), i.e., consumers from other ethnic groups or regions, aiming to understand the consumer demand and improvement direction of kumis as a local specialty product in the cross-cultural consumer market.

The sample selection of this study is diverse, comprehensive, and representative, covering variations in participants' professional backgrounds, cultural identities, and gender. Each participant group plays a clearly defined role in the research, providing specific and valuable insights for constructing the design requirement indicators. Through semi-structured interviews with the aforementioned respondents, the study delves deeply into the multidimensional needs of kumis packaging design, ensuring the validity of the research results.

Collection of original demand data

This study collected raw data on the design requirements for kumis packaging through semi-structured interviews. To ensure the data's detail and comprehensiveness, three separate interview outlines were developed for different respondent groups, namely Design and Marketing Professionals, Mongolian Cultural Practitioners and Researchers, and Consumer Representatives (see Tables 1, 2, and 3). While the overall interview objective remained consistent, the questions were tailored to suit the unique characteristics of each respondent group, ensuring the acquisition of key information related to kumis packaging design demands from their distinct perspectives.

During the interview process, the researchers adhered strictly to the following steps: First, the purpose and procedure of this study were thoroughly explained to the participants, and informed consent was obtained. The interviews were then conducted following the pre-designed outlines. The content of the interviews included respondents' perceptions of kumis packaging design requirements, specific feedback based on their personal experiences, and suggestions for design improvements. Each interview lasted 25 to 30 minutes. The entire interview process was recorded to facilitate subsequent organization and analysis. Additionally, respondents were encouraged to express their detailed views freely, while the researchers avoided leading questions to ensure the authenticity and reliability of the data collected.

Table 1. Interview Outline for Design and Marketing Professionals.

NO.	Open-ended Topic Questions	Probing Questions
1	Have you ever been involved in the design or promotion of kumis packaging or kumis products in your work?	Could you share specific experiences related to this?
2	Based on your understanding of consumers, what do you think are the key functional requirements consumers have for kumis packaging?	

3	From a market competition perspective, how do you think kumis packaging design can better attract consumers?	What do you think consumers expect in terms of the appearance, material, and color of kumis packaging?
4	Based on your understanding of consumers, do you think they have a demand for cultural features in kumis packaging?	What specific cultural features do consumers look for in kumis packaging?
5	Based on your experience in designing kumis packaging and your understanding of consumers, what issues do you think still exist with kumis packaging, or what areas do you think need further optimization?	

Table 2. Interview Outline for Mongolian Cultural Practitioners and Researchers.

NO.	Open-ended Topic Questions	Probing Questions
1	How do you perceive the representation of Mongolian cultural elements in current kumis packaging?	Could you provide examples to illustrate this?
2	In terms of showcasing Mongolian traditional cultural characteristics, what visual expressions do you think are worth trying?	
3	Do you think kumis packaging needs to tell a cultural story? If so, what content should it include?	Could you elaborate further?
4	Regarding color combinations and texture in packaging, which styles do you think best reflect Mongolian culture?	Why?
5	How do you think kumis packaging design should balance cultural representation with market demands?	

Table 3. Interview Outline for Consumer Representatives.

NO.	Open-ended Topic Questions	Probing Questions
1	Have you purchased kumis more than five times?	What aspects of the kumis packaging left a lasting impression on you?
2	In terms of functionality, what areas of the kumis packaging do you think could be improved?	
3	From an aesthetic perspective, what are your expectations for the color combinations, shape, and texture of the packaging?	
4	What are your thoughts on incorporating Mongolian traditional cultural symbols into kumis packaging?	Which Mongolian traditional cultural elements would you find attractive or increase your willingness to purchase?
5	Do you think there are any other issues with kumis packaging or areas that need further optimization?	

Analysis of Design Demand Data and Hierarchical Model Construction for Kumis Packaging

This study invited two alcoholic beverage packaging designers and two professors specializing in packaging design to form an expert panel. The KJ method (affinity diagram method) was employed to systematically organize and analyze the interview content. The research team used Nvivo 12 software for data coding, ensuring objectivity and reliability by conducting cross-coding among multiple researchers, performing independent analyses, and collectively reviewing and discussing the results to minimize subjective bias. The coding results were documented in text form on sticky notes. Based on the similarity and relevance of the demand indicators, the expert panel merged, eliminated, grouped, and categorized the coded content. After multiple iterative rounds of screening, decomposition, and integration, the study finalized four criterion layers and eleven sub-criterion layers for the design demand indicators of kumis packaging. A hierarchical model of design requirements was constructed based on these results, as shown in Table 4.

Table 4. The hierarchical model of design demand indicators for kumis packaging.

Target Layer	Criteria Layer	Sub-criteria Layer
Innovative Design of Kumis Packaging	Aesthetic (A)	Harmonious and Comfortable Color Coordination (A1)
		Unique and Aesthetically Form Design (A2)
		Material Texture Blending Simplicity with a Sense of Quality (A3)
	Functional (B)	Leak-proof and Break-proof Protective Performance (B1)
		Convenience of Use (B2)
		Clear Presentation of Product Information (B3)
	Cultural (C)	Application of Traditional Cultural Symbols (C1)
		Expression of Regional Characteristics (C2)
		Cultural Storytelling (C3)
	Environmental (D)	Use Eco-friendly Materials (D1)
		Material Durability and Service Life (D2)

Determining the Weights and Priority Rankings of Demand Indicators

(1) Construction of the judgment matrix

Constructing the judgment matrix is a core step in the Analytic Hierarchy Process (AHP), used to quantitatively compare the relative importance of various indicators in a decision-making problem (Golden et al., 1989). The judgment matrix is built by pairwise comparisons of indicators at the same level, evaluating their importance relative to the higher-level criterion (Wu et al., 2019). Specifically, the importance relationship between two indicators is represented by integers from 1 to 9 and their reciprocals (as shown in Table 5), with values assigned based on expert opinions (Saaty, 1980). Following this method, this study collected importance ratings for indicators at each level from a sample of 20 respondents. Through multiple rounds of discussion and result consolidation, all fuzzy judgment matrices were generated and the corresponding indicator weights were calculated, as detailed in Tables 6 through 11.

Table 5. Judgment matrix index importance level numerical scale table.

Scale value	Importance Level	implication
1	Equally important	Indicator *i* is of equal importance compared to indicator *j*
3	Slightly important	Indicator *i* is marginally important compared to Indicator *j*
5	Essential important	Indicator *i* is significantly more important than Indicator *j*
7	Extremely important	Indicator *i* is extremely important compared to Indicator *j*
9	Absolutely important	Indicator *i* is absolutely important compared to Indicator *j*
2,4,6,8	Intermediate values between the two adjacent judgments	The importance level is between two adjacent levels
1/2,1/3...1/9	Inverse comparison	If the importance scale of indicator *i* over indicator *j* is "n", the inverse comparison is "1/n".

Table 6. Criterion layer judgment matrix and weights。

V	A	B	C	D	Weights（w）
A	1	1/2	1	5	0.24683
B	2	1	2	7	0.45198
C	1	1/2	1	5	0.24683
D	1/5	1/7	1/5	1	0.05437

Table 7. Judgment matrix and weights for aesthetics criteria.

A	A_1	A_2	A_3	Weights（w）
A_1	1	1/7	1/5	0.07546
A_2	7	1	2	0.59072
A_3	5	1/2	1	0.33382

Table 8. Judgment matrix and weights for functional criteria.

B	B_1	B_2	B_3	Weights（w）
B_1	1	7	4	0.71507
B_2	1/7	1	1/2	0.09782
B_3	1/4	2	1	0.18710

Table 9. Judgment matrix and weights for cultural criteria.

C	C_1	C_2	C_3	Weights（w）
C_1	1	1/3	3	0.24310
C_2	3	1	7	0.66870
C_3	1/3	1/7	1	0.08820

Table 10. Judgment matrix and weights for sustainability criteria.

D	D_1	D_2	Weights（w）
D_1	1	2	0.66667
D_2	1/2	1	0.33333

Table 11. The comprehensive weights and importance ranking of indicators.

Criterion layer	Weights	Sub-criterion layer	Weights	Comprehensive weights	Ranking
A	0.24683	A_1	0.07546	0.01863	10
		A_2	0.59072	0.14581	3
		A_3	0.33382	0.08240	5
B	0.45198	B_1	0.71507	0.32320	1
		B_2	0.09782	0.04421	7
		B_3	0.18710	0.08457	4
C	0.24683	C_1	0.24310	0.06000	6
		C_2	0.66870	0.16506	2
		C_3	0.08820	0.02177	9
D	0.05437	D_1	0.66667	0.03625	8
		D_2	0.33333	0.01812	11

(2) Consistency test

Since the judgment matrix is constructed based on expert evaluations, a consistency check is required to ensure the logical soundness and consistency of the judgments (Naveed et al., 2022). The steps for the consistency test are as follows:

Calculate the Maximum Eigenvalue:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(A\omega)_i}{\omega_i} \quad (1)$$

n is the number of orders of the judgment matrix; $(A\omega)_i$ is the i-th element of the product of matrix A and eigenvector ω .

Calculate the Consistency Index:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (2)$$

λmax is the maximum eigenvalue of the judgment matrix, and n is the order of the judgment matrix.

Calculate the Consistency Ratio:

$$CR = \frac{CI}{RI} \quad (3)$$

In this equation, RI is the random consistency index. The values of RI for matrices of different orders are shown in Table 12.

Table 12. Values of RI for judgment matrices of orders 1-9.

1	2	3	4	5	6	7	8	9
0.000	0.000	0.520	0.890	1.120	1.260	1.360	1.410	1.460

It is generally required that CR < 0.1 for the judgment matrix to be considered valid; otherwise, the judgment matrix needs to be reconstructed, and the consistency check must be performed again. As shown in the calculation results in Table 13, the CR values of all indicator matrices in the hierarchical model are below the allowable threshold of 0.1, indicating that the consistency test is valid and the calculation results are reasonable.

Table 13. Results of consistency test.

Consistency Indicator	V	A	B	C	D
CI	0.003	0.007	0.001	0.004	0.000
RI	0.890	0.520	0.520	0.520	0.000
CR	0.004	0.014	0.002	0.007	0.000

Design Demands Analysis Results

Through the hierarchical analysis and calculation of the design requirements for mare's milk wine packaging, the weights and importance rankings of each indicator were determined. According to the analysis results in Table 5, at the criterion level, functionality (0.45198) ranked highest with the greatest weight, followed by aesthetics (0.24683), cultural value (0.24683), and sustainability (0.05437). At the sub-criterion level, the comprehensive weights of indicators revealed the core design requirements for kumis packaging as follows: Leak-proof and Break-proof Protective Performance (0.32320) > Expression of Regional Characteristics (0.16506) > Unique and Aesthetically Form Design (0.14581) > Clear Presentation of Product Information (0.08457) > Material Texture Blending Simplicity with a Sense of Quality (0.08240) > Application of Traditional Cultural Symbols (0.06000).

The results indicate that the focus of packaging design aligns with previous studies on wine packaging, emphasizing that functional realization remains the foundation of design while also enhancing the aesthetic value of the product. Notably, cultural value was ranked equally important as aesthetics in kumis packaging design, which is likely tied to the regional attributes of the product itself. This suggests that modern consumers' expectations for kumis packaging have evolved beyond the functional level to increasingly value the cultural significance and visual experience of the product. In addition to prioritizing functionality, the design should incorporate traditional cultural elements characteristic of the Mongolian ethnicity to enhance the product's appeal and market competitiveness. Therefore, when innovating the packaging design for kumis, it is essential to deeply explore traditional cultural contents that embody Mongolian impressions, such as horse tack and saddles, gers, and traditional clothing that have strong visual recognition or carry the historical memories and ethnic spirit of the Mongolian people. It is equally important to extract their representative cultural features, such as symbolic patterns, typical color combinations, and distinctive materials, and integrate them with the design of the packaging. Such cultural features serve as visual identifiers, enabling the design to create a unique "Mongolian impression" that resonates with consumers' cultural identity and emotional connections, thereby subtly fostering emotional marketing for the product. This approach ensures that kumis packaging not only meets functional demands but also conveys a strong cultural identity, bridging design, marketing, and heritage to enhance market competitiveness.

From a social perspective, the prioritization of functionality over cultural representation reflects the dual orientation of modern consumers toward practicality and identity expression. For contemporary buyers, functional performance remains a prerequisite for purchase decisions, cultural expression acts as an emotionally engaging layer that enhances users' sense of identity and connection to heritage. This hierarchy of needs mirrors broader consumer culture in which traditional heritage is increasingly appreciated through the lens of modern lifestyles, heritage becomes meaningful when it integrates seamlessly with contemporary usage and aesthetics. Therefore, rather than indicating a decline in cultural awareness or weak demand for cultural consumption, the results suggest that consumers expect cultural representation to coexist with, rather than replace, functional excellence. The design of kumis packaging should thus aim to harmonize utilitarian reliability with culturally resonant expression, ensuring both practical performance and symbolic connection.

Analysis of Mongolian Saddle Culture

Identification and Screening of Mongolian Saddle Samples

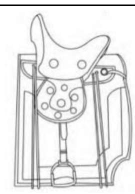
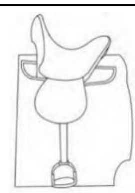
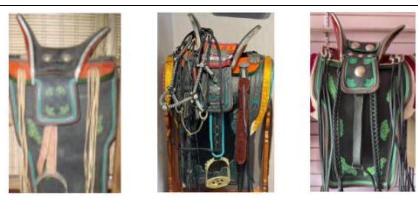
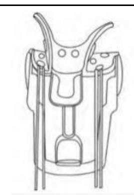
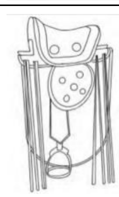
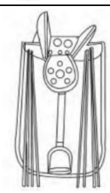
The shapes and types of saddles vary widely across different regions and uses, each showcasing unique aspects of their respective ethnic cultures. Over centuries, the design of Mongolian saddles has undergone a long evolution, gradually forming distinct regional characteristics. In this study, the primary sources for Mongolian saddle sample data include the Inner Mongolia Museum, Ordos Museum, Mongolian Horse Culture Museum, Genghis Khan Mausoleum, traditional saddle-making workshops, and the book *Mongolian Ethnic Saddle and Horse Culture* (He and Qascimeg, 2008). A total of 106 saddle images were collected. To further select representative Mongolian saddle samples for experimentation, this study involved interviews and focus group discussions with three traditional Mongolian saddle inheritors/artisans and two experts/professors specializing in Mongolian culture. Through comparative analysis of the 106 Mongolian saddle images, duplicates and similar samples were filtered out, ultimately identifying 38 representative Mongolian saddles as experimental samples. The affinity diagram method was then used to summarize the typical cultural elements embodied in these experimental samples, constructing a structured visual set of Mongolian saddle culture.

Deconstruction of Cultural Elements in Mongolian Saddles

(1) Extraction of Mongolian Saddle Form Factors

Inner Mongolia, with its vast territory spanning a wide east-west range, is predominantly grassland and home to various tribes. Influenced by a combination of natural and cultural environments, it has developed diverse saddle designs that blend practicality with aesthetic appeal. While the basic structure of Mongolian saddles is consistent—comprising the front pommel, rear cantle, and saddle tree (Duan, 2017)—their design styles vary significantly across regions. The primary types of Mongolian saddles include the Ordos-style saddle, Horchin-style saddle, Ujimqin-style saddle, and Chakhar-style saddle, each exhibiting distinct characteristics in its form. Based on the 38 experimental samples of Mongolian saddles selected in the preliminary screening, saddles of different styles were further studied. Through a comparative analysis of the designs of saddle pads, saddle bodies, and stirrups, five representative morphological characteristics of Mongolian saddles were summarized. Subsequently, the generative rules of shape grammar were used to extract the contour lines of the saddles, which were then refined to create abstract spline curves. Finally, through the above analysis and extraction process, a form factor extraction table was constructed (Table 14).

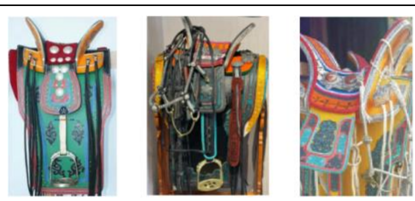
Table 14. Extraction of Mongolian saddle form factors.

Name	Saddle Form Factor Prototype	Contour Feature Line	Simplified Spline Curve
Form Factor 1			
Form Factor 2			
Form Factor 3			
Form Factor 4			
Form Factor 5			

(2) Extraction of Mongolian Saddle Color Factors

The color usage patterns of the Mongolian people are deeply influenced by the natural scenery of the grasslands and their ethnic culture. Their application of colors is characterized by freedom and boldness, resulting in color schemes that align with their historical culture, folk traditions, and aesthetic principles, thereby establishing a unique ethnic color system. Most notably, during the latter half of the 16th century, when Tibetan Buddhism was reintroduced to Mongolia and Tumet Altan Khan converted to Buddhism, the five auspicious colors—blue, yellow, red, green, and black—became popular and gradually shaped the decorative color style of the Mongolian people (Wuyun and Kong, 2016). On the foundation of primary saddle colors, patterns with contrasting local decorative colors are applied in designs using principles such as rotation, bilateral symmetry, and mirroring, creating a dynamic and lively visual effect. In this study, colors were extracted from the images of 38 experimental Mongolian saddle samples selected in the preliminary phase using a color picker tool. The corresponding RGB values were recorded and coded. Comparative analysis revealed that the most common colors in Mongolian saddle decoration are yellow, red, black, blue, and green. Further extraction identified the most frequently occurring RGB values within major categories of the experimental samples, summarizing the typical color elements (Table 15).

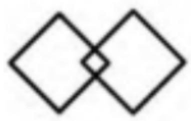
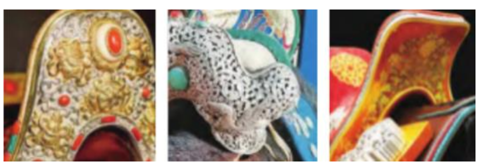
Table 15. Extraction of Mongolian saddle color factors.

Name	Saddle Color Factor Prototype	Color Factors		
Color Factor 1		R:227 G:137 B:10	R:152 G: 82 B:54	R:139 G:22 B:8
Color Factor 2		R:218 G:45 B:61	R:16 G:16 B:16	R:117 G:180 B:132
Color Factor 3		R:173 G:92 B:51	R:106 G:189 B:209	R:174 G:32 B:30
Color Factor 4		R:245 G:208 B:118	R:209 G:13 B:23	R:20 G:27 B:36
Color Factor 5		R:92 G:198 B:177	R:228 G:103 B:38	R:243 G:202 B:30

(3) Extraction of Mongolian Saddle Pattern Factors

The traditional patterns of the Mongolian people have, over a long period of development, inherited ethnic cultural traditions while incorporating elements of agrarian and hunting cultures, forming a unique artistic style. These patterns primarily originate from the Mongolian people's perception, understanding, and imagination of nature. Through abstraction, these perceptions are transformed into simplified motifs and expressed using principles such as parallelism, symmetry, continuity, unity, and rhythm, resulting in balanced designs that emphasize order and harmony. The decorative patterns on Mongolian saddles embody the rich variety and complexity of traditional Mongolian motifs. Common auspicious patterns include the intertwined intestine motif, longevity character motif, scroll grass motif, deer motif, and horn motif, reflecting the Mongolian people's aspirations and longing for a good life. In this study, the proportion of various decorative patterns in the 38 experimental samples of Mongolian saddles selected in the preliminary stage was statistically analyzed. Frequently occurring patterns in saddle decorations were identified. Subsequently, feature lines of these patterns were extracted and summarized using the derivation rules of shape grammar, laying the foundation for subsequent analysis and application (Table 16).

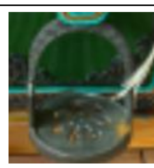
Table 16. Extraction of Mongolian saddle pattern factors.

Name	Saddle Pattern Factor Prototype	Pattern Motif	Pattern Feature Lines
Pattern Factor 1			
Pattern Factor 2			
Pattern Factor 3			
Pattern Factor 4			
Pattern Factor 5			

(4) Extraction of Mongolian Saddle Material Factors

The materials used in Mongolian saddles are an essential part of their cultural significance, reflecting their unique regional style. This study conducted a categorical analysis of the 38 experimental samples of Mongolian saddles selected in the preliminary phase. The overall structural components of the Mongolian saddle were deconstructed, and the commonly used characteristic materials for each component were further analyzed (Table 17).

Table 17. Extraction of Mongolian saddle material factors.

Name	Structural Component	Material Factors	Common Material
Structural Component 1	Saddle Seat: The part where the rider sits, typically located between the front and rear saddle bows.		Leather (mostly cowhide or horsehide tanned in the Mongolian style); or blanket or felt materials
Structural Component 2	Saddle Bow: Divided into the Pommel (front saddle bow) and Cantle (rear saddle bow), these are the main supporting structures of the saddle.		Wood carving or inlaid with metal or silver decorations
Structural Component 3	Saddle Flap: Located on both sides of the saddle, covering the area beneath the rider's legs.		Leather or thick felt, adorned with edging and embroidery
Structural Component 4	Saddle Apron / Saddle Drape: Hanging fabric or leather decorative pieces that cover the rider's legs and the sides of the horse's body.		Mostly soft materials such as leather and felt, often embroidered with patterns, with edges decorated with tassels or metal pieces
Structural Component 5	Saddle Pad / Saddle Blanket: Positioned between the saddle and the horse's back, it acts as a cushion.		Wool felt, blanket material
Structural Component 6	Stirrups: Located on both sides of the saddle, they provide support for the rider's feet.		Metal materials

Generation of Kumis Packaging Design Inspired by Mongolian Saddle Culture Using AIGC

This study constructed the prompt inputs for generative AI based on the extracted visual elements of Mongolian saddle culture (such as patterns, colors, forms, and material characteristics) and the weight calculation results of kumis packaging design demand indicators. First, the design priorities were clarified according to the ranking of the design requirement weights. The key requirement indicators were transformed into descriptive language following their weight ranking; the most important indicators were emphasized by repetition and detailed elaboration in the prompt text to reflect their relative importance. The prompts were entered sequentially according to the priority weights: (leak-proof and break-proof protective performance: 0.32320), (integration of regional characteristic patterns, colors, and material cultural expressions: 0.16506), (unique and aesthetic form design: 0.14581), (clear presentation of product information: 0.08457), and (material texture combining simplicity with quality: 0.08240), together with keywords such as Mongolian saddle cultural elements, kumis packaging design, and ethnic craftsmanship. Second, the structured image set of Mongolian saddles, including linear outlines of shape features, symbolic representations of decorative patterns, RGB values of color factors, and material surface characteristics was used as visual reference input within the Stable Diffusion workspace. The Stable Diffusion v2.1 base model was employed with a CFG scale of 7.5 and 50 sampling steps to balance creative variation and visual coherence. The visual references of Mongolian saddles were placed in the image reference area to guide style and texture generation. Multiple batches were generated and manually screened; unsatisfactory results were refined through iterative prompt adjustment and re-generation until visual and cultural coherence was achieved. The same process was repeated for other concepts, resulting in three final design schemes representing diverse interpretations of Mongolian saddle culture in kumis packaging (see Figure 2). Representative prompt examples are provided in “Supplementary material”-"S1 File".

Fig.2 Kumis packaging design schemes.

The visual characteristics and stylistic choices observed in these three design schemes can be further interpreted through the lens of cultural theory, providing insights into how generative AI manifests cultural elements in the outputs. The cultural theories introduced in the previous section provide important explanatory value for understanding the characteristics of the generated design outputs. For example, several AIGC-generated forms show a tendency to magnify decorative motifs while relatively simplifying structural meanings, a phenomenon consistent with Wang & Adzharuddin’s (2025) concept of “synthetic authenticity,” in which audiences perceive AI-generated heritage as authentic primarily through recognizable stylistic cues rather than deep cultural semantics. Similarly, the selective emphasis on color symbolism in the design outcomes reflects Kirshenblatt-Gimblett’s (1995) argument that heritage often becomes a metacultural production shaped by present aesthetic expectations. These tendencies indicate that AIGC models privilege visually salient cultural features, while deeper functional and ritual meanings require explicit human guidance.

Evaluation and Validation of Design Schemes

To verify the feasibility of the design schemes, this study employs the Fuzzy Comprehensive Evaluation (FCE) method. FCE is suitable for multi-criteria and multi-factor evaluation scenarios, effectively addressing the challenge of quantifying subjective judgments in design evaluations (Wu and Hu, 2020). This study invited the experts involved in the indicator evaluation process to participate in the review. The experts assessed the design schemes using a standardized evaluation form and scored each aspect using a Likert scale. The process of evaluating the schemes using the Fuzzy Comprehensive Evaluation method is as follows:

(1) Establishing the Evaluation Factor Set.

The criteria-level evaluation indicators in the hierarchical model were adopted as the factor set V, V=$\{V_A,V_B,V_C,V_D\}$; the sub-criteria-level indicators were set as $a_i=\{a_1,a_2,...,a_n\}$(i=1,2,3).

(2) Determining the Evaluation Set and Corresponding Scoring Standards.

A Likert five-point scale was used to define the evaluation set and corresponding scoring standards. The evaluation set was defined as $X = \{X_1, X_2, X_3, X_4, X_5\}$= {very satisfied, satisfied, neutral, dissatisfied, very dissatisfied},with different evaluation levels assigned scores as follows: Very Satisfied: 90 – 100, Satisfied: 80 – 90, Neutral: 70 – 80, Dissatisfied: 60 – 70, Very Dissatisfied: below 60.

(3) Constructing the Fuzzy Comprehensive Evaluation Matrix.

The invited expert panel used the mare milk wine packaging design evaluation model to assess the three schemes. The frequency of scores for each sub-criteria-level indicator across different evaluation levels was statistically analyzed to determine the membership degree of each evaluation indicator to each evaluation level. This process was used to construct the fuzzy comprehensive evaluation matrix R for each mare milk wine packaging design scheme. Taking Scheme 1 as an example, R_A , R_B , R_C , R_D represent the evaluation matrices for aesthetics, functionality, cultural , and sustainability, at the sub-criteria level for Scheme 1.

$$R_A=\begin{bmatrix}0.35 & 0.50 & 0.15 & 0.00 & 0.00\\ 0.50 & 0.45 & 0.05 & 0.00 & 0.00\\ 0.30 & 0.60 & 0.10 & 0.00 & 0.00\end{bmatrix}$$

$$R_B=\begin{bmatrix}0.65 & 0.25 & 0.10 & 0.00 & 0.00\\ 0.45 & 0.50 & 0.05 & 0.00 & 0.00\\ 0.05 & 0.50 & 0.40 & 0.05 & 0.00\end{bmatrix}$$

$$R_C=\begin{bmatrix}0.70 & 0.30 & 0.00 & 0.00 & 0.00\\ 0.65 & 0.35 & 0.00 & 0.00 & 0.00\\ 0.55 & 0.40 & 0.05 & 0.00 & 0.00\end{bmatrix}$$

$$R_D=\begin{bmatrix}0.75 & 0.20 & 0.05 & 0.00 & 0.00\\ 0.60 & 0.40 & 0.00 & 0.00 & 0.00\end{bmatrix}$$

Using the weighted average fuzzy operator, the fuzzy comprehensive evaluation matrix is combined with the weights of each evaluation indicator to calculate the evaluation weight vector P for the criteria-level indicators of Kumis packaging design Scheme 1:

$$P_A=\omega_A\circ R_A=(0.4219 \quad 0.5038 \quad 0.0742 \quad 0.0000 \quad 0.0000)$$
$$P_B=\omega_B\circ R_B=(0.5182 \quad 0.3212 \quad 0.1512 \quad 0.0094 \quad 0.0000)$$
$$P_C=\omega_C\circ R_C=(0.6533 \quad 0.3423 \quad 0.0044 \quad 0.0000 \quad 0.0000)$$
$$P_D=\omega_D\circ R_D=(0.7000 \quad 0.2667 \quad 0.0333 \quad 0.0000 \quad 0.0000)$$

On this basis, the comprehensive evaluation vector S of the target layer of kumis packaging design scheme 1 is calculated:

$$S=\omega_V\circ P_V=\omega_V\circ\begin{bmatrix}P_A\\ P_B\\ P_C\\ P_D\end{bmatrix}=(0.5377 \quad 0.3685 \quad 0.0896 \quad 0.0042 \quad 0.0000)$$

By performing weighted calculations using the comprehensive evaluation vector S and the corresponding score values of the evaluation grade set, the overall score for Scheme 1 on a percentage scale was determined to be 84.397. Following the same procedure, the scores for Scheme 2 and Scheme 3 were calculated as 81.537 and 82.694, respectively (detailed calculation data can be found in “Supplementary material”-"S2 File"). Based on the correspondence between fuzzy evaluation grades and scores, all three mare milk wine packaging design schemes were rated as "Satisfactory." This indicates that these design schemes effectively address diverse design requirements and exhibit strong feasibility. Unlike existing kumis packaging, which lacks ethnic characteristics and deeper cultural connotations and thus fails to evoke emotional resonance among consumers, the innovative design schemes proposed in this study achieved particularly high scores in the cultural dimension, demonstrating their ability to effectively convey the rich ethnic culture of the Mongolian people and stand out in a highly competitive market. Furthermore, these design schemes performed well on the environmental and functional dimensions, aligning with current sustainability and usability trends in the packaging industry. The evaluation results validate the strong potential of AIGC tools as valuable co-creators in the design of ethnic cultural and creative products.

These evaluation results also align with the theoretical perspectives discussed earlier. The high cultural scores can be interpreted through Latour’s (2005) STS view of technology as an “actant,” suggesting that AIGC does not merely reproduce cultural motifs but actively shapes the aesthetic translation of Mongolian saddle heritage within the design process. At the same time, the strong performance on culturally symbolic elements, such as color palettes and pattern motifs, corresponds with He et al. (2024), who found that participants unfamiliar with cultural contexts tend to retain visually distinctive features while omitting embedded meanings to some extent. The expert evaluators’ positive responses may therefore reflect the visibility of these symbolic elements rather than full cultural embeddedness, highlighting the need for deeper community participation in future evaluation phases.

Conclusion and Discussion

This study, using the “kumis” packaging design inspired by Mongolian saddle culture as an example, explores the application of generative AI technologies in modern design processes. From identifying and prioritizing design requirements to collecting and deconstructing cultural resources, followed by AIGC design generation and scheme evaluation, this research proposes a full-process innovative design method system that is user-demand-oriented, cultural resource-driven, and AI-supported. The proposed method successfully generated packaging design concepts for kumis inspired by Mongolian saddle culture. The findings indicate that through structured prompt design and cultural factor guidance, AIGC not only generates visually appealing design images but also effectively represents cultural elements to meet design demands. By showcasing kumis packaging design as a case study, this research provides preliminary evidence of the potential value of AIGC as a “co-creator” in supporting the integration of ethnic cultural heritage with modern design innovation. Moreover, this study combines the AIGC tool with scientific methods such as AHP and FCE, enhancing the scientific nature of the systematic analysis of design requirements and the evaluation of design outcomes in the "human + AI" collaborative creation process, thereby providing a paradigmatic reference for future related research. This interdisciplinary approach not only broadens the scope of research in the field of product design but also opens new possibilities for exploring the broader applications of generative AI technologies in cultural creative design and cultural sustainability. The innovation of this study lies not merely in the technical use of AIGC but in constructing an interdisciplinary framework that integrates cultural analysis, human expertise, and AI generation, thereby offering a potential methodological pathway for cultural heritage product innovation.

However, the research also highlights important limitations and wider social and ethical questions that must be addressed for responsible deployment of AIGC in cultural heritage contexts. The first is factors limiting the accuracy and authenticity of AIGC outputs. Although AIGC can reproduce stylistic features rapidly, several factors limit its ability to represent cultural meanings fully: (1) Dataset and representation bias. Many generative models are trained on large-scale datasets with global but uneven cultural coverage. This imbalance can lead to Western-centric or generic aesthetic tendencies and to simplified or stereotyped renderings of non-dominant cultural forms. (2) Stylization and semantic drift. Generative models may emphasize surface patterns, color palettes, or decorative motifs while omitting the performative, ritual, or material practices that confer cultural meaning. The result can be visually compelling but semantically shallow outputs—what might be called "aesthetic surfaces" lacking embedded context. (3) Commodification and reduction. Turning rich heritage into easily marketable visual motifs risks trivializing or commercializing cultural expressions, especially when community perspectives and consent are limited. (4) Tool-specific biases. Different AIGC platforms (and their underlying datasets and generation algorithms) produce distinct stylistic tendencies; outputs are therefore sensitive to tool choice and prompt phrasing.

Recognizing these limitations, the study reframes AIGC as a collaborator in a mediated design process. AIGC serves as a co-creative tool, while human designers play an essential leading role in guiding generation, interpreting and validating the cultural meanings embedded in generated outputs, and screening and optimization processes. While AIGC expands creative possibilities through visual generation, human designers remain the core drivers of innovation. The effectiveness of cultural element transformation and representation does not rely solely on AIGC's generative capability, but on human–AI collaboration that ensures semantic depth, cultural fidelity, and creative intent. To reduce risks and strengthen cultural fidelity, we recommend the following research and practice measures, many of which were integrated into our workflow or are proposed for future work: (1) Expert and community involvement at all stages. Involving cultural practitioners, artisans, and community representatives in element selection, prompt validation, and final evaluation grounds the generative process in lived knowledge and norms of authenticity. (2) Dataset augmentation and local references. Supplementing model guidance with curated local visual references or fine-tuning on ethically sourced, representative imagery reduces over-generalization. (3) Iterative human review. A loop of generation, expert review, prompt refinement (rather than one-shot generation) helps ensure outputs better reflect nuanced meanings. (4) Tool comparative analysis. Testing multiple generation platforms (Stable Diffusion, Midjourney, DALL·E, etc.) reveals tool-dependent artifacts and helps select approaches aligned with cultural fidelity objectives. (5) Ethical guardrails. Clear policies on rights, attribution, and community consent (including compensation where appropriate) should accompany any commercialization. Beyond technical mitigation, the social dimension is central. The method proposed here can contribute to the sustainable inheritance of intangible heritage by making cultural forms legible to new audiences, enabling reinterpretation that supports identity and intergenerational transmission. At the same time, since marketization can create economic opportunities but may also commodify and distort tradition, designers and institutions must balance innovation with protection.

In addition, this study has several specific limitations. First, generated concepts were not undergone physical prototyping or broad market trials. Second, the expert evaluation sample size was moderate and community participatory validation (e.g., structured feedback from a wider group of artisans and local consumers) was limited. However, deeper community participation could reshape the evaluative processes in future studies. Cultural practitioners and artisans do not merely provide supplemental feedback; rather, their interpretive knowledge can introduce culturally grounded evaluative dimensions that extend beyond the current FCE framework. For example, community participants may assess whether generated motifs preserve the symbolic logic, ritual significance, or material coherence embedded in traditional saddle craftsmanship, criteria that experts alone may not fully capture. Integrating such community participatory validation would shift the evaluation from surface-level satisfaction toward culturally informed legitimacy, reinforcing the authenticity, ethical grounding, and cultural continuity of AI-assisted design. In the present study, community participation was included but not fully embedded as a constitutive methodological stage within the evaluation framework. Future research should structurally integrate participatory community co-design into the evaluative process itself. Further methodological refinement should also strengthen the integration of cultural theory into the evaluative framework, moving beyond interpretive discussion toward more theory-informed evaluation design. This deeper involvement would also strengthen the co-creative dynamics among human designers, AI systems, and cultural communities, ultimately helping to produce design outcomes that better reflect lived cultural knowledge and identity. Furthermore, the empirical findings of this study should be interpreted as preliminary rather than conclusive, given that they were generated under specific methodological conditions, including a single generative model, a limited expert panel, and a culturally bounded case study context. As such, the generalizability of the results to other cultural heritage domains or broader AI-assisted design practices remains limited and requires further investigation. Third, we used a single primary generation tool in the current experiments; formal cross-platform comparisons and controlled ablation studies would clarify how tool choice affects cultural representation. Future research should therefore: (1) conduct prototyping and market testing; (2) expand participatory methods to include more direct co-creation and more extensive participatory evaluation with artisans and community stakeholders; and (3) compare outputs across multiple AIGC platforms and model variants.

In sum, AIGC can substantially accelerate the generation and diversification of culturally informed design options, but its responsible application depends on embedding social-scientific attention to authenticity, ethics, community agency, and policy. When positioned as a co-creative partner, guided by expert knowledge, community participation, and transparent methods, AIGC can contribute to innovative, culturally meaningful, and socially sustainable design practices that help revitalize intangible heritage in ways that respect both tradition and contemporary needs.

Supplementary material

S1 File. Representative prompt examples

S2 File. Calculate data supplements

Data availability

All relevant data that supports the findings of this study are available within the manuscript and supplementary material files.

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Competing interests

The authors declare no competing interests.

Ethical approval

All procedures in this study were reviewed and approved by the Ethics Review Board of Inner Mongolia Technical College of Construction (IMTCC) (Approval Number: 202501003) on 3 January 2025. All data were collected, recorded, and stored anonymously and confidentially. The study strictly adhered to relevant ethical guidelines and regulations to ensure the protection of participants' privacy, dignity, and rights. The results presented in this study are original and have not been published or submitted elsewhere. This research did not involve clinical trials, animal experiments, human tissues, biological samples, or sensitive topics such as religious beliefs, racial identity, political views, sexual orientation, or financial information. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed consent

Written informed consent was obtained from all participants prior to data collection. Consent was collected between 5 January 2025 and 28 February 2025 by the corresponding author and research team from all participants involved in this study. Before participation, all participants were provided with an information sheet outlining the research purpose, procedures, voluntary nature of participation, right to withdraw without penalty, data usage, and publication of aggregated results. The consent covered participation in the study, the use of anonymized data for academic analysis, and the publication of aggregated research findings. All participants were fully and clearly informed that no personally identifiable information would be collected, that anonymity would be strictly protected, and that all data would be securely stored and analyzed anonymously. The study posed no foreseeable physical, psychological, or social risks.

Additional information

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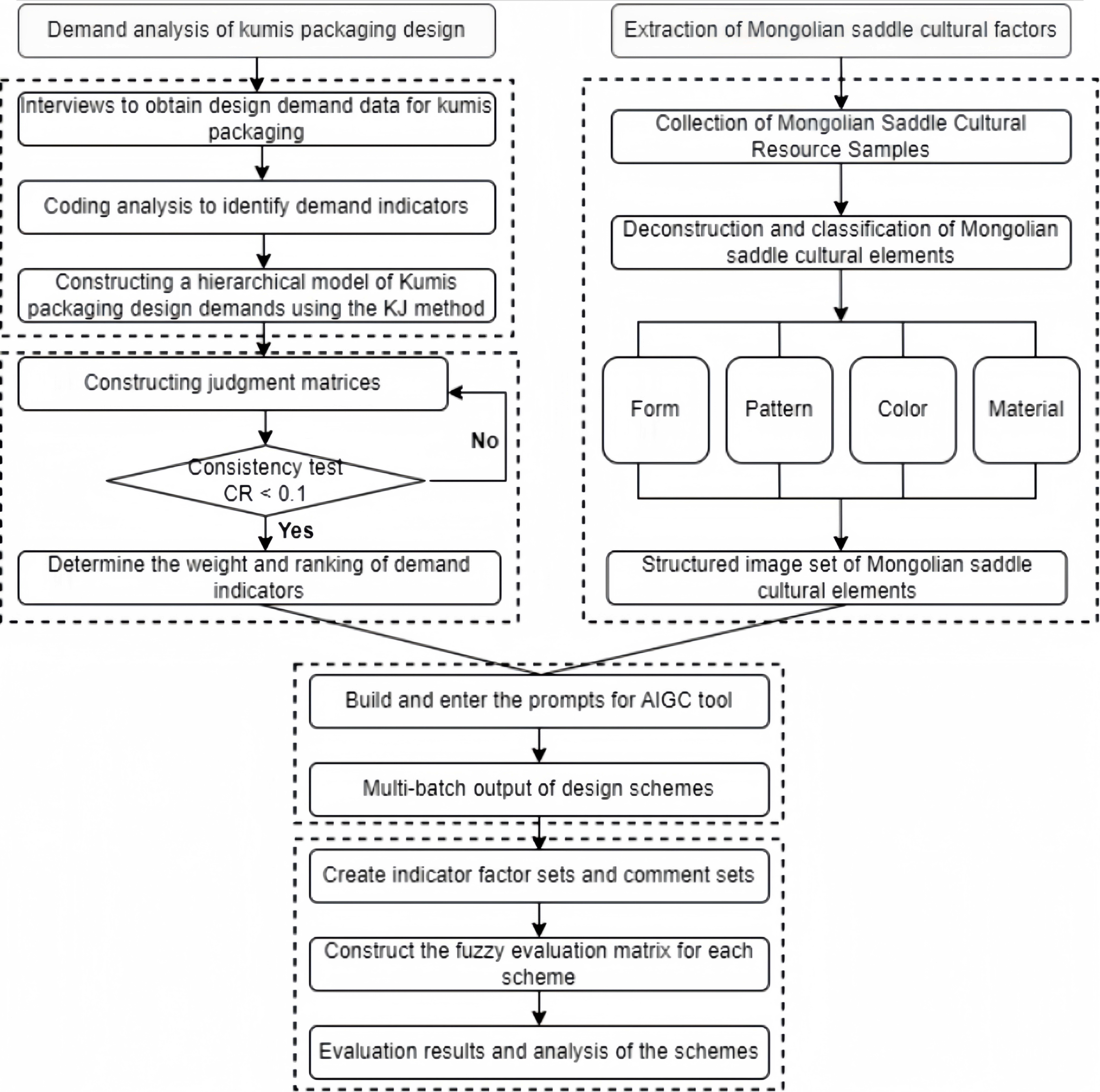
Demand analysis of kumis packaging design
Interviews to obtain design demand data for kumis packaging
Coding analysis to identify demand indicators
Constructing a hierarchical model of Kumis packaging design demands using the KJ method
Constructing judgment matrices
No
Consistency test
CR < 0.1
Yes
Determine the weight and ranking of demand indicators
Extraction of Mongolian saddle cultural factors
Collection of Mongolian Saddle Cultural Resource Samples
Deconstruction and classification of Mongolian saddle cultural elements
Form
Pattern
Color
Material
Structured image set of Mongolian saddle cultural elements
Build and enter the prompts for AIGC tool
Multi-batch output of design schemes
Create indicator factor sets and comment sets
Construct the fuzzy evaluation matrix for each scheme
Evaluation results and analysis of the schemes

scheme 1

scheme 2

scheme 3