

Humanity in the Loop: Ethical AI-Enabled Packaging Design for Rural Agricultural Revitalization in Zhaizixiang, China

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Abstract Although AI-enabled packaging has gained attention in agricultural branding, limited research has examined its ethical and human-centered application in rural revitalization, especially for Generation Z. This study investigates how AI-enabled packaging influences Gen Z's purchase intention for Zhaizixiang agricultural products in China's Shanxi Province under the "Humanity-in-the-Loop" framework.

Using a mixed-method design, we surveyed 400 Gen Z consumers (aged 16–30) in Shanxi Province, China. After data cleaning, 382 valid responses were retained for structural equation modeling (SEM) using AMOS 28.0. And ten semi-structured interviews were also conducted.

Results show that cultural symbol expression ($\beta = 0.61, p < 0.001$), AI-driven interactive experience ($\beta = 0.68, p < 0.001$), and perceived usefulness ($\beta = 0.57, p < 0.001$) significantly enhance emotional experience and cultural identity. The total indirect effects of design elements on purchase intention via the two mediators were $\beta = 0.312$ (95% CI: 0.235–0.394) for emotional experience and $\beta = 0.211$ (95% CI: 0.146–0.282) for cultural identity, suggesting full mediation. AI-driven interaction had the strongest direct effect on emotional experience.

Human-centered, ethical AI packaging effectively promotes rural brand engagement. Practical strategies (AIGC, AR, NFC) are proposed. Limitations include regional sampling (Shanxi only—findings may be most relevant to western China's rural revitalization contexts) and potential digital literacy barriers among elderly or low-literacy users. Generalizability beyond similar rural contexts should be made with caution.

Keywords: Humanity-in-the-Loop; AI-enabled packaging; AI empowerment; Zhaizixiang agricultural products; Cultural heritage

1. INTRODUCTION

Global consumption upgrading and cultural confidence-based development have greatly changed the role of brand packaging. No longer limited to protecting products or providing information, packaging now serves as a core interface for sensory engagement, emotional communication, cultural transmission, and human-centered value expression. For Generation Z (1996–2010), born as "digital natives", consumption behavior goes beyond utility to include self-expression, emotional satisfaction, social interaction, and value affirmation. They seek authentic experiences and genuine connections, embodying a more people-centric mindset in purchasing decisions. The "Humanity in the Loop" theme of this conference directly aligns with these behavioral shifts. (Ke, 2019)

In the Chinese context, national strategies promoting cultural revitalization and innovative development make it important to integrate traditional regional culture into modern design. Shanxi Province has thousands of years of history and rich cultural heritage—merchant culture, architectural traditions, intangible cultural heritage such as paper-cutting and vinegar-

brewing techniques, and unique folk art—providing a strong setting for this research. Local specialty brands, including the famous "Gong Tian Xia" chain, urgently need human-centered and creative packaging that appeals to young consumers. (Cengage, 2019) Most current packaging remains rigid and conventional, not aligned with Generation Z's preference for personalized aesthetics. (Chen, 2023)

Despite growing research on packaging design and consumer behavior, few studies have combined regional cultural symbols, experiential perception mechanisms, and human-centered design ethics into one integrated framework for local specialty brands targeting Generation Z. This gap leads to three main questions: (1) Which dimensions of packaging experience design most strongly drive Generation Z's purchase decisions? (2) How do brand experience perception and packaging experience perception mediate between design inputs and behavioral outcomes? (3) What practical human-centered packaging design strategies enable local brands to engage effectively with Generation Z?

This study addresses these questions through a human-centered, ethically grounded

lens, providing empirical evidence for cultural inheritance and sustainable design. It integrates real consumer experience and ethical design values into an interdisciplinary conversation about people-centered design within cultures, while offering practical guidance for companies seeking to connect tradition with innovation.

2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 THEORETICAL FOUNDATIONS

This study selects three core design theories, all closely integrated with the author's years of teaching practice in agricultural product packaging design within the Packaging System Design course, in which over 100 student works have won national and provincial awards in 84 discipline competitions recognized by the Chinese Ministry of Education. Additionally, the author's provincial project Exploration of Project-Driven Curriculum Reform Based on OBE Concept—Taking the Course of Packaging System Design as an Example (completed) and several published papers on agricultural product packaging provide direct theoretical guidance for variable definition and hypothesis formulation.

Human-centered design theory (Norman, 2013) is the core theoretical foundation. It advocates that design should take human needs, experience, and psychological perception as the starting point and destination, balancing functional, emotional, (Underwood., & Klein, 2002) or (Wang., & Li, 2023) and experiential values. This theory guides the definition of perceived usefulness (reflecting how functional packaging meets users' practical needs) and user emotional experience (reflecting how emotional design evokes resonance), and interprets the core logic of Humanity in the Loop—AI technology is a tool for innovation, (Khen., Rahman., & Fatman, 2022) but true design creativity and emotional goals serve Generation Z consumers' multidimensional needs. (Song., et al, 2023)

Visual communication theory (Visual Hammer) (Ries & Ries, 2011) clarifies that brand communication needs visual images as a “hammer” to implant brand positioning “nails” into consumers' minds, holding that visual symbols are the core carrier of information transmission and cultural expression. Based on this theory, this study defines the cultural symbol expression variable, systematically extracting, visually encoding, and digitally translating regional cultural elements such as loess cave dwellings and pear blossom culture in Zhaizixiang

into packaging design. It also employs synesthetic mechanisms combining vision, hearing, taste, touch, and smell with AI technology.

Experience design theory (Schmitt, 1999) or (Pine & Gilmore, 1998) emphasizes that modern design should create multidimensional, immersive, and interactive experiences through the integration of design elements and technical means, covering sensory, emotional, cognitive, and behavioral experiences. Based on this theory, this study constructs the AI-driven interactive experience variable, integrating digital technologies such as AIGC, AR, and NFC into packaging design to create multi-sensory interactive experiences for Generation Z.

These three core design theories are interrelated and complementary. Together with the conference theme Humanity in the Loop, they form a complete theoretical framework, avoiding overlap with existing dissertation research, (Liu., Zhon, 2023) and providing direct theoretical guidance for variable definition, conceptual framework construction, and hypothesis formulation. (Magnier., & Schoormans, 2015)

2.2 RESEARCH VARIABLES

Based on the three core design theories and AI-enabled packaging design practice in Zhaizixiang, this study defines six core variables. Independent Variables

Cultural symbol expression: Supported by visual communication theory, this variable refers to the digital innovation, (Zhang., & Chen, 2024) and visual transmission of regional cultural elements (loess cave dwellings, pear blossom culture, farming landscapes) in AI-enabled packaging.

AI-driven interactive experience: Based on experience design theory, this variable describes the immersive multi-sensory experience created by AIGC, AR, NFC, and QR codes in interactive packaging scenarios.

Perceived usefulness: Derived from human-centered design theory, this variable reflects consumers' perceived practical value, functional convenience, and sustainable design of packaging. Mediating Variables

User emotional experience: Supported by human-centered and experience design theories, this variable refers to positive emotional responses (pleasure, satisfaction, resonance) triggered by packaging interaction.

Perceived cultural identity: Guided by visual communication and human-centered design theories, this variable indicates consumers' recognition, belonging, and pride toward

Sample size justification: Following guidelines for SEM (Kline, 2016) or (Hair, et al., 2019) a minimum of 10-20 cases per estimated parameter is recommended. The proposed model includes 6 latent variables and 28 estimated parameters, requiring a minimum of 280-560 cases. Our final sample ($N = 382$) falls well within this range, providing adequate statistical power (exceeding 0.80 for medium effect sizes at $\alpha = 0.05$).

3.3 MEASURES

All constructs used validated scales from existing literature, slightly modified for the context of AI-enabled packaging for Zhaizixiang agricultural products in Shanxi. Respondents rated items on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Cultural Symbol Expression (4 items; $\alpha = 0.87$): Adapted to measure the presence and clarity of regional cultural elements in packaging design.

AI-Driven Interactive Experience (5 items; $\alpha = 0.89$): Assessed the immersive and interactive quality of AI-enabled packaging features.

Perceived Usefulness (4 items; $\alpha = 0.86$): Measured the practical function, convenience, and usability of packaging.

User Emotional Experience (5 items; $\alpha = 0.88$): Captured emotional resonance, pleasure, and satisfaction from packaging interaction.

Perceived Cultural Identity (5 items; $\alpha = 0.90$): Evaluated consumers' recognition, belonging, and pride toward local culture conveyed through packaging.

Purchase Intention (5 items; $\alpha = 0.87$): Included purchase willingness, repurchase intention, and recommendation intention.

Construct validity was confirmed by confirmatory factor analysis (CFA); all items loaded significantly on their intended constructs, and the measurement model showed good fit ($CFI > 0.90$, $RMSEA < 0.08$).

3.4 DATA COLLECTION PROCEDURE

Questionnaires were distributed on-site by trained investigators using standardized guidance to ensure accurate understanding. Participation was voluntary, and completion time was controlled at 8–10 minutes.

Semi-structured interviews were conducted with 10 participants: 5 Generation Z consumers who had visited Zhaizixiang or were local residents, 3 local operators, and 2 design practitioners. The interviews focused on agricultural product packaging design preferences and purchase motivations. With informed consent, interviews were recorded and transcribed for thematic coding analysis.

3.5 DATA ANALYSIS

Quantitative data were analyzed using SPSS v.28.0 for descriptive statistics, reliability, and validity tests. AMOS v.28.0 was used to construct structural equation models for path hypothesis testing and mediation effect verification (bootstrap with 5,000 resamples).

Common Method Bias Assessment: Given that all data were collected from self-reports, Harman's single-factor test was conducted to assess the risk of common method variance (CMV). An unrotated exploratory factor analysis on all 28 measurement items yielded seven factors with eigenvalues > 1.0 , and the first factor explained only 27.4% of the total variance, well below the recommended threshold of 50% (Podsakoff et al., 2003). Additionally, a common latent factor (CLF) approach was employed. The CLF model showed that the differences in standardized regression weights between the CLF model and the baseline model were all less than 0.15, and model fit did not improve substantially ($\Delta CFI < 0.01$). These results indicate that common method bias is not a serious concern in this study.

Post-hoc Power Analysis: Following Preacher and Coffman (2006), Monte Carlo simulation (5,000 replications) was conducted. The observed power for the indirect effects was 0.94 (95% CI: 0.90-0.97) for emotional experience mediation and 0.89 (95% CI: 0.84-0.94) for cultural identity mediation, exceeding the recommended threshold of 0.80 (Cohen, 1988).

Qualitative data from semi-structured interviews were analyzed using thematic coding following the procedures of Braun and Clarke (2006), which was then cross-validated with quantitative results.

3.6 ETHICAL CONSIDERATIONS

This study was conducted in accordance with the ethical guidelines of Southeast Asia University. Participants were informed of the study's objectives and their rights, including voluntary participation, anonymity, and the ability to withdraw at any stage. Informed consent was obtained from all participants, and data were anonymized prior to analysis. Data were stored securely and used solely for research purposes.

4. RESULTS

4.1 RELIABILITY AND VALIDITY

All constructs demonstrated excellent reliability. Composite reliability (CR) ranged from 0.86 to 0.90, exceeding the recommended threshold of 0.70. Convergent validity was confirmed, with average variance extracted (AVE) ranging from 0.69 to 0.82 (all > 0.50).

Discriminant validity was supported by the Fornell-Larcker criterion: the square root of AVE

for each construct exceeded its correlation with any other construct.

Table 1. Correlations and Discriminant Validity

Construct	CR	AVE	1	2	3	4	5	6
1. Cultural Symbol Expression	0.86	0.69	0.83					
2. AI-Driven Interactive Experience	0.89	0.77	0.65	0.88				
3. Perceived Usefulness	0.87	0.71	0.68	0.72	0.84			
4. User Emotional Experience	0.88	0.73	0.73	0.74	0.79	0.85		
5. Perceived Cultural Identity	0.90	0.78	0.71	0.76	0.82	0.81	0.88	
6. Purchase Intention	0.86	0.69	0.67	0.70	0.75	0.83	0.80	0.83

Note: Diagonal values (bold) are the square roots of AVE; off-diagonal values are correlations between

4.2 MODEL FIT

The structural equation model achieved excellent overall fit. All indices fully met or exceeded recommended academic criteria: CMIN/DF = 2.17 (≤ 3), GFI = 0.93 (> 0.90), CFI = 0.96 (> 0.90), RMSEA = 0.056 (< 0.08). These results validate the rationality and stability of the proposed *Humanity in the Loop* framework and confirm the model's suitability for hypothesis testing.

4.3 HYPOTHESIS TESTING

All ten hypotheses were supported. Key findings include:

Direct Effects: Cultural Symbol Expression (H1: $\beta = 0.61$, $p < 0.001$), AI-Driven Interactive Experience (H2: $\beta = 0.68$, $p < 0.001$), and Perceived Usefulness (H3: $\beta = 0.57$, $p < 0.001$) all showed significant positive effects on User

Table 2. Path Coefficients and Hypothesis Testing Results

Hypothesis	Path	β	t	p	Result
H1	Cultural Symbol Expression $\rightarrow$ User Emotional Experience	0.61	11.26	<0.001	Supported
H2	AI-Driven Interactive Experience $\rightarrow$ User Emotional Experience	0.68	12.73	<0.001	Supported
H3	Perceived Usefulness $\rightarrow$ User Emotional Experience	0.57	10.41	<0.001	Supported
H4	Cultural Symbol Expression $\rightarrow$ Perceived Cultural Identity	0.70	13.18	<0.001	Supported
H5	AI-Driven Interactive Experience $\rightarrow$ Perceived Cultural Identity	0.65	12.09	<0.001	Supported
H6	Perceived Usefulness $\rightarrow$ Perceived Cultural Identity	0.54	9.87	<0.001	Supported
H7	User Emotional Experience $\rightarrow$ Purchase Intention	0.76	14.92	<0.001	Supported
H8	Perceived Cultural Identity $\rightarrow$ Purchase Intention	0.73	14.25	<0.001	Supported
H9	User Emotional Experience (Mediation)	—	—	<0.001	Supported
H10	Perceived Cultural Identity (Mediation)	—	—	<0.001	Supported

Key findings include: AI-Driven Interactive Experience presented the strongest effect on User Emotional Experience ($\beta = 0.68$). Cultural Symbol Expression showed the strongest effect on Perceived Cultural Identity ($\beta = 0.70$).

4.4 TESTING THE MEDIATING EFFECT

Bootstrap analysis (5,000 resamples) was conducted to test the mediating effects. The results showed significant indirect effects for both mediators, with 95% confidence intervals not containing zero.

Table 3. Correlations and Discriminant Validity

Mediating Path	Indirect Effect	95% CI	Effect Type
Packaging Design Elements → User Emotional Experience → Purchase Intention	0.312	[0.235, 0.394]	Significant
Packaging Design Elements → Perceived Cultural Identity → Purchase Intention	0.211	[0.146, 0.282]	Significant

Note: The term “suggest full mediation” is used cautiously, as full mediation cannot be statistically proven but is indicated by non-significant direct paths after controlling for mediators (Baron & Kenny, 1986).

4.5 KEY FINDINGS OF AI-ENABLED PACKAGING DESIGN

Under the *Humanity in the Loop* framework, this study centers user experience and integrates AI and digital technologies into Zhaizixiang agricultural product packaging. It extends multidimensional digital content within a limited physical space while coordinating technological empowerment, cultural communication, and user needs.

4.5.1 AIGC + AR DIGITAL CONTENT DESIGN

AIGC generates and visually transforms regional cultural elements, and AR creates immersive interactive scenes with 3D landscapes and audio narration. This design follows human perception and fully embodies the people-oriented logic of *Humanity in the Loop*.

4.5.2 NFC + PRODUCT TRACEABILITY INTERFACE DESIGN

NFC enables full-process product traceability covering production, logistics, and quality inspection. Consumers access authentic information via near-field contact. AI-assisted data updating ensures transparency and returns the right of knowledge to users.

4.5.3 QR CODE + VILLAGE CULTURAL MINI-PROGRAM DESIGN

A cultural experience mini-program is built via a package QR code, forming a closed loop of packaging, experience, consumption, and communication. With user needs as core nodes, AI optimizes interaction and provides a practical paradigm for traditional village intelligent packaging.

4.6 QUALITATIVE FINDINGS

Semi-structured interviews with 10 participants (5 Generation Z consumers, 3 local operators, 2 design practitioners) were analyzed using thematic coding (Braun & Clarke, 2006). Interviews lasted 25-40 minutes each, were transcribed verbatim, and coded independently by two researchers.

Inter-rater reliability was high (Cohen's $\kappa = 0.86$). Disagreements were resolved through discussion. Four main themes emerged, each providing contextual depth to the quantitative findings.

Summary of Qualitative Themes and Representative Quotes:

Theme 1: “Technology feels fresh but not overwhelming” – “I scanned the QR code and saw the pear blossom animation – it made me want to learn more about the village” (Consumer, female, 22) Supports H2: AI-driven interactive experience → Emotional experience ($\beta = 0.68$)

Theme 2: “Cultural symbols make it feel authentic” – “The cave dwelling pattern on the box reminded me of my hometown” (Consumer, male, 24) Supports H4: Cultural symbol expression → Cultural identity ($\beta = 0.70$)

Theme 3: “Usability matters more than flashiness” – “We need packaging that works for everyone, not just young people” (Local operator, male, 45) Highlights need for inclusive design; addresses digital literacy barriers.

Theme 4: “Packaging tells the village story” – “When I see these designs, I feel proud of our local heritage” (Consumer, female, 20) Supports H8: Cultural identity → Purchase intention ($\beta = 0.73$)

These qualitative insights corroborate the quantitative findings, confirming that AI-driven interactive experience and cultural symbol expression are powerful drivers but must be balanced with perceived usefulness and universal usability.

5. DISCUSSION AND IMPLICATIONS

5.1 THEORETICAL IMPLICATIONS

This study makes several theoretical contributions to the fields of AI-enabled packaging design, consumer behavior, and rural revitalization.

First, it enriches the application of design theories – human-centered design (Norman, 2013), visual communication theory (Ries & Ries, 2011), and experience design theory (Schmitt, 1999; Pine & Gilmore, 1998) – in the context of rural AI-enabled packaging. The findings verify the

explanatory power of these theories for Generation Z consumer behavior in traditional village agricultural product branding, an area previously underexplored.

Second, this study clarifies the dual mediating mechanism of user emotional experience and perceived cultural identity. While previous research has separately examined emotional responses or cultural identification in packaging design, few studies have integrated both as parallel mediators within a single framework. The results demonstrate that both mediators fully transmit the effects of design elements to purchase intention.

Third, this study improves the theoretical connotation of Humanity in the Loop within packaging design. Existing AI governance research has predominantly focused on technology-centered perspectives, such as algorithmic transparency and data privacy. By contrast, this study provides a design-centered interpretation, demonstrating that AI serves as an innovative tool while human emotional needs, cultural identity, and experiential quality remain the ultimate design goals.

5.2 PRACTICAL IMPLICATIONS

Based on the findings, this study proposes four actionable design strategies for AI-enabled agricultural product packaging in traditional villages such as Zhaizixiang.

AI-assisted cultural visual design – AI-assisted cultural visual design – Practitioners should use AIGC tools to creatively encode regional cultural symbols into packaging visuals. The strong effect of cultural symbol expression on perceived cultural identity ($\beta = 0.70$) indicates that authentic, well-executed cultural representation significantly enhances consumers' sense of belonging and heritage pride.

Lightweight interactive design – Rather than implementing complex, resource-intensive technologies, designers should integrate lightweight, accessible interactive features such as AR scene scanning, QR code-linked mini-programs, and NFC tap-to-trace functions. The finding that AI-driven interactive experience had the strongest effect on user emotional experience ($\beta = 0.68$) suggests that even relatively simple interactive elements can generate significant emotional resonance when well-designed.

Human-centered functional design – Perceived usefulness ($\beta = 0.57$) remains a significant driver of both emotional experience and cultural identity. Designers should not neglect basic functional

considerations such as portability, shockproof protection, user-friendly opening mechanisms, and sustainable materials.

Inclusive design for varied digital literacy levels – The qualitative finding that operators expressed concern about usability for older buyers highlights an important practical consideration. While this study focused on Generation Z consumers, real-world implementation of AI-enabled packaging should consider that purchasing decisions may be made by or influenced by older family members. Recommended inclusive strategies include: (a) providing simple text-only instructions alongside QR codes; (b) ensuring that essential product information (e.g., ingredients, expiration dates) remains visible without requiring digital interaction; and (c) offering non-digital alternatives (e.g., printed cultural booklets) for those who cannot or prefer not to use interactive features. This inclusive approach aligns fully with the Humanity-in-the-Loop philosophy, which prioritizes human needs over technological sophistication.

5.3 COMPARISON WITH PREVIOUS RESEARCH

This study was conducted in Shanxi Province, China. Zhaixiang is a representative poverty-alleviation village in western China, characterized by loess plateau geography, traditional cave dwellings, and pear blossom cultural heritage.

Readers are cautioned that findings may not fully generalize to all rural regions globally. The results are most relevant to western China's rural revitalization contexts, which share similar challenges: aging populations, outmigration of youth, limited digital infrastructure, and strong cultural traditions. Generalizability to economically developed eastern China, international contexts, or non-agricultural rural settings requires further empirical validation

Unique contributions of this study:

(1) First empirical test of AI-enabled packaging in a poverty-alleviation village context (Zhaiziang).

(2) Dual mediation model (emotional + cultural) under Humanity-in-the-Loop framework.

(3) Mixed-method validation with SENI and thematic analysis.

(4) Practical design strategies (AIGC+AR, NFC, QR mini-program) grounded in statistical evidence.

Table 4. Comparative Summary with Prior Literature

Study	Focus	Key Finding	Comparison with Current Study
Magnier & Schoormans (2015)	Sustainable packaging → emotional response	Emotional pathway mediates purchase intention	Supports; we add cultural identity as second mediator
Djafarova & Bowes (2021)	Visual design → Gen Z impulse buying	Visual aesthetics drive engagement	Extends to rural agricultural context with cultural symbols
Wang & Li (2023)	Cultural identity → purchase intention (regional products)	Sensory experience mediates	Refines by adding AI-driven interaction as antecedent
Khan et al. (2022)	Packaging experience → purchase intention	Emotional perception as mediator	Confirms; we add technology (AI, AR, NFC) dimension
Liu & Zhao (2023)	Digital empowerment → rural brand engagement	Interactive packaging positively affects behavior	Supports; we provide empirical SEM evidence
Zhang & Chen (2024)	Human-AI collaboration in packaging	Ethical AI enhances cultural transmission	Extends with Humanity-in-the-Loop framework

6. CONCLUSION

6.1 SUMMARY OF FINDINGS

Based on three major design theories—human-centered design, visual communication theory, and experience design theory—this study constructs and empirically tests a theoretical model of “AI-enabled packaging design elements → emotional experience and cultural identity → purchase intention.” Using structural equation modeling with 400 valid responses and supplemented by qualitative interviews with 10 participants, the study draws the following conclusions.

First, all three packaging design elements—cultural symbol expression, AI-driven interactive experience, and perceived usefulness—significantly and positively affect both user emotional experience and perceived cultural identity. Among these, AI-driven interactive experience exerts the strongest influence on user emotional experience ($\beta = 0.68$), while cultural symbol expression shows the strongest effect on perceived cultural identity ($\beta = 0.70$).

Second, both user emotional experience and perceived cultural identity significantly and positively predict purchase intention, with standardized coefficients of 0.76 and 0.73 respectively. Bootstrap analysis confirms that both variables fully mediate the relationships between design elements and purchase intention, meaning that design elements drive purchase intention primarily through the emotional and cultural pathways rather than directly.

Third, the findings verify the core logic of Humanity in the Loop: AI and digital technologies serve as innovative tools, but the ultimate design goals remain human-centered – meeting Generation Z consumers' needs for emotional resonance, cultural identity, and practical usability.

6.2 LIMITATIONS

This study has several limitations that should be acknowledged.

First, regional limitation: The sample was drawn exclusively from Shanxi Province, China. While Zhaixiang is representative of poverty-alleviation villages in western China, findings may not be fully generalizable to other regions with different cultural, economic, or technological contexts. The results are most applicable to similar western China rural settings; extrapolation to eastern China, international contexts, or non-agricultural rural areas requires additional validation.

Second, digital literacy barriers: As noted in the qualitative findings, local operators expressed concern that older consumers or those with limited technological proficiency might struggle with interactive features. This study did not systematically measure digital literacy levels among participants; future research should include such measures to assess potential moderating effects.

Third, product category specificity: This study did not distinguish between different types of agricultural products (e.g., fresh produce versus processed goods, staple crops versus specialty items). Packaging design requirements and

consumer expectations may vary significantly across categories.

Fourth, intention-behavior gap: The study measured purchase intention rather than actual purchase behavior. While intention is a strong predictor of behavior, the gap between intended and actual purchasing should be acknowledged.

Fifth, cross-sectional design: The study used a cross-sectional survey, which captures relationships at a single time point but cannot establish long-term causal ordering.

Sixth, sampling method: Cluster sampling was employed, which may introduce clustering effects. Future research should consider stratified random sampling to enhance representativeness.

6.3 FUTURE RESEARCH DIRECTIONS

Based on the limitations and findings of this study, several directions for future research are proposed.

Cross-regional comparative studies: Future research should expand to multiple provinces across eastern, central, and western China, enabling comparative analysis of how regional economic development levels and cultural contexts moderate the relationships identified.

Digital literacy as a moderator: Future research should systematically measure digital literacy and age to examine whether the effectiveness of AI-enabled packaging varies across different user groups. Design strategies that are inclusive across age groups and technological familiarity levels would align more fully with the Humanity-in-the-Loop philosophy.

Product category comparison: Researchers should compare different agricultural product categories (e.g., fresh produce vs. processed goods, staple crops vs. specialty items). High-value specialty products may benefit more from elaborate AI-enabled packaging than everyday staple products.

Bridging the intention-behavior gap: Future research should validate purchase intention against actual purchase behavior. Possible approaches include (a) tracking QR code scan-to-purchase conversion rates; (b) conducting A/B testing with prototype packaging in actual retail settings; or (c) partnering with e-commerce platforms to link survey responses with subsequent purchase data (with proper ethical approvals). Such validation would significantly strengthen the empirical credibility of the proposed framework.

Longitudinal studies: Tracking consumers over multiple purchase cycles would help determine whether the strong effects observed persist over time or diminish with repeated exposure.

Emerging technologies: The metaverse, blockchain-based provenance tracking, and voice-interactive packaging offer new possibilities for rural brand engagement. Future research could explore how these technologies interact with cultural symbol expression and emotional experience.

AI ethics and cultural authenticity: Future research should examine potential negative consequences of AI-enabled packaging, such as cultural misrepresentation, privacy concerns related to data collection via QR codes/NFC, and the risk of "techno-solutionism" that overlooks underlying rural development challenges.

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