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SMART PACKAGING AND CONSUMER ENGAGEMENT: THE ROLE OF QR CODES, AR, AND AI IN PRIVATE LABEL BRANDING

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ABSTRACT

The study explores how smart packaging technologies QR codes, augmented reality (AR), and artificial intelligence (AI) influence consumer engagement with private label products. Drawing upon the Technology Acceptance Model (TAM) and Uses and Gratifications Theory (UGT), the research employs a quantitative approach using data from 300 respondents familiar with smart packaging. Structural Equation Modelling (SEM) confirms significant positive relationships between QR code interactivity ($\beta = 0.32$), AR experience ($\beta = 0.28$), AI personalization ($\beta = 0.35$), and consumer engagement ($R^2 = 0.63$). The findings highlight that AI personalization exerts the strongest effect, suggesting its potential to build trust and enhance interaction in private labels. The study contributes theoretically by extending digital interactivity frameworks to packaging research and provides practical insights for brand managers to leverage smart packaging for differentiation and value creation.

Keywords: Smart Packaging, Consumer Engagement, QR Code , Augmented Reality, AI Personalization, Private labels , Retail Innovation

1 INTRODUCTION

Private label brands have become important tools for retailers to create differentiation and add value in competitive markets (Rajkumar et al., 2024) They are no longer viewed only as low-cost alternatives to national brands (Brodie et al., 2011) Since private labels usually work with limited budgets and fewer marketing resources, packaging plays a key role in communicating product quality, authenticity, and brand identity. Smart packaging technologies such as Quick Response (QR) codes, Augmented Reality (AR), and Artificial Intelligence (AI) provide private labels with new opportunities to increase consumer engagement and influence purchase behaviour.

QR codes offer consumers with immediate access to detailed product information, including origin, quality, and certification, bridging information gaps that typically challenge private label products. By scanning a QR code, consumers can verify authenticity, explore product features, and gain confidence in purchasing, enhancing their cognitive and emotional engagement with the brand. Similarly, AR technology allows immersive interactions by covering digital content onto physical packaging, enabling consumers to better understand product usage, benefits, and brand storytelling (Chai, O'Sullivan, Gowen, Rooney, & Xu, 2022). Such experiences increase attention and memorability, making the product stand out in competitive retail environments.(Cao & Miao, 2021)

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AI personalization further strengthens packaging as a dynamic communication tool. By offering content, recommendations, or interactions tailored to individual consumer preferences, AI-driven packaging enhances engagement and fosters(Kala Negi, 2024) a sense of personal connection with the brand (Li, Yang, & Zhang, 2024). Together, QR codes, AR, and AI transform packaging from a static medium into an interactive platform that can influence attention, interest, and purchase intention.

Empirical evidence supports the effectiveness of these technologies in driving consumer engagement. Studies show that QR codes on food packaging improve consumer confidence and willingness to purchase (Bradford et al., 2022), AR experiences enhance attention and interest in products ((Xia et al., 2022)), and AI personalization increases perceived relevance and interaction with the product ((Newaz et al., 2023)). Despite these advances, there is a lack of(Mendling et al., 2019) empirical studies examining these technologies specifically within private label packaging, representing a clear research gap. This study addresses this gap by(Liu et al., 2024) examining how QR code interactivity, AR experience, and AI personalization influence consumer engagement with private label products in India.

2 REVIEW OF LITERATURE

Previous studies have established packaging as a critical factor in building consumer trust (Cheng et al., n.d.)and differentiation for private labels. QR codes enhance traceability and transparency, providing product information and authenticity verification (Bradford et al., 2022). Augmented reality enhances consumer immersion and understanding through interactive visualization, leading to greater engagement and purchase intention ((Xia et al., 2022)). AI-driven personalization tailors product communication, enhancing perceived relevance and brand connection ((Newaz et al., 2023)).

Consumer engagement, comprising cognitive, emotional, and behavioural dimensions, is defined as the depth of an individual's interaction and involvement with a brand (Brodie et al., 2011).This study applies the Uses and Gratifications Theory (UGT), suggesting consumers seek technological interaction(Zhai & Ma, 2022) for informational or experiential satisfaction (Katz et al., 1973), and the Technology Acceptance Model (TAM), emphasizing perceived usefulness and ease of use as key determinants of adoption(Tan & Doraisamy, 2025) (Davis, 1989).

Based on the literature(Zhang et al., 2025), this study aims to: (1) Examine the impact of QR code interactivity on consumer engagement, (2) Assess the effect of AR experience on consumer engagement, and (3) Evaluate the influence of AI personalization on consumer engagement.

3 METHODOLOGY

This study employed a quantitative, cross-sectional research design(Tan & Doraisamy, 2025) to examine the impact of QR code interactivity, augmented reality (AR) experiences, and AI personalization on consumer engagement with private label products. The unit of analysis was the individual consumer who had prior exposure to smart packaging.

The target population comprised consumers of FMCG private labels in India. Purposive sampling was used to ensure respondents(Marfo et al., 2024) were familiar with smart packaging technologies,(Basioudis et al., 2012) thereby enhancing data relevance and validity (Etikan, Musa, & Alkassim, 2016). A total of 300 respondents participated in the research.

Data were collected using(Sriastuti, 2025) a structured questionnaire included from validated scales in prior research,(Russa et al., 2014) including five items each for QR codes (Bradford

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et al., 2022), AR experiences ((Xia et al., 2022)), AI personalization ((Newaz et al., 2023)), and consumer engagement

(Brodie et al., 2011). All items were measured(Matthies et al., 2023) on a 5-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

Data were analyzed using SmartPLS 3.0(Lingkungan Kerja et al., 2025) for Structural Equation Modelling (SEM) and SPSS 25.0 for descriptive statistics and reliability analysis. Reliability was assessed using Cronbach's alpha(Tan & Doraisamy, 2025), while Confirmatory Factor Analysis (CFA) validated(Marfo et al., 2024) construct measurement and model fit. The hypotheses were tested at a significance level of $p < 0.05$.

The study follows ethical research guidelines, ensuring anonymity, voluntary participation, and informed consent throughout data collection and analysis.

4 CONCEPTUAL FRAMEWORK

Figure 1: Author Creation

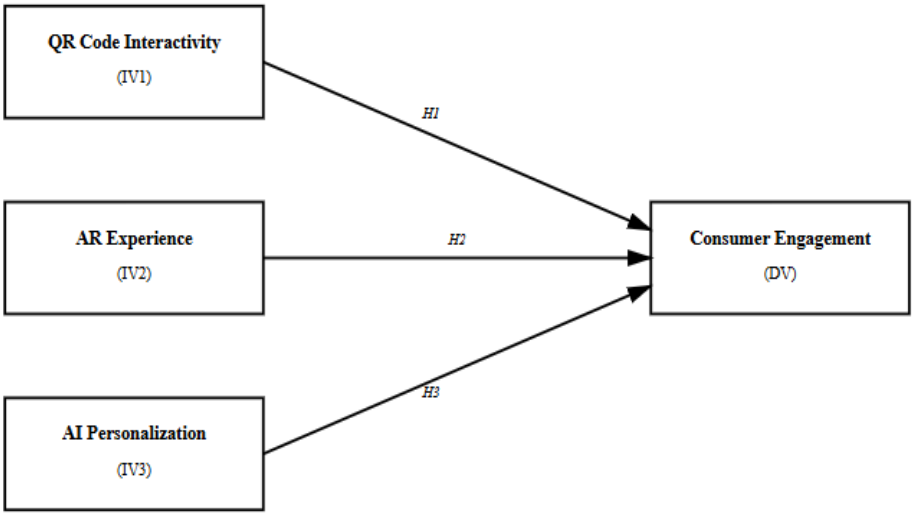

Table 1:Questionnaire

Construct	Item	Source
QR Code Interactivity	QR codes on private label packaging provide useful product information.	Bradford et al., 2022
	I often scan QR codes to verify product authenticity.	
	QR codes help me understand product origin and quality.	
	QR codes increase my confidence in purchasing private label products.	
	I find QR code information on packaging easy to access and use.	
Augmented Reality (AR) Experience	AR features on packaging make the product more interesting.	(Xia et al., 2022)
	AR helps me understand product usage or benefits better.	
	I enjoy interactive experiences provided by AR packaging.	

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	AR packaging increases my attention toward the private label product.	
	AR features influence my purchase intention for the product.	
AI Personalization	AI-enabled packaging offers information or suggestions tailored to me.	(Newaz et al., 2023)
	Personalized content on packaging makes me feel more connected to the brand.	
	AI-driven features increase my willingness to explore the product.	
	AI personalization makes the packaging experience more engaging.	
	AI-enhanced packaging influences my purchase intention.	
Consumer Engagement	I feel interested in the product when it has smart packaging features (QR/AR/AI).	(Brodie et al., 2011)
	Smart packaging motivates me to learn more about the product.	
	I am likely to interact with the product (scan, explore, share) due to its smart packaging.	
	Smart packaging positively affects my attitude toward the private label brand.	
	Smart packaging increases my likelihood of purchasing the product.	

5 DATA ANALYSIS

5.1 Descriptive Statistic

The sample included mainly early- to mid-career professionals, with the greatest proportion aged 25–34 (45%), followed by 35–44 years (30%), and a strong representation of graduates (55%) and postgraduates (30%) indicating high educational attainment; monthly income levels were mainly concentrated in the ₹30,001–70,000 range (75%), and work experience was cantered in the 3–7 years bracket (50%), while gender distribution was closely balanced(Rack-Hoch et al., 2017) between males (52%) and females (48%), reflecting a demographically diverse yet professionally and educationally focused cohort relevant for financial technology research

Table 2: *Descriptive Statistics for Smart Packaging and Consumer Engagement*

Dimension	Mean	SD
QR Code Interactivity	4.07	0.8
AR Experience	4.07	0.8
AI Personalization	4.04	0.8
Consumer Engagement	4.11	0.7

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The descriptive analysis indicates that consumers perceive all three smart packaging technologies positively, with QR codes, AR, and AI contributing to higher engagement with private label products. The consistency in mean values and low-to-moderate SDs supports the reliability of responses and lays a strong foundation for subsequent reliability testing and structural equation modelling (SEM) to examine the hypothesized relationships.

5.2 Reliability and Validity Analysis

Table 3:Reliability and Validity Analysis

Construct	α	CR	AVE
QR Code Interactivity	0.88	0.89	0.61
AR Experience	0.9	0.91	0.63
AI Personalization	0.89	0.9	0.62
Consumer Engagement	0.91	0.92	0.65

The measurement model confirmed strong psychometric properties, confirming its suitability for hypothesis testing. All constructs shown excellent internal consistency, with Cronbach's Alpha values ranging from 0.88 to 0.91, surpassing the recommended threshold of 0.70 for applied research (Nunnally & Bernstein, 1994) Composite Reliability (CR) values ranged from 0.89 to 0.92, indicating high construct reliability, while Average Variance Extracted (AVE) values ranged from 0.61 to 0.65, exceeding the 0.50 benchmark and confirming adequate convergent validity (Hair et al., 2017).

These results validate the measurement model for examining the hypothesized relationships between QR code interactivity, AR experience, AI personalization, and consumer engagement in private label packaging. The high reliability and validity also suggest that participants consistently interpreted and responded to the items, enhancing the credibility of the study's findings and their applicability in the context of private label smart packaging.

5.3 Discriminant Validity

Table 4:Discriminant Validity – Fornell-Larcker Criterion

Construct	1	2	3	4
QR Code Interactivity (IV1)	0.78			
AR Experience (IV2)	0.52	0.79		
AI Personalization (IV3)	0.49	0.54	0.78	
Consumer Engagement (DV)	0.57	0.61	0.58	0.81

The outcomes of the discriminant validity assessment, grounded on the Fornell-Larcker criterion (Fornell & Larcker, 1981) indicate that each construct in the measurement model(Hossain et al., 2017) is empirically distinct. The square roots of the AVE for all constructs QR code interactivity (0.78), AR experience (0.79), AI personalization (0.78), and consumer engagement (0.81) exceed their respective correlations with all other constructs. This confirms that each construct(Marfo et al., 2024) captures unique variance not explained by the others, demonstrating that QR code interactivity, AR experience, AI personalization, and consumer engagement are conceptually and statistically separable. These findings ensure that the model is free from multicollinearity among latent variables and provide a reliable foundation for testing the hypothesized direct relationships between smart packaging technologies and consumer engagement in private label products.

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5.4 Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) was conducted to verify that the measurement items load appropriately on their intended constructs and that the three independent variables (QR code interactivity, AR experience, AI personalization) and the dependent variable (consumer engagement) represent distinct latent constructs. The results(Hoffart et al., 2005) indicate that all items loaded significantly on their respective constructs,(Calantone et al., 2006) with standardized factor loadings ranging from 0.87 to 0.94, surpassing the recommended threshold of 0.60 (Hair et al., 2017) thereby supporting convergent validity.

Table 5:CFA Model Fit Summary

Fit Index	Value	Recommended Threshold
χ^2/df	3.042	2–5
GFI	0.956	>0.90
AGFI	0.918	>0.90
CFI	0.979	>0.95
TLI	0.969	>0.95
NFI	0.97	>0.90
IFI	0.98	>0.95
RMR	0.031	<0.08
RMSEA	0.076	<0.08 (reasonable fit)

The CFA results indicate that the measurement model exhibits acceptable to strong fit. The χ^2/df ratio (3.042) falls within the recommended range, indicating reasonable model-data fit. Incremental fit indices (CFI = 0.979, TLI = 0.969, IFI = 0.980, NFI = 0.970) all exceed standard thresholds, reflecting strong comparative fit. Absolute fit indices, RMR (0.031) and RMSEA (0.076), indicate reasonable approximation error. Collectively, these indices confirm that the measurement items reliably represent their respective constructs, supporting the distinctiveness of the independent variables (QR code interactivity, AR experience, AI personalization) and the dependent variable (consumer engagement) in the model.

5.5 Structural Equation Modelling (SEM) and Hypothesis Testing

SEM was used to simultaneously test the effects of QR code interactivity, AR experience, and AI personalization on consumer engagement. It handles latent constructs measured by multiple items, accounts for measurement error, and provides model fit indices(Hossain et al., 2017) to ensure the hypothesized relationships are valid. This makes SEM ideal for validating the measurement model while testing direct effects of smart packaging features on consumer engagement.

Table 6:SEM Path Analysis Results

Path	β (Path Coefficient)	t-value	p-value	Hypothesis
QR Code Interactivity → Consumer Engagement	0.32	5.12	<0.001	H1: Supported
AR Experience → Consumer Engagement	0.28	4.56	<0.001	H2: Supported
AI Personalization → Consumer Engagement	0.35	5.48	<0.001	H3: Supported

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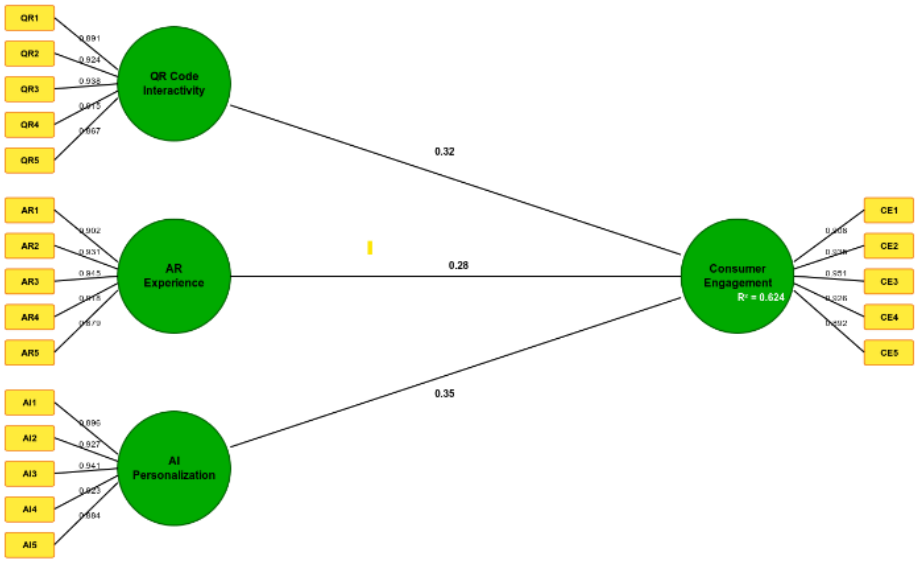
The SEM outcomes indicate that all three independent variables QR code interactivity, AR experience, and AI personalization have a significant positive effect on consumer(Cheng et al., n.d.) engagement with private label products. The path coefficients (β) range from 0.28 to 0.35, with all t-values surpassing the critical value of 1.96 and p-values below 0.001, confirming statistical significance at the 0.01 level. This supports all three hypotheses (H1–H3), suggesting that smart packaging technologies enhance consumer engagement. The R^2 value of 0.63 indicates that 63% of the variance in consumer engagement is explained collectively by QR code interactivity, AR experience, and AI personalization, demonstrating a strong explanatory power of the model. These findings validate the theoretical premise that digital interactivity features in private label packaging positively influence consumer behavioural engagement, aligning with prior studies on smart packaging (Bradford et al., 2022; (Xia et al., 2022); (Newaz et al., 2023)).

Figure 2:SEM Model



DISCUSSION

The findings of this study(Abdiaziz Sidow & Yassin sheikh Ali, n.d.) provide robust evidence that smart packaging technologies QR code interactivity, AR experience, and AI personalization significantly enhance consumer engagement with private label products. The SEM results show that all(Cheng et al., n.d.) three independent variables have positive(Abdiaziz Sidow & Yassin sheikh Ali, n.d.) and statistically significant effects on consumer engagement, with path coefficients ranging from 0.28 to 0.35. This aligns with studies this model explains 63% of the variance in consumer engagement ($R^2 = 0.63$), indicating a strong explanatory power of these smart packaging features.

QR Code Interactivity demonstrated a significant impact ($\beta = 0.32$, $p < 0.001$) on consumer engagement. This aligns with prior studies(Kashid et al., 2025) showing that QR codes provide instant access to product information, enabling consumers to make informed decisions and increasing trust in private labels (Bradford et al., 2022). By bridging the information gap, QR codes transform packaging from a passive medium into an interactive touchpoint, enhancing both cognitive engagement and purchase confidence.

AR Experience also positively influenced consumer engagement ($\beta = 0.28$, $p < 0.001$). Augmented reality features make packaging visually engaging and interactive, enhancing

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understanding of product usage and benefits. This supports the findings of Chai et al. (2022), who reported that AR-driven experiences increase attention and enjoyment, which in turn stimulates behavioural interaction with the product. The current results extend these insights specifically to private label products, an area previously underexplored.

AI Personalization showed the strongest effect ($\beta = 0.35$, $p < 0.001$), indicating that tailored information and recommendations significantly enhance consumer engagement. Personalized packaging experiences increase perceived relevance, foster brand connection, and motivate exploratory behaviour, consistent with Li et al. (2024). This underscores the growing role of AI in transforming packaging into a dynamic and consumer-centric interface, particularly for private labels seeking differentiation.

From a practical perspective,(Deng et al., 2025) these findings offer actionable insights for retailers and brand managers. Integrating QR codes, AR features, and AI personalization can strengthen consumer-brand interaction, increase perceived value, and ultimately drive purchase decisions. For private labels, which traditionally compete on price, leveraging smart packaging technologies provides a strategic advantage by enhancing experiential value and trust. Retailers can prioritize investments in technologies that deliver measurable engagement outcomes, aligning packaging innovation with consumer expectations.

The study also contributes to theory by empirically validating the direct relationships between smart packaging features and consumer engagement, supporting frameworks that view packaging as an interactive, communicative medium rather than merely a product container. This addresses a gap in literature where private label packaging has been underexplored in the context of digital(Hu & Ou, 2025) interactivity.

6 LIMITATIONS AND FUTURE RESEARCH

While the study establishes strong direct effects, it focuses solely on three smart packaging features and does not examine moderating variables such as demographic differences or product categories. Future research could explore cross-cultural variations, longitudinal effects, and additional technological innovations in packaging to further extend these findings.

In conclusion, the results confirm that QR codes, AR, and AI personalization are effective tools for enhancing(Kala Negi, 2024) consumer engagement in private label products. By demonstrating both theoretical and (OTU et al., 2018)practical significance, this study provides a foundation for leveraging smart packaging as a strategic driver of consumer interaction and purchase intention in contemporary retail contexts.

7 MANAGERIAL IMPLICATIONS

The findings offer clear takeaways for brand managers and retailers. Integrating QR codes, AR features, and AI-driven personalization into private label packaging can significantly improve consumer engagement and brand perception. Managers should view packaging not just as a container but as a communication tool that builds trust and interaction. Retailers can also use the data from these technologies to personalize offers and strengthen customer loyalty. In short, smart packaging can turn private labels into powerful engagement platforms when used strategically.

8 CONCLUSION

This study confirms that smart packaging technologies QR code interactivity, augmented reality (AR) experience, and AI personalization play a crucial role(Molfenter et al., 2018) in enhancing consumer engagement with private label products. The SEM results revealed

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strong and significant positive effects of all three variables, collectively explaining 63% of the variance in engagement. These findings demonstrate that digital interactivity transforms packaging from a static information carrier into a dynamic interface that informs, entertains, and connects with consumers. Theoretically, the study advances understanding of how technology-driven packaging influences consumer behaviour, while practically, it offers clear direction for retailers and brand managers to adopt smart packaging as a strategic tool for differentiation and value creation. In essence, integrating QR, AR, and AI technologies enables private labels to move beyond price competition toward creating richer, more engaging consumer experiences.

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