An EEG Study on Visual Imagery and Consumer Acceptance of Upcycled Food Packaging

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ABSTRACT

Purpose: This study aims to investigate how different packaging label elements influence consumer engagement and preference toward upcycled food products.

Design/methodology/approach: An experimental approach featuring EEG and preference rankings was employed to examine six distinct packaging designs.

Findings: Photographic imagery elicited significantly higher neural engagement, with EEG interest values showing the least negative deviation from baseline ($M = –0.12$, $SE = 0.05$) compared to the 3R environmental logo, which generated the lowest interest ($M = –0.45$, $SE = 0.07$). Preference rankings aligned with these neural findings: photographic labels were rated most favorably (mean rank = 1.8), while the 3R logo was least preferred (mean rank = 5.6; $\chi^2 = 37.89$, $p < 0.001$).

Practical implications: These findings demonstrate that packaging elements influence consumer responses at both neural and conscious levels. Photographic imagery enhanced early-stage attentional processing, as reflected in higher EEG interest values and increased P300 amplitudes, indicating stronger unconscious engagement. In contrast, sustainability-related eco-labels evoked lower immediate neural attention but may contribute to System 2–driven evaluations of credibility and trust in the longer term. This suggests that effective marketing strategies for upcycled foods should combine visually engaging designs to capture unconscious attention with eco-labels to reinforce deliberate, credibility-based decision making.

Originality/value: This research uniquely integrates EEG metrics with behavioral preference rankings to evaluate consumer responses to upcycled food packaging, offering novel insights for sustainable marketing strategies.

Keywords: Upcycled foods; Packaging design; Electroencephalography; Dual-process theory; Consumer acceptance

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1. Introduction

Food waste represents a critical global challenge: according to FAO, roughly one-third of all food produced for human consumption—about 1.3 billion tons annually—is lost or wasted globally, causing substantial economic, environmental, and social burdens (FAO, 2011).To tackle this problem, upcycled foods—products created from ingredients that would otherwise be discarded—have emerged as an innovative, sustainability-oriented solution. These foods leverage agricultural by-products and surplus produce, embodying circular economy principles and directly reducing food waste. Despite the promise of upcycled foods, consumer acceptance remains a major barrier due to limited awareness and inherent skepticism towards eating "rescued" ingredients. Consequently, effective consumer communication strategies are imperative for mainstream adoption.

Packaging label design represents a crucial vehicle for consumer education and persuasion in novel food categories. Acting as a "silent salesman," effective packaging communicates product attributes, engages consumers emotionally, and influences purchase decisions at the point of sale. Prior research highlights the powerful role of visual and textual elements on labels, particularly photographic imagery, in shaping consumer perceptions (De Cicco et al., 2021; Dixon et al., 2025). However, while conventional studies have relied predominantly on self-report measures such as surveys and interviews, these methods may not fully capture consumers' genuine subconscious reactions. Social desirability biases, ambiguity surrounding novel products, and the potential disconnect between consumers' stated intentions and actual behaviors underline the limitations of traditional survey methodologies.

Neurophysiological tools, such as electroencephalography (EEG), offer a direct way to address the limitations of survey methods by capturing subconscious reactions—including attention, emotion, and cognition—in real time (Bazzani et al., 2020). Yet, EEG applications remain underexplored in sustainable food research, particularly for upcycled foods. Filling this gap is crucial to designing packaging that effectively communicates sustainability benefits, reduces skepticism, and enhances consumer acceptance.

In addressing this gap, the present study applies EEG to evaluate consumer responses to varying label designs for upcycled food products, complemented by traditional self-report methods. Specifically, we examine whether intuitive, visual-based packaging cues (photographic imagery) primarily activate rapid, subconscious attention and emotional engagement associated with System 1 processing, while explicit sustainability information (environmental and upcycling labels) engages more reflective, deliberate evaluations consistent with System 2 processing. By empirically linking EEG measures (e.g., interest values, P300 amplitudes) with preference rankings, the study not only adopts dual-process theory as a framework but also tests its applicability in the context of sustainable product marketing. Practically, this research aims to provide marketers and packaging designers with empirically grounded insights into creating effective labels, thereby facilitating consumer acceptance and market adoption of upcycled foods.

2. Literature Review

2.1 CONSUMER ACCEPTANCE OF UPCYCLED FOODS

The global issue of food waste has given rise to innovative sustainability solutions, among which upcycled foods represent a rapidly growing category. Upcycled foods, defined as products created by transforming ingredients traditionally regarded as surplus or waste into new, valuable consumer goods, have increasingly attracted attention as a viable strategy for waste reduction and environmental sustainability (Thorsen et al., 2024). While market interest in upcycled products grows, consumer acceptance remains an obstacle due to factors such as unfamiliarity, skepticism,

and the psychological barrier commonly termed food neophobia—consumers' hesitancy toward novel and unfamiliar foods (Siddiqui et al., 2022).

Food neophobia has long been studied in consumer psychology and is often measured using the Food Neophobia Scale (Pliner & Hobden, 1992). Research indicates that higher levels of neophobia are associated with avoidance of novel food categories, reduced willingness to try sustainable or alternative products, and heightened perceptions of risk (Damsbo-Svendsen et al., 2017; Siegrist & Hartmann, 2020). In the context of upcycled foods, neophobia may amplify concerns regarding product safety and taste, limiting consumer openness despite environmental benefits. Existing studies emphasize that acceptance of upcycled foods is closely linked to consumers' perceptions of safety, taste quality, and environmental benefits. Addressing these perceptions effectively through targeted consumer communication is thus critical for market success (Lu et al., 2024; Aschemann-Witzel et al., 2023). Existing studies emphasize that acceptance of upcycled foods is closely linked to consumers' perceptions of safety, taste quality, and environmental benefits. Addressing these perceptions effectively through targeted consumer communication is thus critical for market success (Lu et al., 2024; Aschemann-Witzel et al., 2023).

2.2 PACKAGING DESIGN AND CONSUMER BEHAVIOR

Packaging design significantly influences consumer decision-making processes by serving as a primary communication channel for product attributes (Silayoi and Speece, 2007; Liu et al., 2025). Packaging functions as a "silent salesman," conveying critical information that can instantly attract consumer attention, shape initial impressions, and ultimately drive purchasing behavior (De Cicco et al., 2021). Among design elements, visual imagery—particularly photographic images—has proven highly effective in increasing perceived authenticity, attractiveness, and perceived quality of food products (Liang et al., 2024; Dixon et al., 2025).

However, findings are not always consistent. Some studies caution that photographic imagery can generate overly positive expectations, which, if unmet, may reduce satisfaction and trust (Torous et al., 2021). Others suggest that minimalist or symbolic designs may be more effective for premium or sustainability-oriented products, as they convey sophistication and credibility rather than indulgence (Kim et al., 2019). These nuances highlight that the effectiveness of visual imagery depends on product type, target consumer group, and the broader context of label information. Thus, while visuals play a key role in attracting attention and reducing uncertainty, their impact should be evaluated in conjunction with other design cues and consumer expectations.

2.3 SUSTAINABLE FOOD LABELING AND CONSUMER RESPONSES

Research on sustainable food marketing emphasizes the critical role of labels in effectively communicating environmental attributes to consumers (Cook et al., 2023; Huang et al., 2024; Shaikh et al., 2024). Labels with clear sustainability messaging, such as eco-labels or certification seals, help reduce consumer uncertainty and enhance perceived product trustworthiness and environmental benefits (Bleda and Valente, 2009).

However, findings regarding the efficacy of eco-labels are mixed. While informative eco-labels and certification logos (e.g., Fair Trade, Organic certifications) reassure consumers and align with their environmental values, they often have a limited immediate impact compared to intuitive visual elements like compelling imagery (Heyes et al., 2020). Some studies further suggest that eco-labels can be overlooked in cluttered packaging designs, misunderstood due to low consumer literacy, or even provoke skepticism when trust in certifying institutions is weak (Thøgersen, 2002; Grunert et al., 2014; Tiboni-Oschilewski et al., 2024; Kabaja et al., 2023). These contradictory findings highlight that eco-label effectiveness is context-dependent and moderated by factors such as label design, consumer knowledge,

and trust in certifiers. This discrepancy indicates that sustainable product marketing may benefit from combining explicit informational cues with affective visual elements to enhance consumer appeal and understanding (Seo & Mori, 2024).

2.4 NEUROMARKETING METHODS IN CONSUMER RESEARCH

Conventional consumer research predominantly relies on self-report methodologies (e.g., surveys, interviews), which are subject to limitations such as social desirability bias and difficulty capturing subconscious responses (Latkin et al., 2017). To overcome these limitations, researchers have increasingly turned to neuromarketing methods, including electroencephalography (EEG), functional magnetic resonance imaging (fMRI), and eye-tracking technologies. Among these tools, EEG has emerged as particularly valuable due to its non-invasive nature, real-time data capture, and capability to measure subconscious cognitive and emotional reactions such as attention, arousal, and approach-avoidance tendencies (Bazzani et al., 2020; Moya et al., 2020). EEG-based research in consumer contexts shows that neural indicators, such as frontal alpha asymmetry (reflecting emotional engagement or approach motivation) and theta band activity (indicating cognitive processing), provide objective metrics of consumer interest and attention that may not be fully captured by traditional self-report methods (Shestyuk et al., 2019; Gkintoni et al., 2025).

At the same time, EEG is not without limitations. Data are highly sensitive to artifacts caused by eye blinks, muscle movements, and environmental electrical noise, requiring rigorous preprocessing. Moreover, substantial inter-individual variability in brain activity can complicate interpretation, and the relatively low spatial resolution of EEG limits precise localization of neural sources (Luck, 2014). These methodological challenges highlight the need for careful experimental design and cautious interpretation when applying EEG in consumer research. Nevertheless, EEG offers valuable complementary insights when combined with self-report and behavioral measures, particularly in the context of evaluating novel or sustainability-oriented product communications.

2.5 DUAL-PROCESS THEORY IN CONSUMER DECISION-MAKING

Dual-process theory offers a robust framework for understanding consumer decision-making by distinguishing two cognitive systems: System 1 (intuitive, automatic, and emotionally driven) and System 2 (analytical, deliberate, and rational) (Da Silva, 2023). Packaging design research has increasingly applied dual-process theory, noting that consumers frequently rely on System 1, intuitive processes—rapid, emotion-based judgments triggered by visual stimuli—when evaluating products at the point of purchase (Riswanto et al., 2025). In contrast, System 2 processes involve more deliberate evaluation, often influenced by informational cues such as labels or textual descriptions. Previous studies demonstrate that intuitive visual cues, such as vivid photographic imagery, typically evoke stronger and quicker consumer responses compared to purely textual or informational elements (Poirier et al., 2024).

In this study, dual-process theory is not only used as a conceptual framework but is also operationalized through EEG and behavioral measures. Specifically, we hypothesize that visual packaging cues (e.g., photographic imagery) primarily engage System 1 processes, reflected in neural markers such as increased frontal alpha asymmetry (indicating approach motivation) and heightened theta activity (indicating attentional engagement). Conversely, sustainability-related textual and logo-based labels are expected to invoke System 2 processes, which are assessed through preference rankings and self-reported evaluations, and may also correspond to later event-related components such as the P300, associated with controlled cognitive evaluation. Applying this dual-process perspective to sustainable food products, such as upcycled foods, thus allows us to empirically examine how intuitive versus deliberative processing pathways are reflected in both EEG responses and explicit consumer preferences.

2.6 RESEARCH GAPS AND CONTRIBUTIONS OF THE PRESENT STUDY

Despite significant advances in packaging and sustainability communication research, important gaps remain in understanding consumer responses to upcycled food packaging. Most notably, the existing literature lacks empirical studies that specifically employ neuroscience-based methodologies to evaluate the effectiveness of label design elements for upcycled products. Prior studies on upcycled foods have primarily relied on traditional survey methods to assess consumer perceptions, preferences, and willingness-to-pay, without capturing deeper subconscious responses (Bhatt et al., 2021; Grasso et al., 2023). This limitation is particularly critical given that subconscious, automatic responses can significantly shape consumer acceptance of novel food products (Baker et al., 2022). Additionally, few studies have explicitly examined how visual versus informational label cues differentially influence consumer attitudes and neurological responses in the context of sustainable products.

Addressing these research gaps, the current study applies EEG techniques alongside traditional self-report methods to systematically evaluate consumer reactions to different label design elements (photographic imagery, informational eco-labels) on upcycled food packages. By doing so, we extend dual-process theory into sustainable product marketing, investigating how intuitive versus deliberative cognitive processes influence consumer preferences and behaviors towards upcycled products. Furthermore, this research contributes novel empirical insights for both theoretical advancement and practical application, providing robust evidence to guide effective package design strategies. Ultimately, our findings offer valuable implications for marketers and designers aiming to enhance consumer acceptance of sustainable, upcycled food products, thereby contributing meaningfully to broader food waste reduction goals.

3. Methodology

3.1. STIMULI DESIGN

This study employed six systematically designed package labels as experimental stimuli to evaluate consumer reactions to upcycled food products. Previous literature indicates that package elements such as visual imagery, nutritional content information, country-of-origin cues, and eco-friendly certifications significantly influence consumer perceptions and decision-making processes (Schifferstein et al., 2021; Yuan et al., 2023). Following these insights, we developed six distinct mock-up labels, each varying primarily in one key aspect while holding all other design features constant (Fig. 1). The six labels were designed using standardized templates, identical font styles, and consistent color palettes to ensure that only the focal design element varied. The labels included:

Package 1 (Photographic imagery): featured a prominent, high-quality photographic image of the product with minimal textual information, intended to highlight intuitive visual appeal (García-Madariaga et al., 2019).

Package 2 (Illustration imagery): employed an illustrative style image rather than photographic imagery, aiming to test differences in consumer engagement based on image realism (Wu et al., 2021).

Package 3 (Nutritional information): prominently displayed clear nutritional information panels, including calorie and nutrient details. The product imagery was minimized to emphasize informational content (Ikonen e et al., 2020).

Package 4 (Origin information): highlighted product origin using explicit "Made in [Country]" labels and relevant national symbols to leverage country-of-origin effects (Morgan et al., 2007).

Package 5 (Upcycled food logo): clearly featured a recognized upcycled food certification logo, emphasizing the product's sustainability credentials and its contribution to reducing food waste (Seo and Mori, 2024).

Package 6 (3R environmental mark): showcased the widely recognized "Reduce, Reuse, Recycle (3R)" logo to directly signal environmental sustainability and circular economy values (Gong et al., 2025).

The brand name, product size, packaging format, and general layout were standardized across all stimuli to isolate the impact of the manipulated design elements. This experimental design aligns with established neuromarketing approaches for evaluating consumer responses to packaging (García-Madariaga et al., 2019; Moya et al., 2020). To avoid potential confounds such as brand familiarity, all packages displayed a fictitious brand name created solely for this experiment. Prior familiarity with upcycled foods was measured in the pre-experiment survey and included as a control variable in the analysis.

FIGURE 1. PACKAGE LABEL DESIGN

3.2. PARTICIPANTS AND DATA COLLECTION

Participants were recruited from Tokyo, Japan, through convenience sampling and provided informed consent before participating. The final sample comprised 30 adult consumers (15 males, 15 females, mean age = 28.6 years, SD = 4.7; age range 22–39) familiar with snack foods but without specific prior knowledge of upcycled foods, ensuring representative responses typical of mainstream consumers. Ethical approval was obtained from the Research Ethics Committee for Life Sciences and Medical Research Involving Human Subjects at Tokyo University of Science (Approval No. #23071). All participants provided written informed consent prior to participation.

The experimental procedure consisted of two parts:

Questionnaire survey: Participants first completed a structured survey capturing demographic information (age, gender, occupation), their familiarity and prior experience with upcycled food products, attitudes towards food waste reduction, and preferences regarding snack food attributes (taste, price, packaging, novelty, and ingredient sourcing).

EEG measurement: Following the survey, participants engaged in EEG recording sessions in a quiet, controlled laboratory environment. EEG data were captured using the FLEX 2 Saline - 32 Channel Wireless EEG Head Cap System (Emotiv, USA). Participants sat comfortably 105 cm from a computer screen, which sequentially displayed the six package label designs. Each stimulus appeared for precisely ten seconds, separated by short inter-stimulus intervals to mitigate carryover effects. All participants viewed all six labels, with stimulus presentation randomized across repeated trials to mitigate order effects (Table 1). Three separate EEG recording sessions were conducted per participant, interspersed with rest periods to minimize fatigue and maintain consistent neural engagement.

TABLE 1. RANDOMIZED STIMULUS PRESENTATION ORDER FOR EEG MEASUREMENT SESSIONS

Trial	First Sequence	Second Sequence
1	1 → 3 → 5 → 2 → 4 → 6	1 → 3 → 5 → 2 → 4 → 6
2	2 → 4 → 3 → 1 → 6 → 5	2 → 4 → 3 → 1 → 6 → 5
3	3 → 1 → 6 → 4 → 5 → 2	3 → 1 → 6 → 4 → 5 → 2
4	4 → 6 → 3 → 2 → 5 → 1	4 → 6 → 3 → 2 → 5 → 1
5	5 → 4 → 6 → 1 → 2 → 3	5 → 4 → 6 → 1 → 2 → 3
6	6 → 1 → 5 → 3 → 2 → 4	6 → 1 → 5 → 3 → 2 → 4

3.3. EEG DATA RECORDING AND ANALYSIS

EEG signals were recorded using Emotiv Pro software, which quantifies neural activity into specific metrics, notably Interest (In), reflecting heightened neural engagement towards preferred stimuli (Gkintoni et al., 2025). Raw EEG data were collected at a 128 Hz sampling rate, with signals referenced to the mastoid electrodes. Preprocessing included band-pass filtering (0.5–40 Hz), automatic and manual artifact rejection for eye blinks and muscle movements, and baseline correction relative to pre-stimulus intervals.

The primary EEG-dependent variable was the deviation of Interest (In) levels from baseline values during stimulus viewing. In addition, event-related potentials were examined, with particular focus on the P300 component, as an indicator of controlled evaluative processing (System 2). Frontal alpha asymmetry was interpreted as a neural marker of approach motivation, reflecting System 1 processes. Mean Interest levels per stimulus type were calculated across participants.

To statistically assess neural interest and ERP differences across the six stimuli, Friedman's non-parametric repeated measures ANOVA was employed. Post-hoc comparisons were conducted using Wilcoxon signed-rank tests with Bonferroni correction to identify pairwise stimulus differences (Zhang et al., 2025). Effect sizes (Cohen's d) were also reported to supplement significance testing. All EEG data were analyzed using EmotivPro 3.0 and SPSS 29.0 statistical software.

3.4. PREFERENCE RANKING PROCEDURE

To complement EEG measures, participants also completed a conscious, explicit ranking task post-EEG measurement. Participants ranked the six package designs from most preferred (rank = 1) to least preferred (rank = 6) based on personal attractiveness and likelihood of purchase. To statistically verify differences in explicit consumer rankings, a separate Friedman test was conducted, consistent with standard approaches for analyzing ordinal preference data (García-Madariaga et al., 2019). Post-hoc pairwise comparisons with Bonferroni correction were applied, and Kendall's W was reported as a measure of effect size to assess the strength of agreement across participants. Preference ranking results were interpreted as an indicator of deliberate, System 2 processing, thereby complementing EEG measures of subconscious System 1 responses.

3.5. INTEGRATIVE DATA INTERPRETATION APPROACH

This mixed-method approach (EEG and explicit preference ranking) allowed a comprehensive analysis of both subconscious neural reactions (System 1) and conscious, deliberate evaluations (System 2) to determine the consistency and divergence of consumer responses to packaging attributes. By integrating neuroscientific evidence with traditional marketing measures, this study provides robust empirical insights into how package design elements specifically influence consumer interest, informing both theoretical models of consumer decision-making and practical design strategies for sustainable food marketing. Specifically, concordance between EEG interest values and preference rankings was examined by comparing the relative order of package designs across both measures. Divergence between implicit neural attraction and explicit preference rankings was interpreted as evidence of implicit–explicit discrepancy, consistent with dual-process theory predictions. This integrative perspective ensured that both intuitive and deliberative pathways were empirically evaluated within the same experimental framework.

4. Results

4.1. PARTICIPANT CHARACTERISTICS

A total of 19 participants (16 males and 3 females; age range: 24–40 years) took part in the study. Of these, 47.4% reported familiarity with upcycled foods, but only 5.3% had previously purchased them. Regarding the perceived importance of reducing food waste, most participants strongly agreed (63.2% rated the highest score of 7, on a 7-point Likert scale), indicating high environmental awareness. When purchasing snacks, participants ranked "Taste" as most important, followed by "Price" and "Quantity," with "Food labeling" rated least important.

4.2. EEG-BASED INTEREST ANALYSIS

The EEG analysis revealed significant differences in neural engagement (Interest values) among the six packaging designs (Fig. 2). Package Label Design 1 (featuring photographic imagery) elicited the highest neural interest (least negative deviation from baseline), suggesting greater unconscious attraction. In contrast, Package Label Design 6 (displaying the 3R environmental logo) generated the lowest interest, indicating minimal subconscious engagement.

Differences among the remaining four label designs (illustration, nutrition information, origin indication, and upcycled logo) were smaller and not statistically significant, suggesting comparatively similar levels of neural attention.

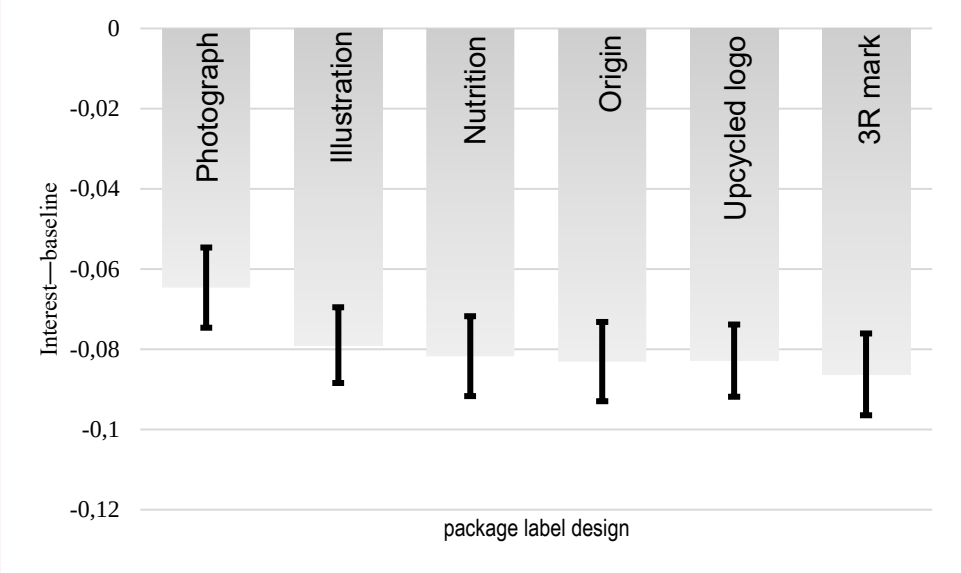

FIGURE 2. EEG-MEASURED NEURAL INTEREST ACROSS PACKAGING DESIGNS (MEAN ± SE). LOWER NEGATIVE VALUES INDICATE HIGHER INTEREST.

4.3. RANKING-BASED PREFERENCE ANALYSIS

Participants explicitly ranked the packaging designs based on personal preference (Fig. 3). Consistent with EEG findings, Package Label Design 1 (photographic imagery) was ranked most favorably (lowest rank score). Package Label Design 6 (3R environmental logo) received the least favorable ranking (highest score), highlighting a clear alignment between neural and conscious preferences. A Friedman test confirmed statistically significant differences in preferences among the designs ($\chi^2 = 37.89$, $p < 0.001$), supporting the reliability of these rankings.

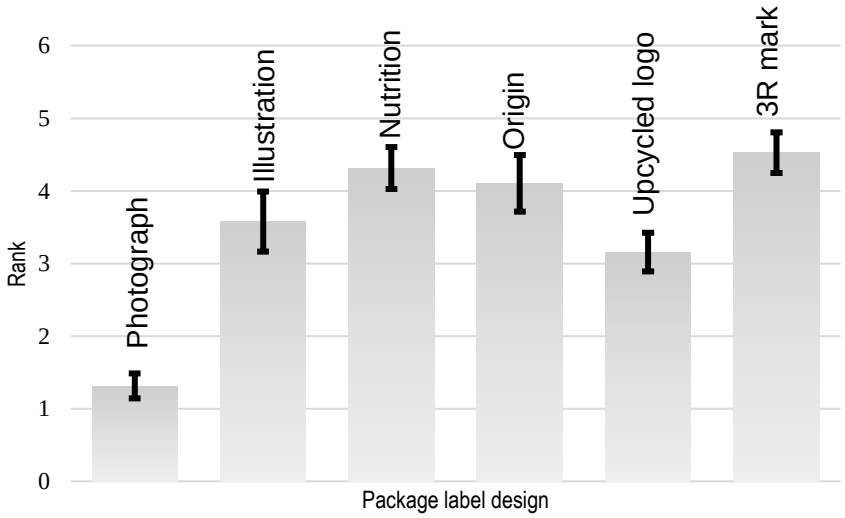

FIGURE 3. PARTICIPANT PREFERENCE RANKINGS OF PACKAGING DESIGNS (MEAN RANK ± SE). LOWER SCORES REFLECT HIGHER PREFERENCE

5. Discussion

The findings from this study demonstrate that incorporating photographic imagery significantly influences consumer responses toward upcycled food packaging, aligning with and extending dual-process theories of consumer decision-making (Schnurr, 2019; Duong et al., 2024). Dual-process theory differentiates between intuitive, automatic "System 1" processing and deliberative, analytic "System 2" processing (Barrouillet, 2011). Our EEG results suggest that photographic imagery primarily activates System 1 by capturing attention and eliciting immediate emotional responses. Specifically, heightened frontal alpha asymmetry indicated approach motivation, while increased theta activity reflected attentional engagement. In contrast, P300 responses were associated with more controlled, deliberative evaluations consistent with System 2 processing. This aligns with recent evidence indicating that visual stimuli quickly communicate product attributes, thereby reducing cognitive load and facilitating consumer acceptance of novel sustainable products (Tang et al., 2025; Granato et al., 2022).

These findings offer new insights into sustainable food marketing literature, particularly regarding the effectiveness of visual storytelling. Prior research primarily focused on text-based claims or sustainability logos (Bhatt et al., 2021). In contrast, our findings uniquely highlight how visual imagery on packaging significantly enhances consumer engagement at both subconscious and conscious levels. The high neural engagement elicited by photographic labels underscores the efficacy of visual communication strategies in reducing perceived uncertainty and enhancing product appeal. Notably, the alignment between EEG measures (subconscious engagement) and explicit ranking preferences underscores the robust effectiveness of visual storytelling as a packaging strategy.

Additionally, this research reinforces the critical role of consumer trust and familiarity in acceptance of sustainable innovations. Despite prior explanation about upcycled food concepts, participants exhibited cautious subconscious and conscious preferences, consistent with literature identifying food neophobia as a significant barrier (Pliner and Hobden, 1992; Erhard et al., 2023). Trust-building appears essential, particularly when introducing novel food concepts like upcycling, as low familiarity typically triggers instinctive skepticism. These results align with recent findings highlighting that consumer trust in safety and quality significantly drives acceptance of upcycled products (Seo and Mori, 2024). Thus, integrating clear quality assurances and credible sustainability claims into packaging could effectively mitigate trust-related barriers. For instance, displaying side-by-side images of upcycled ingredients and the final snack product on the package can concretely reassure consumers of product quality and safety, effectively reducing hesitation associated with the unfamiliar concept of upcycling.

Our results further indicate that conventional eco-labels, such as "Upcycled Certified," have limited standalone effectiveness unless consumers clearly understand and trust these labels. Awareness and credibility are prerequisites for eco-label efficacy, as consumers often approach unfamiliar sustainability claims with skepticism (Sonntag et al., 2023). Consistent with prior literature, our findings suggest that eco-labels become impactful only when coupled with tangible reassurances, such as appealing visuals or familiar product attributes. Hence, eco-labels should be complemented by informative strategies that clarify their meaning and enhance consumer trust.

Moreover, the interplay between photographic imagery and labeling strategies provides insights into how consumers reconcile emotional and analytical responses toward sustainable foods. Our results empirically demonstrate how System 1 and System 2 mechanisms interact: compelling visuals moderate initial intuitive aversions (System 1), which in turn facilitates more positive deliberative evaluations (System 2) as captured by P300 responses and explicit rankings. Compelling visuals seem capable of moderating initial instinctive aversions (System 1), thereby facilitating

more positive analytical evaluations (System 2). This dual-process alignment extends previous research by showing empirically that packaging elements can significantly influence consumer acceptance of sustainability claims (Vermeir and Roose, 2020). Our findings underscore that consumer acceptance is not solely rational but deeply influenced by affective and intuitive reactions, thereby enriching theoretical understandings of sustainable consumption behaviors.

5.1. THEORETICAL IMPLICATIONS

This study advances consumer behavior theory by empirically demonstrating dual-process theory in a sustainability context, specifically how automatic and deliberative processes interact when evaluating novel sustainable foods. EEG data directly illustrated subconscious hesitancy toward unfamiliar sustainable products, confirming that intuitive, emotional responses can diverge from explicitly stated attitudes. By identifying how visual heuristics (photographic imagery) can alleviate cognitive barriers, this study bridges a significant gap in the literature on sustainable food acceptance. Moreover, our findings underscore the critical role of trust and credence attributes—qualities that consumers cannot independently verify—in theoretical models of food acceptance (Jacobsen et al., 2020). By demonstrating how packaging visuals can effectively communicate credence attributes and reduce perceived risk, this research contributes to existing frameworks such as the Technology Acceptance Model, emphasizing the need for visual reassurance alongside informational interventions. Additionally, our findings refine labeling theory by revealing conditions under which eco-labels effectively influence consumer decisions, highlighting the importance of consumer awareness thresholds and credibility in determining eco-label effectiveness (Hou et al., 2023; Quoc et al., 2025).

5.2. PRACTICAL IMPLICATIONS

From a managerial perspective, our findings offer actionable recommendations for packaging designers and marketers of upcycled foods. First, emphasizing photographic imagery on packaging effectively communicates product appeal and reduces uncertainty. Visual storytelling—such as depicting the upcycled ingredient alongside the final product—can immediately enhance consumer trust and acceptance. Second, clearly signaling safety, quality, and tangible product benefits alongside sustainability claims can mitigate consumer skepticism. Informative labels highlighting safety certifications or familiar attributes (e.g., nutritional content) are essential to building consumer confidence. Finally, eco-labels should be strategically used and paired with educational initiatives to build consumer familiarity and credibility over time. Given that consumer recognition of eco-labels is still developing, packaging should combine visual cues with simple, informative messages explaining sustainability claims. These insights provide concrete strategies for effectively marketing upcycled products and other novel sustainable foods, thereby potentially accelerating consumer adoption and market success.

5.3. LIMITATIONS AND FUTURE RESEARCH

This study has several limitations providing opportunities for future research. Firstly, the controlled laboratory setting and limited sample size restrict the generalizability of findings to real-world purchasing behaviors. Future studies should validate these findings in naturalistic retail environments using virtual reality or field experiments. Secondly, the relatively homogeneous participant demographic may limit cross-cultural applicability. Future research should incorporate diverse, representative samples to test the robustness of packaging design effects across cultures. Thirdly, the study focused on a single product category (upcycled snacks), necessitating broader research across different food categories and types of upcycled ingredients. Longitudinal studies assessing repeat purchase behavior and brand loyalty would further clarify the sustained effectiveness of identified packaging strategies. Additionally, incorporating complementary neurophysiological methods, such as eye-tracking or facial expression analysis, could enrich

understanding of consumer responses. Addressing these limitations through continued research will enhance practical and theoretical insights into effective marketing strategies for sustainable food innovations.

6. Conclusion

This research advances our understanding of consumer preferences for upcycled food products by demonstrating that photographic imagery on packaging significantly enhances consumer engagement and product appeal. Employing EEG-based neuroscientific methods alongside consumer preference rankings, we established that visual elements effectively capture consumer attention, quickly conveying tangible product benefits and alleviating uncertainty associated with novel sustainable foods. Grounded in dual-process theory, our findings highlight that intuitive, affect-driven responses triggered by imagery facilitate rational acceptance of sustainability concepts, such as food upcycling. Conversely, unfamiliar eco-labels alone exhibited limited effectiveness due to consumer skepticism and trust-related concerns, underscoring the necessity of credible, reassuring contexts (e.g., safety, quality) for sustainability claims.

From a practical standpoint, our study provides actionable insights for marketers and packaging designers. Specifically, we recommend strategically employing photographic visuals to communicate authenticity and product appeal clearly and instantly. Complementary informational strategies, such as explicit safety assurances and transparent sustainability explanations, are equally critical in reinforcing consumer trust. This dual approach—combining visual storytelling with credible sustainability cues—can significantly enhance consumer acceptance of upcycled foods.

Theoretically, our research enriches the literature by empirically illustrating how subconscious (System 1) and deliberative (System 2) processes jointly shape consumer responses to sustainable packaging. As the market for upcycled foods continues to grow, our findings contribute important knowledge on effective consumer communication strategies, offering pathways for future academic investigation and industry practice. Ultimately, by refining packaging and messaging approaches, this study aims to facilitate broader consumer adoption of sustainable food products, thereby supporting environmental goals and encouraging sustainable consumption patterns.

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