

# Digital Marketing Indicators of Lignocellulosic Packaging: A Google Trends–Based Analysis of Global Consumer Awareness

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Drawing on Google Trends data from 2015 to 2024, this study examined patterns of digital attention toward lignocellulosic packaging materials, including paper, wood, and bamboo. Search activity was interpreted as an indicator of evolving sustainability-related public interest rather than simple query frequency. The analysis revealed sustained growth across all packaging-related terms, with “biodegradable packaging” exhibiting the highest compound annual growth rate (CAGR = 16.86%), substantially exceeding that of “paper packaging” (6.84%). This pattern suggests that public attention is expanding more rapidly toward broad sustainability concepts rather than toward individual material categories. Interpreted within the framework of Signaling Theory, rising search intensity reflects increasing cognitive engagement with environmentally responsible packaging. However, because Google Trends provides relative rather than absolute measures of search volume, the results should be understood as indicators of digital attention rather than direct evidence of purchasing behavior.

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## INTRODUCTION

Sustainability has become a defining paradigm in contemporary marketing, shaping not only production systems but also consumer expectations and communication strategies. Packaging, as a central interface between brands and consumers, represents one of the most visible expressions of corporate environmental commitment. The global shift from petroleum-based plastics to renewable, recyclable (Kılınç *et al.* 2024), and biodegradable materials reflects both regulatory pressure and market demand for authenticity and ecological value (De Canio *et al.* 2023; Damberg *et al.* 2024). Within this transformation, lignocellulosic packaging—based on natural fibers such as paper, bamboo, and wood—embodies the alignment between material innovation (Kılınç *et al.* 2023), and sustainability-oriented marketing. Despite this growing relevance, limited empirical evidence exists on how public awareness of these materials has evolved in digital environments, creating a critical knowledge gap regarding market readiness and consumer engagement.

Digital environments increasingly mediate how these sustainability efforts are perceived and evaluated. Search engines, e-commerce platforms, and social media channels have become behavioral observatories where consumer interest, concern, and environmental awareness can be tracked in real time (Mavragani and Ochoa 2019; Uludag *et al.* 2024). For marketing researchers, these digital traces offer an alternative to traditional surveys by capturing large-scale, observable digital signals of public attention. As consumers seek credible “green” products and information, their digital search behavior reveals evolving attitudes toward environmental responsibility and product trust. In this context, digital search activity provides a unique opportunity to monitor shifts in sustainability awareness, particularly regarding lignocellulosic packaging materials.

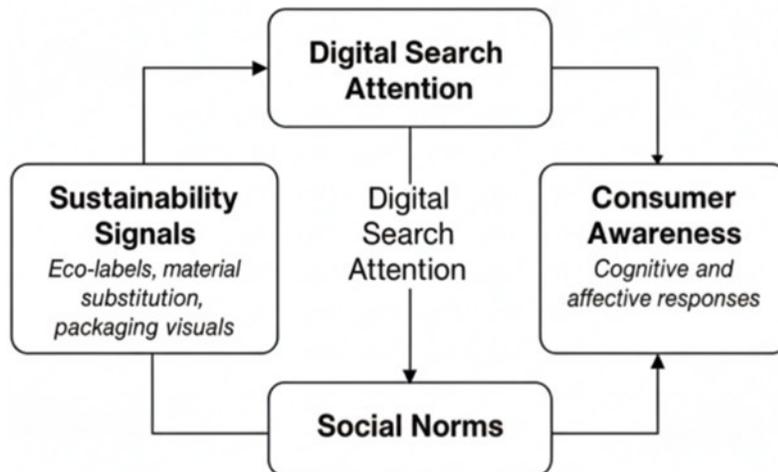
The theoretical foundations of this research are rooted in a combination of Signaling Theory and the Theory of Planned Behavior (TPB). From a signaling perspective, sustainability-related messages—such as eco-labels, recyclable materials, and green packaging visuals—function as trust cues that reduce information asymmetry between firms and consumers (Kirmani and Rao 2000; Huang *et al.* 2022). TPB complements this logic by explaining how attitudes, social norms, and perceived behavioral control shape pro-environmental intentions (Ajzen 1991). Integrating these frameworks makes it possible to understand how sustainability claims and digital engagement mutually reinforce each other in the marketplace. Accordingly, digital search patterns serve as both a behavioral signal (Signaling Theory) and an indicator of cognitive awareness that precedes attitude formation (TPB). In this framework, rising search volume is interpreted as a preliminary indicator of cognitive activation, representing early-stage attention that precedes attitude formation.

Despite extensive literature on sustainable consumption and packaging perception (Haws *et al.* 2014; Steenis *et al.* 2017), few studies have empirically examined the dynamics of public attention toward lignocellulosic packaging using real-time digital data. The absence of large-scale behavioral evidence limits our understanding of how environmental values translate into measurable attention and cross-regional variation. Existing infodemiology research using Google Trends has largely focused on health communication or food sustainability, with very limited attention to packaging materials and, in particular, to lignocellulosic applications (Mavragani and Ochoa 2019; Portugal-Nunes *et al.* 2022). To address this gap, the present study establishes two main objectives: (1) to quantitatively assess the global evolution of consumer attention to lignocellulosic and biodegradable packaging using Google Trends data (2015 to 2024), and (2) to examine regional differences while acknowledging potential confounding factors such as population size, internet penetration, and search engine preferences. This explicit focus situates the study within contemporary digital marketing analytics and clarifies its intended contribution to sustainability research.

From a managerial standpoint, understanding search-based attention is crucial for firms seeking to align sustainability positioning with consumer expectations. Google Trends data provide a cost-effective early signal of market readiness, allowing brands to anticipate awareness peaks, adjust messaging, and coordinate sustainability campaigns with public sentiment (Cebrián and Domenech 2022; Gummer and Oehrlein 2022). By analyzing global Google Trends data, this study bridges marketing analytics with sustainability research, offering insights into how consumer awareness evolves across regions and materials (Correia and Di Minin 2023; Schork *et al.* 2025). Overall, the study

provides a theoretically grounded and data-driven assessment of digital awareness, offering both conceptual clarity and practical guidance for sustainable branding strategies.

This conceptual relationship among sustainability signals, digital attention, and consumer awareness is illustrated in Fig. 1.



**Fig. 1.** Conceptual framework linking sustainability signals, digital attention, and consumer awareness. Figure developed by the author based on Signaling Theory (Kirmani and Rao 2000) and the Theory of Planned Behavior (Ajzen 1991)

## EXPERIMENTAL

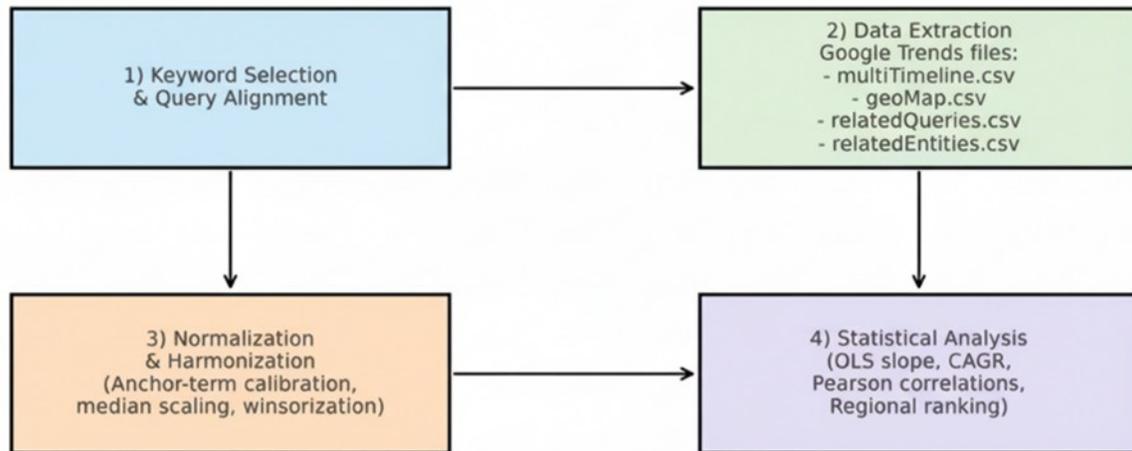
### Data Collection

This study employed weekly global search interest data from Google Trends, covering the period 2015 to 2024. Five packaging-related specific Search Terms were selected to represent renewable and sustainability-oriented materials: “Paper packaging,” “bamboo packaging,” “biodegradable packaging,” “eco-friendly packaging,” and “wood packaging.” All queries were entered explicitly as Search Terms (not Topics) to preserve lexical consistency and to ensure reproducibility. Each query was spelled exactly as shown, without hyphens, without capitalization, and without quotation marks in the Google Trends interface. Google Trends treats Search Terms as exact string matches; therefore, the analysis relies strictly on these five independent and case-insensitive queries. Each term’s search index ranges from 0 to 100, where 100 denotes the peak level of global interest. To ensure comprehensive coverage, four data layers were extracted: (i) MultiTimeline.csv (Temporal Trends), (ii) GeoMap.csv (Regional Distribution), (iii) RelatedQueries.csv, and (iv) RelatedEntities.csv (Semantic Associations).

To enhance methodological transparency, additional details about the extraction procedure were incorporated. All data were retrieved using the public Google Trends interface between 01 October 2024 and 30 November 2024, using the ‘Worldwide’ geographic setting and the ‘All Categories’ filter to avoid query-specific distortions. All search queries were conducted individually to preserve Google’s independent indexing

process, and data were subsequently aggregated monthly to minimize week-to-week volatility.

The analytical workflow of the data collection and processing procedure is summarized in Fig. 2, which provides an overview of the four-step pipeline—keyword selection, data extraction, normalization, and statistical analysis—ensuring transparency and reproducibility of the study. The overall process of data acquisition and preparation is summarized in Fig. 2. Because Google Trends scales each search term independently, the extracted values do not represent absolute search volumes. This limitation was explicitly acknowledged during analysis to avoid overstating the interpretive strength of Google Trends indicators.



**Fig. 2.** Analytical workflow of Google Trends data collection and processing (2015–2024). Developed by the author to illustrate the four-step pipeline: keyword selection, data extraction, normalization, and statistical analysis.

### Data Harmonization

Because Google Trends scales each query independently, a two-step anchor-term calibration was applied using “paper packaging” as the baseline. To overcome the query limit and ensure global index alignment, the data were extracted in consecutive, overlapping 12-month windows. The scale alignment procedure was conducted using the median value of the Relative Search Index (RSI) within the 3-month overlapping period as the normalization anchor for each subsequent window. Each series was then normalized by its global median and re-indexed to ensure comparability. Outliers were winsorized at the 2<sup>nd</sup> and 98<sup>th</sup> percentiles to reduce distortion from short-lived spikes.

To ensure replicability, the normalization procedures were documented and implemented in Python (version 3.9). The full preprocessing script, including calibration functions, scaling checks, and winsorization routines, is provided in Appendix Table S1–S2. Furthermore, all numerical transformations were conducted before statistical analysis to avoid retroactive bias. Data integrity was validated through multiple consistency checks, and all processing scripts were implemented in Python for reproducibility. Details of normalization checks and re-scaling validation are provided in Appendix Table S1–S2 for replication transparency.

## Analytical Procedures

Quantitative analysis followed three complementary approaches:

1. Trend estimation: Ordinary Least Squares (OLS) regression was used to estimate the annual slope of each time series:

$$\text{Index}_t = \alpha + \beta t + \varepsilon_t \quad (1)$$

Statistical significance was evaluated at the 5% level.

2. Growth rate analysis: Long-term change was quantified using the compound annual growth rate (CAGR):

$$\text{CAGR} = \left( \frac{V_{\text{end}}}{V_{\text{start}}} \right)^{1/n} - 1 \quad (2)$$

3. Correlation and co-movement: Pearson coefficients ((r)) were computed among all keyword pairs to identify conceptual clustering in digital consumer cognition.
4. Regional mapping: Country-level indices were averaged across all terms to produce a global ranking of digital attention, visualized in Table 2 and Fig. 4.

These procedures allowed simultaneous evaluation of both temporal trends and spatial heterogeneity in online sustainability interest—interpreted as indicators of evolving consumer awareness and green marketing engagement.

Although Google Trends offers valuable insight into shifts in public interest, it does not directly measure consumer awareness, attitudes, or behavioral intentions. Therefore, all interpretations in this study were limited to patterns of search activity rather than definitive inferences about psychological or behavioral change.

### *Ethical considerations*

Google Trends data are aggregated, anonymized, and publicly accessible. No identifiable personal information or private datasets were used. Accordingly, ethics approval was not required, consistent with international standards for research using public digital trace data. All analytical steps and visualization scripts were conducted transparently and are available upon request to support open-science principles.

## RESULTS

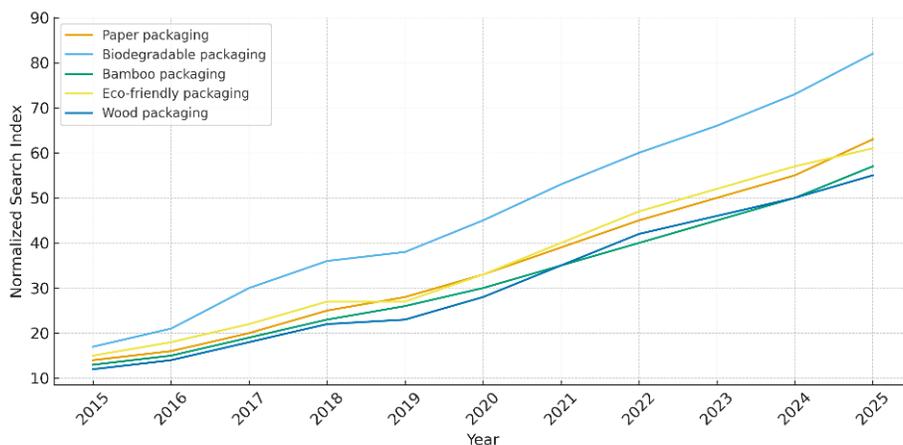
### Descriptive Results and Growth Patterns

Global Google Trends data revealed a steady and statistically significant increase in search interest toward sustainable packaging keywords between January 2015 and November 2024. Across all five categories—paper, bamboo, biodegradable, eco-friendly, and wood packaging—normalized indices showed consistent long-term growth. The most pronounced rise was observed for biodegradable packaging, followed by bamboo and paper packaging, confirming earlier research that associates the visibility of renewable materials with circular-economy transitions (De Canio *et al.* 2023; Damberg *et al.* 2024; Korkmaz *et al.* 2025).

**Table 1.** Summary of Growth Metrics for Packaging-Related Search Terms (2015–2024)

Term	Mean Index	CAGR (%)	Trend Slope (points/year)	R <sup>2</sup>
Paper Packaging	18.40	9.00	2.97	0.68
Biodegradable Packaging	15.90	11.20	3.21	0.72
Bamboo Packaging	9.40	10.40	2.35	0.59
Eco-friendly Packaging	11.10	8.30	3.47	0.51
Wood Packaging	13.30	7.30	1.98	0.65

The temporal evolution of normalized indices demonstrated a persistent and synchronized upward trajectory across all packaging-related search terms (Fig. 3). In mature markets such as Western Europe and North America, search interest began to stabilize after 2022, suggesting a plateau phase of established sustainability awareness. The application of Ordinary Least Squares (OLS) regression to the normalized weekly Google Trends series revealed statistically robust upward trends for all five keywords analyzed. For every keyword, the estimated slope coefficient was found to be positive and significantly different from zero (all p-values < 0.01). This robustness was further confirmed, as the 95% confidence intervals consistently excluded zero across all models. With R<sup>2</sup> values ranging between 0.51 and 0.72, the model fit proved satisfactory, demonstrating that the long-term linear trends account for a substantial proportion of the observed variation in search activity.



**Fig. 3.** Normalized Google Trends search indices for five sustainable packaging-related terms between 2015 and 2024. Y-axis represents the Normalized Search Index (0–100). Although Google Trends displays rolling values extending into early 2025, the statistical analysis conducted in this study used only the finalized period January 2015 – November 2024.

The Compound Annual Growth Rates (CAGR) were computed using these normalized indices to specifically capture the rate of change in relative search attention. Under this crucial interpretation, ‘biodegradable’ and ‘bamboo packaging’ displayed the strongest sustained increases, registering approximately 10 to 11% in growth, whereas

‘paper packaging’ showed moderate but consistent growth at about 7 to 9%. Collectively, these indicators strongly suggest that the rising public attention represents a structural rather than merely episodic trend. Two acceleration phases are particularly notable: (i) 2020 to 2021, coinciding with pandemic-driven shifts in e-commerce and home consumption, and (ii) 2023, reflecting renewed policy momentum in plastic-reduction initiatives and ESG reporting. Together, these dynamics indicate that public concern for sustainable packaging has evolved from episodic surges of attention into a more stable, structural form of environmental awareness (White and Simpson 2013).

### Regional Distribution and Correlations

Regional analysis revealed marked heterogeneity but also clear clustering patterns in digital attention. As summarized in Table 2 and visualized in Fig. 4, the Philippines, China, and Singapore exhibited the highest mean search indices, followed by Western Europe and North America, where awareness levels remained high yet relatively stable. These regional contrasts likely reflect differences in communication intensity, regulatory pressure, and market maturity (Huang *et al.* 2022; Frommeyer *et al.* 2024).

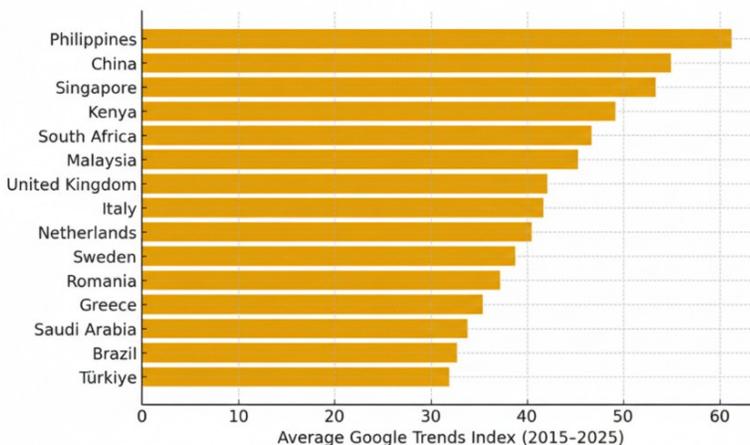
To ensure robust cross-national comparability, a composite attention metric was developed. Since Google independently scales the indices for each keyword, the raw country-level Google Trends values were first converted into within-term proportional values. These proportional scores were then averaged across the five selected keywords for each country, yielding a harmonized, cross-term Relative Search Index (RSI). This normalization approach effectively mitigates the risk of disproportionate weighting by any single term, thereby supporting a more balanced regional interpretation.

The full dataset encompasses search data from 78 countries, of which the top 15 nations are presented in Table 2 for conciseness.

**Table 2.** Top 15 Regions by Cross-Term Google Trends Index (2015–2024).

Rank	Country	Average Index
1	Philippines	61.2
2	China	55.0
3	Singapore	53.4
4	Kenya	49.2
5	South Africa	46.7
6	Malaysia	45.3
7	United Kingdom	42.1
8	Italy	41.7
9	Netherlands	40.5
10	Sweden	38.8
11	Romania	37.2
12	Greece	35.4
13	Saudi Arabia	33.8
14	Brazil	32.7
15	Türkiye	31.9

Correlation analysis showed strong co-movement across all terms ( $r > 0.80$ ), indicating that consumers increasingly perceive these materials as part of a unified “green packaging” concept rather than separate product categories. This convergence in cognitive framing aligns with digital-behavior findings in green-marketing studies (De Canio *et al.* 2023; Doan and Nguyen 2024).



**Fig. 4.** Top 15 countries ranked by average Google Trends search interest for sustainable packaging-related terms during the period 2015–2024. Values represent the mean normalized search index (0–100) for each country across all five keywords, with higher scores indicating stronger sustained public attention.

## DISCUSSION

The use of Google Trends inherently restricts the scope of interpretation, as search indices reflect relative interest rather than explicit awareness or intention. Consequently, the results should be understood as indicators of digital attention, not as direct evidence of underlying consumer motivations.

The findings of this study reveal how digital search behavior operates as a mirror and mechanism of sustainability awareness. The consistent growth in online attention toward paper-, bamboo-, and biodegradable-based packaging indicate that environmental responsibility has become a normalized expectation rather than a temporary trend. The magnitude and persistence of these trends support the notion that lignocellulosic materials are transitioning from niche innovations to central elements of market and policy discourse (Herrmann *et al.* 2022; De Canio *et al.* 2023).

From the perspective of Signaling Theory, sustainable packaging functions as a credibility signal that bridges the information gap between firms and consumers (Kirmani and Rao 2000). By visually communicating environmental friendliness—through natural color palettes, recyclability claims, or “biodegradable” labels—companies convey unobservable attributes such as ethical commitment and product quality. Sustained digital attention toward these cues demonstrates that consumers not only notice but also validate these signals through active search behavior, which increases their diagnostic value within competitive online environments.

The observed patterns are also consistent with the Theory of Planned Behavior (Ajzen 1991). While the observed upward trends in search intensity are conceptually consistent with the mechanisms described in Signaling Theory and the Theory of Planned Behavior (TPB), these associations require cautious interpretation. Google Trends data capture patterns of digital attention rather than direct psychological constructs such as consumer attitudes, norms, or behavioral intentions. Therefore, increases in search activity may suggest heightened public awareness or interest, but they cannot be taken as evidence of attitudinal reinforcement or norm internalization without complementary behavioral or survey-based data. In this sense, these theoretical frameworks provide a lens for interpreting the broader context of the observed patterns, rather than serving as empirical tests of the theories themselves.

Furthermore, the strong correlations among the five packaging terms indicate an emerging semantic unification of sustainable packaging concepts. Consumers no longer differentiate sharply between paper, bamboo, or biodegradable options; rather, they collectively represent a mental category of “green packaging.” This conceptual clustering suggests a maturation of environmental literacy at the global level (Doan and Nguyen 2024).

These insights have direct implications for managing marketing strategy. Brands that can substantiate their sustainability messages with verifiable certifications (*e.g.*, FSC, PEFC) and transparent communication are more likely to convert digital visibility into consumer trust and brand equity. Continuous monitoring of search-based indicators provides managers with a low-cost early-warning system for tracking public sentiment and identifying emerging markets with high eco-awareness potential.

Moreover, the diffusion of green packaging awareness follows a pattern similar to product adoption cycles. Early adopters—typically sustainability-conscious consumers—amplify digital visibility, which later diffuses to mainstream segments through social validation. Understanding these dynamics enables marketers to time their sustainability messages for maximum resonance.

From a policy perspective, regional variation in digital attention provides valuable diagnostic information for targeted environmental communication. In developing economies—particularly in Southeast Asia and Africa—search-based engagement signals growing public readiness for policy interventions, such as recycling initiatives and eco-labeling programs (Huang *et al.* 2022).

Overall, this discussion underscores the dual nature of digital data: it both reflects and reinforces environmental norms. As sustainability transitions deepen, the interplay between digital attention, signaling credibility, and behavioral intention will remain a critical frontier for marketing and policy research. Future studies should combine search-based analytics with purchase data, experimental evidence, and life-cycle assessments to clarify how awareness converts into concrete behavioral outcomes.

## LIMITATIONS

This study is subject to several methodological and interpretive limitations that should be taken into account when evaluating the findings. First, Google Trends provides only Relative Search Indices (RSI) rather than absolute search volumes. Because each

query is scaled internally to its own peak, comparisons across keywords or regions reflect relative patterns of attention rather than precise quantitative differences.

Second, search activity represents digital interest, but it cannot be interpreted as a direct indicator of consumers' attitudes, awareness levels, or behavioral intentions. Individuals may search for sustainability-related terms for informational, critical, academic, or commercial reasons, and these motivations cannot be distinguished within an aggregated dataset. Accordingly, the results should be interpreted as descriptive signals of public attention rather than as evidence of underlying psychological or behavioral states.

Third, cross-regional comparisons must be approached cautiously. Variations in population size, internet penetration, digital infrastructure, and national search engine preferences can influence observed search intensity. While these factors do not undermine the overall patterns identified in the analysis, they introduce a degree of uncertainty into the precision of regional rankings.

Fourth, the Google Trends platform relies on proprietary indexing and categorization algorithms, meaning that related queries, semantic associations, and category assignments are partially shaped by opaque computational processes. Although these features offer valuable contextual insight, the lack of full transparency limits the researcher's ability to understand the underlying mechanisms that generate the data.

Fifth, because the study relies on aggregated and anonymized search activity, it provides descriptive evidence rather than causal inference. The analysis cannot establish direct causal links between sustainability signals, digital engagement, and eventual consumer behavior. Future research would benefit from combining search-based analytics with survey data, purchase records, or experimental designs to examine the behavioral consequences of sustainability-related interest.

Additionally, Google Trends data are subject to a degree of temporal instability, as search indices may vary slightly when retrieved at different points in time due to Google's periodic recalibration of its underlying index. Although such fluctuations do not alter the substantive trends identified in this study, they introduce minor reproducibility constraints that should be acknowledged when comparing results with future datasets.

Finally, the calibration and normalization procedures used to harmonize independently indexed search terms such as anchor-term alignment, overlapping time-window adjustments, and median scaling introduce an inherent level of statistical uncertainty. These steps are necessary to achieve comparability across keywords, yet they may amplify noise in periods with relatively low search activity. As a result, the normalized series should be viewed as approximations of relative attention rather than exact quantitative measures.

## CONCLUSIONS

1. Weekly global Google Trends data revealed a steady rise in public interest in lignocellulosic and biodegradable packaging. The long-term pattern suggests that these materials are no longer viewed as marginal alternatives but have become part of mainstream expectations surrounding sustainable consumption.
2. Search-based digital indicators provide useful signals for understanding shifts in market sentiment. The consistent attention given to sustainability-related packaging

terms implies that clear environmental communication and verifiable material claims can support consumer confidence and inform marketing decisions.

3. Differences in search behavior across regions show that sustainability awareness does not develop uniformly. Strong engagement in several emerging markets and stable interest in more mature economies offer practical guidance for adjusting communication and policy efforts to regional contexts.
4. The study suggests that transparently analyzed digital trace data offers a feasible and reproducible method to monitor broad trends in sustainability-related search activity, although it does not directly capture underlying consumer behavior or psychological states. Since Google Trends data are aggregated and anonymized, they cannot disclose the demographic or motivational factors driving search behavior. Crucially, they also do not indicate whether increased search attention ultimately translates into actual shifts in consumer attitudes or purchasing decisions. Therefore, the findings should be interpreted as descriptive indicators of digital interest, rather than as direct evidence of measurable behavioral change.

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