Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9, 715-730
2025
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v9i9.9951

Global economic and sustainability trends in green packaging: A systematic literature review

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Abstract: Green packaging is increasingly recognized as a vital pathway for reconciling environmental sustainability with economic development on a global scale. This study aims to synthesize recent research trends and identify knowledge gaps to better understand the drivers, barriers, and future directions of green packaging adoption. A systematic literature review was conducted using the PRISMA 2020 methodology to analyze 40 high-quality articles selected from quartile-one journals indexed in Scopus and Google Scholar between 2019 and 2024. In line with global economic and sustainability trends, the findings reveal that rising consumer awareness, regulatory support, and material innovations drive the adoption of green packaging, enhance business performance, and advance sustainability through waste reduction and circular economy practices. However, there are still significant challenges concerning high costs, lack of technology and infrastructure, consumer behavior, and regulatory issues. To enable the rapid expansion of sustainable packaging worldwide, strategies must integrate policy, innovation, and education. This review thus offers a systematic analytical perspective and suggests that future studies should focus on sector-specific analysis, economic viability, consumer willingness, and digital technology usage in the implementation of green packaging. Analyzing these research areas from different approaches is expected to improve sustainable business models and help achieve the Sustainable Development Goals.

Keywords: *Global economic trends, Green packaging, Sustainability trends, Sustainable development goals, Systematic literature review.*

1. Introduction

These days, industries focus more on sustainability due to rising environmental and economic concerns. The packaging industry, which greatly affects pollution and resource consumption, is now shifting toward eco-friendly packaging options that support the Sustainable Development Goals [1, 2]. These solutions open new business chances and affect market trends as well as cutting waste and saving resources [3]. Furthermore, sustainability efforts are influencing consumer actions, business approaches, and government policies. Main trends are more demand for eco-friendly packaging, stronger green rules, and new ideas in sustainable materials and recycling [4].

Packaging is vital in global distribution because it keeps products safe, lasts longer, and helps with logistics. However, despite its essential functions, packaging is also one of the largest contributors to municipal solid waste, accounting for approximately 30–35% in developed countries and 15–20% in developing countries [5]. The increase of global consumption, the growth of e-commerce, and the trends toward practical lifestyles have accelerated the production of single-use plastic packaging, leading to environmental, economic, and social issues. Awareness of this issue has driven the emergence of the concept of green packaging or sustainable packaging, which integrates environmental, social, and economic dimensions into its design and use [6, 7]. This approach requires the simultaneous application

History: Received: 11 July 2025; Revised: 5 August 2025; Accepted: 8 August 2025; Published: 12 September 2025
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of eco-efficiency and eco-effectiveness principles, which aim to maximize environmental performance without compromising the primary function of packaging, material efficiency, and consumer safety.

To minimize the use of standard plastics, the food industry is turning to biodegradable films and environmentally friendly packaging [7]. Growing global awareness of environmental sustainability has driven substantial transformations in the packaging sector through the adoption and advancement of green packaging practices. Pressure from international regulations, changing consumer preferences, and corporate social responsibility demands are accelerating the adoption of sustainable packaging innovations [8]. The industry faces the challenge of balancing functional requirements, cost efficiency, and environmental impact in selecting and implementing packaging solutions [6]. Besides environmental concerns, economic dimensions play an important role in the adoption of green packaging. Many companies associate packaging sustainability with potential competitive advantages, cost efficiency, and market share expansion [2, 9]. However, barriers such as unclear cost-benefit analysis, high upfront investments, and technical complexities make it difficult for companies to simultaneously fulfill packaging functionality and sustainability goals [2, 6]. For example, a study in the European food sector found that decisions to adopt sustainable packaging involve multi-criteria considerations that include service quality, labor costs, and consumer expectations [9].

Consumer demands and government rules are a major role why green packaging is used. Although awareness of biodegradable packaging among consumers is increasing, purchase intentions often do not align with actual behavior due to factors such as price, aesthetics, and perceived benefits. For example, minimalist packaging design can strengthen consumers' green trust in everyday products [1, 10] but its success depends heavily on the credibility of sustainability claims and market context [3]. Government regulations, such as Extended Producer Responsibility, plastic taxes, and environmental labeling standards, also play a crucial role in promoting the adoption of sustainable packaging [6]. In countries with strict policies, these regulations spur material innovation and increased recycling, although their impact varies across sectors and company sizes [3, 9]. The transition to green packaging is thus a complex, multidimensional phenomenon involving the interplay of global economic trends, technological innovation, public policy, and consumer behavior dynamics. Nevertheless, existing literature remains fragmented, with many studies focusing on isolated aspects such as material technology or consumer behavior without providing a comprehensive overview that holistically connects drivers of adoption, implementation barriers, and the subsequent performance effects associated with green packaging [5, 6, 8, 11].

To fill this gap, the study uses a Systematic Literature Review (SLR) to explore global trends and impacts of green packaging from 2019 to 2024, covering economic, sustainability, and market views. This method allows for a clear and complete studies from different areas. As sustainable packaging becomes more important under global challenges, the study points out key trends, barriers, and opportunities, considering the environment, economy, and business. The aim is to fill current research gaps and build a strong base for future studies, innovations, and policy decisions in global sustainable packaging. The review focuses on four areas: materials and their features, management practices, consumer behavior, and waste management in sustainable packaging. By integrating insights from these domains, the study aims to provide a comprehensive understanding of global economic and sustainability trends shaping green packaging. Ultimately, this approach seeks to inform strategic business decisions, technological innovation, and policy frameworks that facilitate effective adoption of sustainable packaging solutions. Although the topic of green packaging has been widely discussed in international literature, studies that integrate global economic trends, business performance, contributions to sustainability, and barriers to adoption are still relatively limited. Most studies focus on a single aspect, such as material innovation or consumer behavior, without providing a comprehensive cross-dimensional and cross-regional overview. The period from 2019 to 2024 is a critical phase marked by accelerated global environmental policies, increased consumer awareness, and supply chain disruptions caused by the pandemic, which have not yet been systematically analyzed in the context of

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9: 715-730, 2025
DOI: 10.55214/2576-8484.v9i9.9951

green packaging. Therefore, this study formulates four research questions as a guide for the literature review:

RQ1: What are the global economic and market trends in the adoption of green packaging from 2019 to 2024?

RQ2: How does the implementation of green packaging affect business performance and profitability?

RQ3: How does green packaging contribute to sustainability and circular economy practices globally?

RQ4: What are the main challenges and barriers faced by industries in adopting green packaging solutions?

Through this comprehensive approach, this study aims to provide strategic insights to support business decision-making, technological innovation, and the development of effective policies to facilitate the adoption of sustainable packaging for long-term growth and competitive advantage in the industry.

2. Literature Review

2.1. Global Economic Trends Influencing Green Packaging

Companies are being pushed by the global economy to use sustainable and efficient methods. In the global market, businesses need innovations in products as well as their production and distribution. In this context, green packaging helps companies gain economic benefits, follow regulations, and meets consumer demand for sustainability. [2, 3]. Furthermore, adopting green packaging can serve as a competitive differentiator, particularly in environmentally conscious markets. Companies that improve material efficiency, optimize logistics, and extend product lifecycles can enhance market share and long-term profitability [6, 9]. Yet, significant economic barriers—such as high initial investment costs and uncertain returns—continue to limit the widespread adoption of sustainable packaging technologies.

2.2. Sustainability Trends and Circular Economy in Packaging

People are now becoming aware of environmental and social problems. Rules are getting stricter, and companies are pushed by stakeholders to put circular economy practices into action. Green packaging is valued because it can cut plastic waste and improve material use. To accomplish this, companies are testing biodegradable materials, designing recyclable packages, and handling waste more effectively. Research shows that paper-based or bioactive packaging is more eco-friendly than plastic, but issues with quality and expense still remain. Meanwhile, the success of the circular economy relies a lot on how consumers act and transparent marketing, which help for building trust in sustainability [1, 3].

2.3. Innovations and Consumer Behavior in Green Packaging

Green packaging materials are developing fast, including active packaging with antibacterial coatings and materials made from natural fibers or farm waste [7, 12]. Nevertheless, understanding how consumers respond to these new ideas is essential, since their buying decisions depend on factors like aesthetic appeal, health benefits, and trust in environmental claims [10, 13]. Empirical research shows a clear gap between what consumers intend to do for the environment and what they actually buy, influenced by factors like price, availability, and how believable sustainability claims seem [1]. Although simple and transparent packaging can enhance consumer trust in green products, its effect depends on market conditions and the level of consumer awareness [10]. Consequently, designing targeted marketing and communication is the key to encourage more people to adopt sustainable packaging.

Edelweiss Applied Science and Technology
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2.4. Challenges and Opportunities in the Adoption of Green Packaging

Studies have shown that the move toward green packaging still runs into several obstacles. Although it is often promoted as a key solution for sustainability, putting it into practice can be difficult. Producing environmentally friendly materials generally costs more than traditional alternatives. In addition, regulations vary across countries and cooperation among companies is not always straightforward [9, 14]. Despite these hurdles, many experts argue that the effort is justified. Companies that switch to green packaging can enhance their public image, comply with global standards, and contribute to the Sustainable Development Goals (SDGs) [15, 16]. To address these issues, researchers recommend strategies such as improving innovation management, using life cycle costing, and strengthening policy frameworks. Equally important is the engagement of all stakeholders—including producers, consumers, and regulators—in fostering an environment conducive to the growth of green packaging [6, 17].

3. Research Methodology

A Systematic Literature Review (SLR) methodology is employed in this study to rigorously analyze research on green packaging trends during 2019–2024. The SLR provides a transparent and replicable framework for identifying, evaluating, synthesizing multidisciplinary studies, addressing fragmentation in the literature, and offering a comprehensive overview of global economic, sustainability, and market perspectives. The review follows several sequential steps to ensure a reproducible and unbiased process. Findings from the analyzed literature indicate that the global adoption of green packaging between 2019 and 2024 has been influenced by a combination of economic pressures, market demand, and increasing sustainability expectations. To answer the research questions and contribute to existing knowledge on the effectiveness of geospatial technologies in urban planning for monitoring unauthorized building modifications, this study applied the PRISMA 2020 framework. PRISMA provides a standardized and evidence-based protocol that guides the rigorous and transparent reporting of systematic reviews. This systematic literature review follows the PRISMA 2020 guidelines to ensure a clear, systematic, and reproducible synthesis [18]. Articles were selected through sequential stages of identification, screening, eligibility evaluation, and inclusion using predefined criteria, as illustrated in the PRISMA 2020 flow diagram (Figure 1). Data extraction and quality assessment were performed to maintain the validity of the findings and minimize potential bias.

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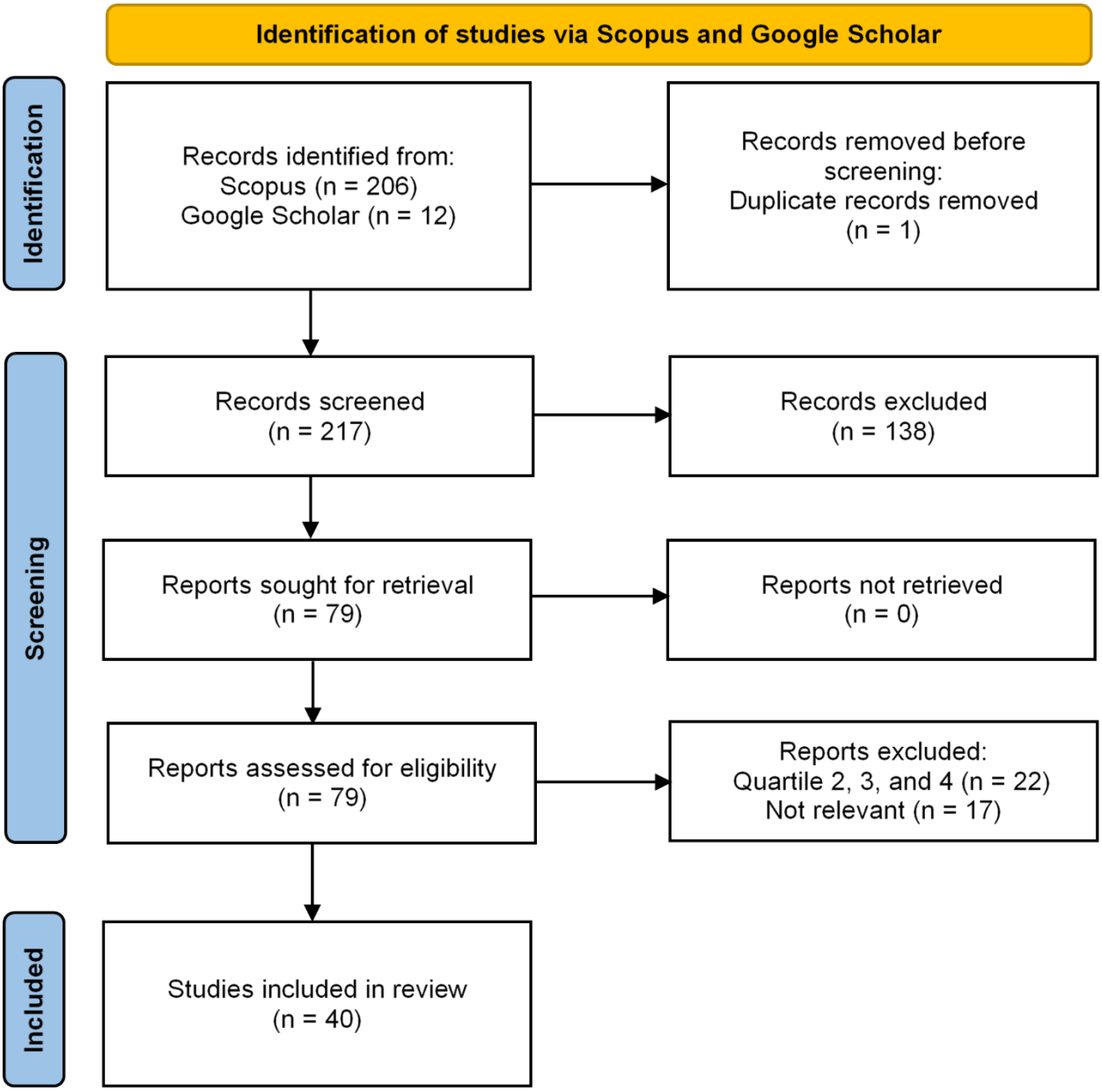

Figure 1.
PRISMA 2020 framework.
Source: Haddaway, et al. [18].

3.1. PRISMA Process Steps

The PRISMA method involves a series of steps to ensure the literature review process consistent and objective. The process can be summarized in three phases: identification, screening, and inclusion. In the identification phase, relevant articles are systematically searched in databases. In the screening phase, duplicates are removed and titles and abstracts are evaluated for eligibility. Finally, in the inclusion phase, the remaining studies that meet the criteria are fully assessed and incorporated into the review.

3.1.1. Identification

Comprehensive searches were conducted across multiple electronic databases, including Scopus and Google Scholar, to identify relevant studies on sustainable or green packaging focusing on economic, business, market, and sustainability aspects. An initial broad search was performed with the following Boolean query to capture a wide range of articles related to sustainable packaging and its economic and sustainability dimensions. This initial search yielded a total of 218 records across databases, including Scopus and Google Scholar. After removing one duplicate record originating from multiple databases, 217 records remained for further screening (see Table 1).

Table 1.
The Search String Used for Identification.

Database	Search String Used
Scopus and Google Scholar	TITLE-ABS-KEY(("sustainable packaging" OR "green packaging" OR "eco packaging" OR "biodegradable packaging") AND ("economic" OR "business" OR "market" OR "profitability" OR "industry trend" OR "global trend") AND ("sustainability" OR "circular economy")) AND PUBYEAR > 2018 AND PUBYEAR < 2025

3.1.2. Screening

After removing duplicates, 217 articles remained and proceeded to the screening stage. At this stage, the titles and abstracts of the 217 articles were carefully examined to assess their relevance to the research focus on green packaging in terms of economics, sustainability, and global market trends. This screening process aimed to eliminate articles that were clearly irrelevant, such as those discussing topics outside the scope of the research (e.g., technical material topics already excluded from the search query), non-English articles, or those not within the specified subject area. The titles and abstracts of the remaining records were screened against predefined inclusion and exclusion criteria to identify potentially relevant studies. Articles that did not address the core topic or were outside the timeframe were excluded at this stage. A total of 138 articles were excluded because they did not meet the criteria at this screening stage. These articles generally did not adequately discuss economic, business, or sustainability aspects, or their focus was too technical and specific to packaging materials that were not part of the scope of the study (see Table 2). Thus, 79 articles proceeded to the eligibility stage for a more in-depth assessment of the full text (full-text review).

Table 2.
The Search String Used for Screening.

Database	Search String Used
Scopus and Google Scholar	TITLE-ABS-KEY(("sustainable packaging" OR "green packaging" OR "eco packaging" OR "biodegradable packaging") AND ("economic" OR "business" OR "market" OR "profitability" OR "industry trend" OR "global trend") AND ("sustainability" OR "circular economy")) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND NOT TITLE-ABS-KEY("film" OR "coating" OR "barrier property" OR "mechanical property" OR "nanocomposite" OR "biopolymer" OR "polymer blend" OR "enzymatic degradation" OR "thermal property") AND (LIMIT-TO(SUBJAREA, "ENVI") OR LIMIT-TO(SUBJAREA, "BUSI") OR LIMIT-TO(SUBJAREA, "SOCI") OR LIMIT-TO(SUBJAREA, "ECON") OR LIMIT-TO(SUBJAREA, "MULT")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(DOCTYPE, "ar"))

3.1.3. Included

After passing the screening stage, 79 articles proceeded to the eligibility stage for a more in-depth full-text assessment. At this stage, articles were screened again, taking into account the quality of the journal based on quartiles and the relevance of the content. Articles from quartiles two, three, and four, as well as those that were not substantially relevant, were excluded. Ultimately, 40 high-quality articles from quartile one journals were selected for comprehensive analysis as the primary sources in this literature review.

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ISSN: 2576-8484
Vol. 9, No. 9: 715-730, 2025
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3.2. Publication Trends and Data Visualization

3.2.1. Publication Trends

Based on the data in Table 3, publications on global economic trends and sustainability in the context of environmentally friendly packaging show a fluctuating pattern throughout the 2019–2024 period. In 2019, there were 5 publications, then a sharp decline in 2020 to only 2 publications. After that, the number of publications increased again in 2021 to 5 publications and continued to increase, reaching 7 publications in 2022. However, in 2023, the number decreased slightly to 5 publications before surging significantly in 2024 with 16 publications. This surge reflects an increased academic interest in sustainability issues and global economic developments in eco-friendly packaging. This trend is illustrated in Figure 2, which clearly depicts the rising academic interest in sustainability issues and global economic developments in eco-friendly packaging. Overall, 40 publications were identified over the six years, indicating growing attention to the interconnection between economic and sustainability aspects in the field of packaging.

Table 3.
Publication Trends on Global Economic and Sustainability Research (2019–2024).

Year	Number of Publications
2019	5
2020	2
2021	5
2022	7
2023	5
2024	16
Total	40

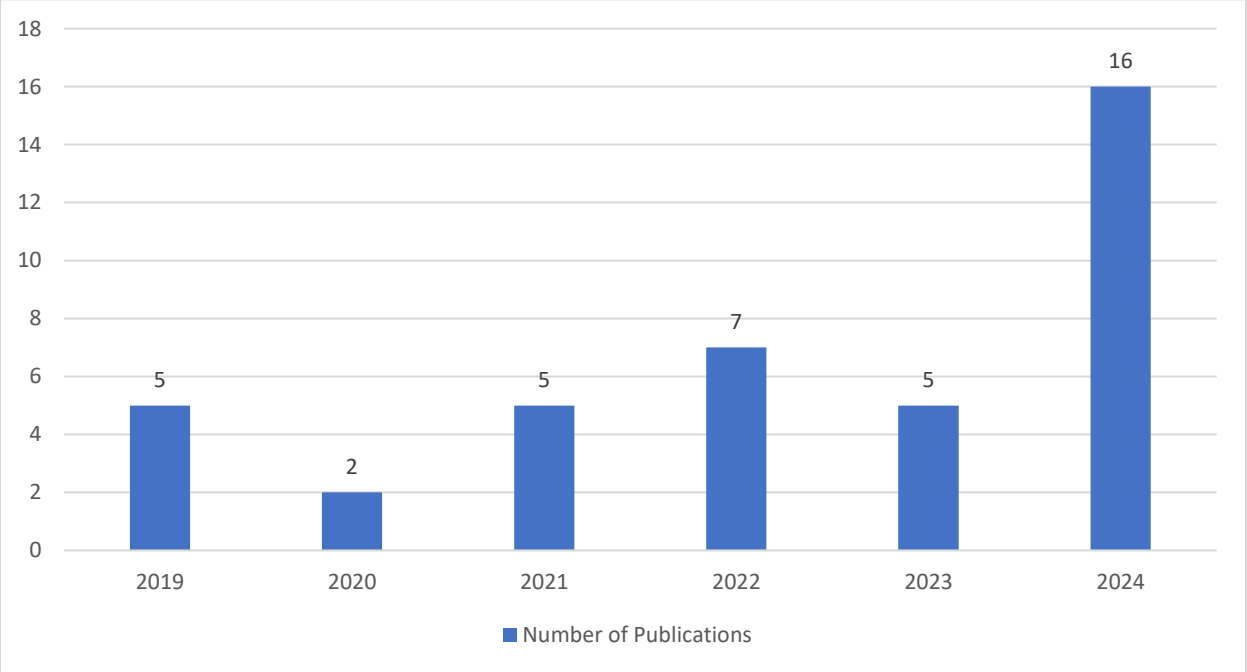

Figure 2.
Publication Trends on Global Economic and Sustainability Research (2019–2024).

3.2.2. Distribution of Articles by Journal

The distribution of articles in Table 4 shows that research related to global economic trends and sustainability in the context of environmentally friendly packaging has been published in various

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ISSN: 2576-8484
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scientific journals. As shown in Figure 3, the highest number of articles was found in Sustainability with 12 publications, while the Journal of Cleaner Production ranked second with 7 publications. Additionally, there are specific journals such as Foods (3 articles), Sustainable Production and Consumption (3 articles), and several other journals with only 1 article each. This indicates that while research on green packaging is growing, its publications remain relatively scattered across various fields of study.

Table 4.
Distribution of Articles by Journal (2019-2024).

Journal	Total Articles
Sustainability	12
Journal of Cleaner Production	7
Foods	3
Sustainable Production and Consumption	3
Forest Policy and Economics	1
Sustainable Materials and Technologies	1
Frontiers in Sustainable Food Systems	1
International Journal of Environmental Science and Technology	1
Emerging Science Journal	1
Advanced Sustainable Systems	1
Cleaner and Responsible Consumption	1
Business Strategy and the Environment	1
Circular Economy and Sustainability	1
Case Studies in Chemical and Environmental Engineering	1
Resources, Conservation, and Recycling Advances	1
Review of Managerial Science	1
IEEE Engineering Management Review	1
Global Challenges	1
Environment, Development and Sustainability	1
Total Articles	40

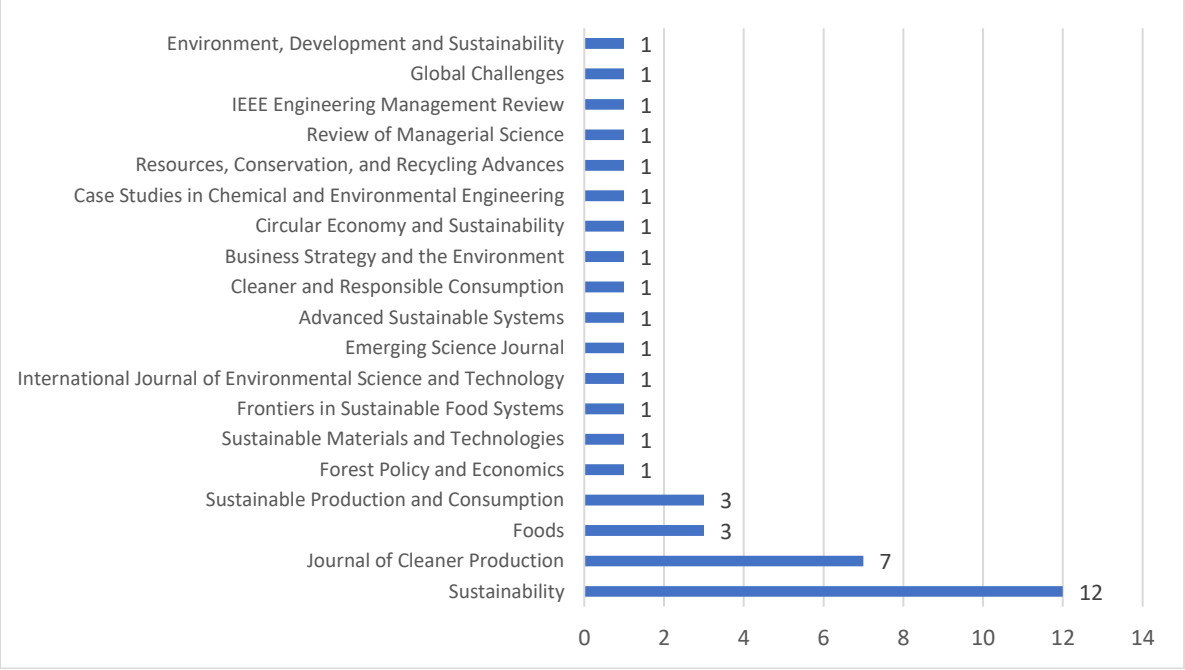

Figure 3.
Distribution of Articles by Journal (2019–2024).

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Vol. 9, No. 9: 715-730, 2025
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4. Results and Discussions

4.1. Global Economic and Market Trends in the Adoption of Green Packaging

Consumer awareness of environmental degradation and waste management has been a key driver, leading to increased interest in biodegradable and minimalist packaging solutions [1, 10]. Consumers now prioritize not only the functionality of packaging but also aesthetic aspects that support green trust, making innovations such as biodegradable antimicrobial films and electrospun membranes concrete examples of progress toward active and sustainable packaging solutions [7]. Brand trust and environmental quality perceptions of packaging play a significant role in influencing consumer purchase intent, especially in competitive markets [17]. Trends in sustainable packaging research and implementation in the Greater China region indicate increased adoption driven by consumer awareness and regulatory support [19].

However, economic considerations remain a key factor in the adoption of green packaging. Companies face trade-offs between cost efficiency and environmental performance, and must comply with strict regulations while managing the higher costs of environmentally friendly materials. Strategic evaluation of the cost-effectiveness of recycled and reusable materials is crucial, as demonstrated by European market analysis [2, 9]. Packaging color also influences perception and willingness to pay (WTP). White and green packaging enhances perceptions of health, trust, and premium value. Consumer responses differ between organic and non-organic segments, emphasizing the importance of market segmentation in sustainable packaging strategies [13].

Supply chain adaptation plays a crucial role in accelerating the adoption of green packaging. The application of circular economy principles that integrate a life cycle-based decision framework facilitates the optimization of material selection and the reduction of environmental impacts overall [6, 20, 21]. Successful implementation requires collaborative strategies, technological innovation, and policy incentives aligned with sustainability goals [22]. The use of renewable resources and agro-industrial waste as alternative raw materials is also increasingly important [12, 23, 24].

Research indicates a perception gap between consumers and life cycle assessment (LCA) results for liquid packaging, highlighting the need for information transparency and consumer education to enhance market acceptance [25]. Additionally, green marketing has been proven to encourage environmentally responsible behavior among young consumers, strengthening demand for eco-friendly packaging [15, 26]. Positive perceptions of paper packaging as an alternative to plastic have also been shown to influence consumer behavior [27].

The food and beverage sector, fast-moving consumer goods (FMCG), cosmetics, and e-commerce dominate the green packaging market and lead innovation and adoption of sustainable solutions. Integrating green packaging into business strategies based on natural resources strengthens the achievement of a company's sustainable development goals. The food and beverage industry is the primary driver of green packaging demand growth, due to high consumption volumes and the need for packaging that is safe, functional, and environmentally friendly [8, 28, 29].

A study in Bangladesh shows that Gen Z has a positive relationship between green consumption values and green purchase intentions, with consumer attitudes as a mediator between environmental knowledge, green consumption values, and packaging perceptions [30]. This confirms that consumer perceptions and preferences are crucial in determining the adoption of green packaging, especially among younger consumers.

From the perspective of waste management and process sustainability, waste management scenario simulations for packaging materials emphasize the need for an effective circular economy support system to reduce environmental impacts. Packaging design that considers the life cycle (life cycle design) maximizes resource efficiency while meeting functional needs [31-33]. Consumer understanding of packaging design can enhance market acceptance and support industrial transformation toward a sustainable model.

Overall, the period from 2019 to 2024 shows consistent and gradual progress in the global adoption of green packaging, marked by complex interactions between increasingly environmentally conscious

Edelweiss Applied Science and Technology
ISSN: 2576-8484
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consumer expectations, economic considerations, and long-term brand value, technological innovations in environmentally friendly materials, and supply chain strategies and sustainability policies that run in parallel. The synergy of these aspects forms the foundation for the transformation of the packaging industry toward a more sustainable industrial model.

4.2. Implementation of Green Packaging Affects Business Performance

Green packaging not only drives business performance and profitability through cost efficiency and supply chain optimization, but also through its positive impact on brand image, consumer trust, and the company's strategic position in an increasingly sustainability-oriented market. The implementation of green packaging has proven to have a significant impact on business performance, both in the short term (sales and revenue) and the long term (customer loyalty and competitive advantage).

The adoption of environmentally friendly packaging enhances a company's reputation and builds green trust, which strengthens customer loyalty [6]. This aligns with the findings of Bojanowska and Sulimierska [1] and Avrami, et al. [3], which show that consumer preferences for biodegradability and sustainability are the primary drivers of purchase intent. Minimalist design innovations and sustainable materials are not only environmentally friendly but also improve production and distribution efficiency [7, 10].

Materials influence sustainability. For example, steel kegs are more environmentally friendly than single-use plastics because they can be reused multiple times. The effectiveness of materials in green packaging depends on physical properties, the number of usage cycles, and available recycling systems, as linked to supply chain optimization and material lifecycle [6, 20, 34]. Additionally, Rahmawati, et al. [24] highlight gallic acid as a bioactive agent in active, biodegradable, and edible packaging. This compound not only enhances food preservation functions (antibacterial, antifungal, antioxidant) but also improves the mechanical properties, permeability, and UV barrier of packaging materials. This supports the effectiveness of materials in green packaging that balances functionality, food safety, and sustainability.

In a regional context, Mattia, et al. [35] found that sustainable packaging design is part of the long-term business strategy of large Italian companies and serves as an important market differentiation tool in Italy. This research confirms that sustainable packaging in Italy is not only driven by EU regulations related to the circular economy and plastic regulations but also receives strong support from the supply chain, which collaborates systematically to promote environmentally friendly packaging design innovations that are also strategically beneficial for business. Their findings also highlight that the effectiveness of green packaging must be engineered through the synergy of technology and marketing to be accepted by the market as a sustainable competitive advantage. Pasta, et al. [36] add that sustainable packaging plays a crucial role in shaping product safety perceptions among young consumers, enhancing purchase preferences and loyalty toward traditional products, while also serving as a communication tool for sustainability values and product authenticity.

Competitive advantage is achieved through decision-making that prioritizes sustainable packaging, strengthening the company's long-term strategic position in a market increasingly oriented toward sustainability values [2, 9]. Green packaging supports the circular economy and enhances the company's social image, which is a crucial aspect for retaining consumers and stakeholders in today's business environment [21].

Overall, the implementation of green packaging not only improves economic aspects through cost efficiency but also strengthens positive consumer perceptions, enhances loyalty, and reinforces the company's strategic position. Thus, green packaging serves as a business tool that integrates the critical dimension of sustainability in creating sustainable competitive advantage, both in developed markets (Western Europe, Japan) and emerging markets (Poland, Russia, Italy).

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4.3. Contribution of Green Packaging to Sustainability and Circular Economy Practices Globally

Green packaging contributes significantly to global sustainability and circular economy practices through several key aspects. Green packaging uses environmentally friendly materials such as biodegradable, recyclable, and renewable resources that reduce waste and carbon footprints throughout the product life cycle. The implementation of environmentally friendly packaging using biodegradable and recyclable materials helps reduce waste and minimize the use of non-renewable fossil raw materials, thereby supporting natural resource conservation and reducing the carbon footprint throughout the product lifecycle [1, 7]. The implementation of sustainable materials reduces dependence on non-renewable fossil raw materials, thereby supporting natural resource conservation and more responsible waste management. Selecting packaging materials designed with Life Cycle Assessment (LCA) in mind enables improved resource efficiency and extended product lifespan through reuse, recycling, and composting [6, 32, 33].

However, the adoption of bio-based materials faces challenges related to investment and operational costs, lack of standards, and varying regulations [14]. Companies manage the trade-off between sustainability and economics through strategies such as certification, partnerships with NGOs, association collaborations, and the application of LCA. This approach not only enables more effective management of environmental impacts but also supports circular economy principles, including reuse, recycling, and optimization of material lifecycles [24, 34].

Green packaging also facilitates the shift from the linear "take-make-dispose" model toward a circular economy system that keeps materials circulating within production and consumption cycles. This reduces the burden on landfills and minimizes negative environmental impacts [3, 21, 31]. This concept focuses on the reuse of packaging, which is an important aspect in reducing environmental impacts. A study in Poland shows that while the implementation of reusable bags has not been fully successful, consumers demonstrate interest and willingness to adapt to recyclable packaging [37]. This potential highlights significant opportunities for integrating green packaging into circular economy models across various countries.

Upstream packaging strategies are also important in the circular economy. Plastic waste management categorize into three strategies: elimination, reuse, and material circulation. This approach emphasizes design from the early stages as the key to enhancing circularity. The use of bio-based materials, such as lignocellulose from wood, non-wood, and agro-residues, produces fibers with good mechanical and physical properties, cost-effectiveness, and environmental friendliness, while replacing synthetic polymers and utilizing agro-industrial waste [38, 39].

In Poland, approximately 1.26 billion kg of post-consumer plastic packaging waste was recorded in 2021. This highlights the significant potential of packaging waste as a resource in the circular economy. Effective management of packaging waste—through recycling, reuse, or material substitution—can strengthen the contribution of green packaging to global sustainability [40].

Overall, green packaging not only helps preserve the environment by reducing waste and emissions, but also supports the principles of the circular economy through a holistic approach to the product lifecycle. Synergy between appropriate packaging design, sustainable material selection, efficient supply chain strategies, and compliance with regulations is key to maximizing environmental benefits while providing long-term economic gains.

4.4. Challenges and Barriers in the Adoption of Green Packaging Solutions

The transition to green packaging faces complex challenges across economic, technological, infrastructural, behavioral, and regulatory dimensions. One of the most persistent barriers is the economic trade-off, as sustainable materials often incur higher production and operational costs than conventional alternatives [2, 9]. Firms in the food and consumer goods sectors must balance these costs with competitive pricing in price-sensitive markets. Additionally, supply chain complexity, particularly where traceability, product safety, and environmental compliance are required, creates structural obstacles.

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Effective adaptation of supply chains to support circular economy principles often demands complex coordination among stakeholders, adding operational difficulty [6, 20]. Non-technical barriers also exist, including limited knowledge among consumers, producers, and waste managers regarding the benefits and practices of green packaging, which can slow market acceptance [14]. Consumer preference for sustainable packaging is influenced by sensory experience and product quality, indicating that behavioral and perceptual factors can hinder adoption if not addressed strategically [4].

Technological constraints also hinder large-scale adoption. Innovative materials such as biodegradable antimicrobial films, electrospun membranes, and life cycle–optimized composites present opportunities for sustainable packaging; they often require specialized production capabilities and infrastructure for end-of-life management, including composting and recycling facilities [6, 7, 41]. The lack of such infrastructure critically restricts the practical recyclability or biodegradability of green packaging materials, confining their environmental advantages to localized or pilot-scale markets. Dieckmann, et al. [42] similarly emphasize that bio-based innovations must align with cost-efficiency and infrastructure readiness to achieve successful market integration.

Infrastructural deficits are closely tied to behavioral barriers. Although environmental awareness among consumers is rising, purchasing decisions remain heavily influenced by price sensitivity and convenience, limiting market pull for higher-cost green alternatives [3, 10, 41]. Moreover, consumer confusion regarding what constitutes "truly biodegradable" packaging—exacerbated by misleading claims and greenwashing—undermines demand and delays industry investment [1]. This reflects the well-documented intention–behavior gap, where declared pro-environmental attitudes do not consistently translate into actual purchasing behavior.

Regulatory fragmentation adds another layer of complexity. Differences in sustainability standards, extended producer responsibility requirements, and certification schemes across regions increase uncertainty and compliance costs, complicating global scaling of green packaging solutions. Empirical studies also show that collaboration with NGOs, industry associations, product certification, and life cycle assessments can help manage economic and environmental trade-offs, though operational complexity and costs remain significant challenges [14, 16, 34].

In the industrial context, the adoption of reusable transit packaging (RTP) in the US, for example, is constrained by a lack of mandatory policies, operational complexity, and cost concerns, highlighting the need for both internal motivation and external regulatory support [16]. Similarly, innovations in sectors like foodservice show that aligning long-term sustainability benefits with existing business models and distribution systems is critical to adoption [43].

Technological and infrastructural limitations further impede adoption. Biodegradable, recyclable, or reusable materials require industrial infrastructure for composting, recycling, and circular economy integration, which is often lacking. Consumer confusion and low recognition of truly biodegradable packaging further limit market demand, as misidentification and greenwashing undermine investment incentives [1].

Behavioral and market barriers persist even when sustainable alternatives are available; price sensitivity and inconsistent consumer demand limit adoption rates. Bojanowska and Sulimierska [1] note that although consumers declare pro-environmental attitudes, actual purchasing behavior does not always align with sustainability goals, reflecting the intention–behavior gap. Collectively, these barriers suggest that achieving large-scale adoption of green packaging requires a combination of economic incentives, regulatory alignment, technological advancement, and consumer education to overcome the interlinked financial, infrastructural, and behavioral constraints.

Empirical studies also show that strategies for managing the trade-off between sustainability and cost can be implemented through collaboration with NGOs, industry associations, product certification, and the implementation of life cycle assessments to minimize negative impacts while maximizing resource efficiency [14, 34]. However, the complexity of implementing reusable transit packaging (RTP) in the US industry highlights that operational, capacity, and cost constraints remain significant barriers despite strong internal motivation [16].

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9: 715-730, 2025
DOI: 10.55214/2576-8484.v9i9.9951

The successful adoption of green packaging requires a holistic, systems-level approach that addresses all five dimensions of these barriers. Effective strategies should integrate economic incentives, targeted investment in circular infrastructure, harmonized and predictable regulations, technological innovations to improve cost-effectiveness and material performance, and robust consumer education initiatives. This perspective is reinforced by prior studies, which collectively highlight that overcoming economic, technological, infrastructural, behavioral, and regulatory constraints is essential for achieving large-scale, impactful adoption of sustainable packaging solutions [1, 2, 7, 9, 42].

5. Conclusion and Recommendations

The adoption and integration of green packaging solutions from 2019 to 2024 represent a transformative advance in both market practice and sustainability strategy worldwide. Across industries, heightened environmental awareness, evolving regulatory frameworks, and increased consumer demand have accelerated the transition toward biodegradable, recyclable, and resource-efficient materials. Global trends reveal that not only is consumer expectation for sustainability rising, but so too is the market's appreciation for green trust, brand reputation, and the functional–aesthetic blend in packaging innovations.

Modern business performance extends beyond operational cost management to include adherence to sustainability principles, reinforcing loyalty, differentiation, and lasting competitiveness. Industries like food and beverage, FMCG, cosmetics, and e-commerce exemplify the role of green packaging in stimulating innovation, adjusting supply chains, and integrating cross-functional operations.

Nevertheless, realizing the full potential of green packaging is challenged by persistent economic, technological, infrastructural, behavioral, and regulatory barriers. High raw material expenses, supply chain complexities, and insufficient recycling and composting infrastructure limit its widespread adoption. The persistence of behavioral inertia, fluctuating consumer willingness to pay, and discrepancies between intended and actual behaviors point to a critical requirement for comprehensive consumer education and transparent communication. Regional regulatory variations further hinder compliance and operational consistency, reinforcing the need for standardized regulations and collaborative approaches throughout the value chain.

In the face of these barriers, evidence across mature and emerging markets shows that green packaging not only contributes to environmental protection by reducing waste and emissions but also plays a foundational role in circular economy models, enabling material reuse, resource optimization, and holistic life cycle value.

For industry, policymakers, and researchers, the imperative is clear: the widespread and effective adoption of green packaging requires integrated approaches that unite economic incentives, supportive policies, investments in circular infrastructure, technological advancements, and comprehensive consumer engagement. Only through such system-level strategies can the packaging sector fully transform toward sustainability, delivering shared value for business, society, and the environment.

5.1. Implications for Practice

This systematic literature review highlights several practical implications for industry practitioners, policymakers, and stakeholders, aiming to implement sustainable green packaging practices. First, integrating biodegradable and recyclable materials into packaging design is essential to fulfill environmental objectives as well as consumer demands. Companies need to invest in technological innovations that enhance material performance while minimizing their environmental footprint. Second, regulatory frameworks act as a catalyst for the adoption of green packaging by setting mandatory benchmarks and reinforcing sustainable practices within industry sectors. Policymakers should tailor these frameworks to address sector-specific barriers identified in this review, such as cost implications and supply chain complexities. Third, consumer behavior insights suggest that transparent communication about the environmental benefits and recyclability of packaging can effectively influence purchase decisions. Accordingly, marketing and educational campaigns should be designed strategically

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9: 715-730, 2025
DOI: 10.55214/2576-8484.v9i9.9951

to raise consumer awareness and trust in sustainable packaging. Businesses must consider the interplay between sustainability and profitability by adopting circular economy principles to optimize resource use, reduce waste, and open new market opportunities. As a result, fostering collaboration among supply chain stakeholders remains a decisive factor in achieving meaningful progress toward sustainable packaging.

5.2. Recommendations for Future Research

In the short term, it is essential for future research to concentrate on sector-specific analyses to uncover the unique obstacles and incentives for adopting green packaging in industries such as food, pharmaceuticals, and e-commerce. Comparative studies across these sectors would shed light on the contextual factors influencing adoption, as highlighted in previous systematic reviews on barriers and performance outcomes [5, 11].

In the medium term, researchers should conduct longitudinal and empirical analyses of the economic viability and consumer acceptance of innovative packaging materials. This is particularly important for bio-based, reusable, and antimicrobial materials, which remain underexplored in terms of business scalability, market viability, and cost–benefit tradeoffs. Recent advances in sustainable packaging materials illustrate their potential but also underline the need for more applied research in business contexts [6, 7].

Further empirical investigations into the long-term economic impacts and consumer acceptance of innovative packaging materials, including bio-based and antimicrobial packaging, are necessary to underpin sustainable business models. Moreover, future research should explore the role of digital technologies, such as blockchain and IoT, in enhancing transparency and traceability in sustainable packaging supply chains, which may boost consumer confidence and regulatory compliance [16].

Finally, interdisciplinary approaches combining environmental science, economics, and behavioral studies are encouraged to develop comprehensive frameworks that support the transition toward sustainable packaging and circular economy principles globally.

Data Statement:

All data has been presented in this manuscript. All data supporting the findings of this study are derived from published articles included in the systematic literature review. Details of the sources and selection process are presented within the manuscript. Additionally, these data can be accessed via https://docs.google.com/spreadsheets/d/e/2PACX-1vTxuB5-C36l8zGGEZW9IukREL7GX7lYUW55q7kGYiUV-PohbnWhMcr_mL1xoBm8sQ/pubhtml or on Mendeley Data at doi: 10.17632/t59ft85f8c.1

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Acknowledgments:

The authors sincerely appreciate the support of Bina Nusantara (BINUS) University, which provided funding and access to research databases that facilitated the completion of this research.

References

[1] A. Bojanowska and A. Sulimierska, "Consumer awareness of biodegradability of food products packaging," *Sustainability*, vol. 15, no. 18, p. 13980, 2023. https://doi.org/10.3390/su151813980

[2] G. Granato, A. R. H. Fischer, and H. C. M. van Trijp, "The price of sustainability: How consumers trade-off conventional packaging benefits against sustainability," *Journal of Cleaner Production*, vol. 365, p. 132739, 2022. https://doi.org/10.1016/j.jclepro.2022.132739

[3] E. Avrami *et al.*, "A new concept of consumer behavior in the circular economy," *Emerging Science Journal*, vol. 8, no. 4, pp. 1536-1553, 2024. https://doi.org/10.28991/ESJ-2024-08-04-018

[4] V. Srivastava, S. Singh, and D. Das, "Decision support system for assessing quality and consumer acceptance of active biocomposite based food packaging," *Environment, Development and Sustainability*, 2024. https://doi.org/10.1007/s10668-024-05782-0

[5] K. Afif, C. Rebolledo, and J. Roy, "Drivers, barriers and performance outcomes of sustainable packaging: A systematic literature review," *British Food Journal*, vol. 124, no. 3, pp. 915-935, 2021. https://doi.org/10.1108/BFJ-02-2021-0150

[6] D. Mudgal, E. Pagone, and K. Salonitis, "Selecting sustainable packaging materials and strategies: A holistic approach considering whole life cycle and customer preferences," *Journal of Cleaner Production*, vol. 481, p. 144133, 2024. https://doi.org/10.1016/j.jclepro.2024.144133

[7] E. Drago, R. Campardelli, and P. Perego, "Sustainabledevelopment of biodegradable antimicrobial electrospun membranes for active food packaging and economic analysis," *Advanced Sustainable Systems*, vol. 8, no. 12, p. 2400360, 2024. https://doi.org/10.1002/adsu.202400360

[8] C. C. Lau and C. W. Wong, "Achieving sustainable development with sustainable packaging: A natural-resource-based view perspective," *Business Strategy and the Environment*, vol. 33, no. 5, pp. 4766-4787, 2024. https://doi.org/10.1002/bse.3720

[9] R. Weinrich *et al.*, "Decision-making processes on sustainable packaging options in the European food sector," *Journal of Cleaner Production*, vol. 434, p. 139918, 2024. https://doi.org/10.1016/j.jclepro.2023.139918

[10] Y. Ding, X. Meng, and C. Sun, "Simplicity matters: Unraveling the impact of minimalist packaging on green trust in daily consumer goods," *Sustainability*, vol. 16, no. 12, p. 4932, 2024. https://doi.org/10.3390/su16124932

[11] J. A. Morashti, Y. An, and H. Jang, "A systematic literature review of sustainable packaging in supply chain management," *Sustainability*, vol. 14, no. 9, p. 4921, 2022. https://doi.org/10.3390/su14094921

[12] Y. Hossam and I. S. Fahim, "Towards a circular economy: fabrication and characterization of biodegradable plates from sugarcane waste," *Frontiers in Sustainable Food Systems*, vol. Volume 7 - 2023, 2023. https://doi.org/10.3389/fsufs.2023.1220324

[13] L. B. Nagy and Á. Temesi, "Color matters: A study exploring the influence of packaging colors on university students' perceptions and willingness to pay for organic pasta," *Foods*, vol. 13, no. 19, p. 3112, 2024. https://doi.org/10.3390/foods13193112

[14] D. Turkcu and N. Tura, "The dark side of sustainable packaging: Battling with sustainability tensions," *Sustainable Production and Consumption*, vol. 40, pp. 412-421, 2023. https://doi.org/10.1016/j.spc.2023.07.007

[15] M. U. Majeed, S. Aslam, S. A. Murtaza, S. Attila, and E. Molnár, "Green marketing approaches and their impact on green purchase intentions: Mediating role of green brand image and consumer beliefs towards the environment," *Sustainability*, vol. 14, no. 18, p. 11703, 2022. https://doi.org/10.3390/su141811703

[16] I. Kudrenko and L. Hall, "Adoption of reusable transit packaging in US industries: A framework for enhanced sustainability," *Review of Managerial Science*, vol. 19, no. 9, pp. 2633-2666, 2025. https://doi.org/10.1007/s11846-024-00826-1

[17] A. K. Sah and Y.-M. Hong, "Circular economy implementation in an organization: A case study of the taiwan sugar corporation," *Sustainability*, vol. 16, no. 17, p. 7865, 2024. https://doi.org/10.3390/su16177865

[18] N. R. Haddaway, M. J. Page, C. C. Pritchard, and L. A. McGuinness, "PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and open Synthesis," *Campbell Systematic Reviews*, vol. 18, no. 2, p. e1230, 2022. https://doi.org/10.1002/cl2.1230

[19] R.-L. Wang, T.-F. Hsu, and C.-Z. Hu, "A bibliometric study of research topics and sustainability of packaging in the greater china region," *Sustainability*, vol. 13, no. 10, p. 5384, 2021. https://doi.org/10.3390/su13105384

[20] J. Korhonen, A. Koskivaara, and A. Toppinen, "Riding a Trojan horse? Future pathways of the fiber-based packaging industry in the bioeconomy," *Forest Policy and Economics*, vol. 110, p. 101799, 2020. https://doi.org/10.1016/j.forpol.2018.08.010

[21] N. Yokokawa, E. Amasawa, and M. Hirao, "Design assessment framework for food packaging integrating consumer preferences and environmental impact," *Sustainable Production and Consumption*, vol. 27, pp. 1514-1525, 2021. https://doi.org/10.1016/j.spc.2021.03.027

[22] L. Meherishi, S. A. Narayana, and K. S. Ranjani, "Sustainable packaging for supply chain management in the circular economy: A review," *Journal of Cleaner Production*, vol. 237, p. 117582, 2019. https://doi.org/10.1016/j.jclepro.2019.07.057

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 9: 715-730, 2025
DOI: 10.55214/2576-8484.v9i9.9951

[23] F. Arfelli *et al.*, "Environmental impacts of food packaging: Is it all a matter of raw materials?," *Sustainable Production and Consumption*, vol. 49, pp. 318-328, 2024. https://doi.org/10.1016/j.spc.2024.06.032
[24] I. Rahmawati *et al.*, "Gallic acid: A promising bioactive agent for food preservation and sustainable packaging development," *Case Studies in Chemical and Environmental Engineering*, vol. 10, p. 100776, 2024. https://doi.org/10.1016/j.cscee.2024.100776
[25] S. Boesen, N. Bey, and M. Niero, "Environmental sustainability of liquid food packaging: Is there a gap between Danish consumers' perception and learnings from life cycle assessment?," *Journal of Cleaner Production*, vol. 210, pp. 1193-1206, 2019. https://doi.org/10.1016/j.jclepro.2018.11.055
[26] M. Kardos, M. R. Gabor, and N. Cristache, "Green marketing's roles in sustainability and ecopreneurship case study: Green packaging's impact on romanian young consumers' environmental responsibility," *Sustainability*, vol. 11, no. 3, p. 873, 2019. https://doi.org/10.3390/su11030873
[27] O. O. Oloyede and S. Lignou, "Sustainable paper-based packaging: A consumer's perspective," *Foods*, vol. 10, no. 5, p. 1035, 2021. https://doi.org/10.3390/foods10051035
[28] Z. Boz, V. Korhonen, and C. Koelsch Sand, "Consumer considerations for the implementation of sustainable packaging: A review," *Sustainability*, vol. 12, no. 6, p. 2192, 2020. https://doi.org/10.3390/su12062192
[29] P. Jain and D. M. Hudnurkar, "Sustainable packaging in the FMCG industry," *Cleaner and Responsible Consumption*, vol. 7, p. 100075, 2022. https://doi.org/10.1016/j.clrc.2022.100075
[30] M. R. H. Polas *et al.*, "Towards agreener horizon: Unravelling the links between environmental awareness, consumption values, and packaging in consumer decision-making," *IEEE Engineering Management Review*, pp. 1-42, 2024. https://doi.org/10.1109/EMR.2024.3438124
[31] A. Asadollahi, H. Tohidi, and A. Shoja, "Sustainable waste management scenarios for food packaging materials using SimaPro and WARM," *International Journal of Environmental Science and Technology*, vol. 19, no. 10, pp. 9479-9494, 2022. https://doi.org/10.1007/s13762-022-04327-0
[32] J. Keller, C. Scagnetti, and S. Albrecht, "The relevance of recyclability for the life cycle assessment of packaging based on design for life cycle," *Sustainability*, vol. 14, no. 7, p. 4076, 2022. https://doi.org/10.3390/su14074076
[33] E. Pauer, B. Wohner, V. Heinrich, and M. Tacker, "Assessing the environmental sustainability of food packaging: An extended life cycle assessment including packaging-related food losses and waste and circularity assessment," *Sustainability*, vol. 11, no. 3, p. 925, 2019. https://doi.org/10.3390/su11030925
[34] M. Martin, S. Herlaar, A. Jönsson, and D. Lazarevic, "Fromcircular to linear? Assessing the life cycle environmental and economic sustainability of steel and plastic beer kegs," *Circular Economy and Sustainability*, vol. 2, no. 3, pp. 937-960, 2022. https://doi.org/10.1007/s43615-021-00142-w
[35] G. Mattia, A. Di Leo, and C. A. Pratesi, "Recognizing the key drivers and industry implications of sustainable packaging design: A mixed-method approach," *Sustainability*, vol. 13, no. 9, p. 5299, 2021. https://doi.org/10.3390/su13095299
[36] C. Pasta *et al.*, "Cantraditional food product communication convey safety to the younger generations? the role of sustainable packaging," *Foods*, vol. 12, no. 14, p. 2754, 2023. https://doi.org/10.3390/foods12142754
[37] Ł. Hadaś, R. Domański, H. Wojciechowski, A. Majewski, and J. Lewandowicz, "The role of packaging in sustainable omnichannel returns—the perspective of young consumers in poland," *Sustainability*, vol. 16, no. 6, p. 2231, 2024. https://doi.org/10.3390/su16062231
[38] K. S. Salem, V. Naithani, H. Jameel, L. Lucia, and L. Pal, "Lignocellulosic fibers from renewable resources using green chemistry for a circular economy," *Global Challenges*, vol. 5, no. 2, p. 2000065, 2021. https://doi.org/10.1002/gch2.202000065
[39] N. Terzioğlu, F. Ceschin, S. Jobling, and K. Tarverdi, "Archetypes to categorise upstream packaging strategies for a circular economy," *Resources, Conservation & Recycling Advances*, vol. 21, p. 200211, 2024. https://doi.org/10.1016/j.rcradv.2024.200211
[40] B. Waszczyłko-Miłkowska and K. Bernat, "Using the amount of plastic packaging placed on the market to determine the annual amount of plastic packaging waste generated in poland to enable sustainable waste management," *Sustainability*, vol. 16, no. 12, p. 5048, 2024. https://doi.org/10.3390/su16125048
[41] S. U. M. Jagoda, J. R. Gamage, and H. P. Karunathilake, "Environmentally sustainable plastic food packaging: A holistic life cycle thinking approach for design decisions," *Journal of Cleaner Production*, vol. 400, p. 136680, 2023. https://doi.org/10.1016/j.jclepro.2023.136680
[42] E. Dieckmann, K. Eleftheriou, T. Audic, K.-Y. Lee, L. Sheldrick, and C. Cheeseman, "New sustainable materials from waste feathers: Properties of hot-pressed feather/cotton/bi-component fibre boards," *Sustainable Materials and Technologies*, vol. 20, p. e00107, 2019. https://doi.org/10.1016/j.susmat.2019.e00107
[43] S. Pougnet, C. Martin-Rios, and S. Pasamar, "Keg wine technology as a service innovation for sustainability in the foodservice industry," *Journal of Cleaner Production*, vol. 360, p. 132145, 2022. https://doi.org/10.1016/j.jclepro.2022.132145