

Research on Innovative Design of Takeaway Food Packaging Materials and Functions Under the Concept of Sustainable Development

Lin Zhu¹

Abstract

In the context of global advocacy for sustainable development and the Sustainable Development Goals (SDGs), the rapid expansion of the takeaway industry has resulted in a significant increase in packaging waste. Traditional food packaging materials often fail to meet environmental standards, are functionally limited, and lack innovation. This research examines how to address the functional needs of takeaway food packaging while minimizing its negative environmental impact, emphasizing innovative solutions aligned with eco-humanism development principles. By analyzing the challenges, limitations, and functional requirements of existing Chinese takeaway packaging, the study proposes design solutions that integrate sustainable development principles. Utilizing methods such as literature analysis, case studies, market research, and material experimentation, the research explores the application of new eco-friendly materials and optimization of packaging multifunctionality. The findings aim to promote sustainable practices, enhance user experiences, and reduce environmental waste, thereby supporting the green transformation of the takeaway industry. This study provides practical insights for designers, businesses, and policymakers, fostering innovation and sustainable development within the packaging industry and aligning with broader environmental goals.

Keywords: *Sustainable Development Goals (SDGs), Ecohumanism Development, Packaging Waste, Takeaway Food Packaging, Sustainable Materials, Innovative Design.*

Introduction

With the accelerated pace of urban life, people's living habits have undergone significant changes. Coupled with the impact of the COVID-19 pandemic a few years ago, takeaway food (including online delivery and dine-in takeaway) has become a mainstream dining option. Along with the rapid development of the takeaway industry, the usage of food packaging has increased dramatically, resulting in a significant amount of disposable plastic products and other non-degradable materials, which have caused severe environmental pollution. The excessive use of takeaway food packaging not only increases resource consumption but also exacerbates the burden of urban solid waste, posing a direct threat to the sustainability of global ecosystems. Therefore, the critical issue at hand is how to design environmentally friendly takeaway packaging materials and functionalities that satisfy consumers' needs for food safety and convenience. In recent years, with the growing emphasis on sustainable development globally, various industries have begun exploring green and eco-friendly solutions. For the takeaway industry, innovative design in food packaging should not only focus on the environmental friendliness of materials but also on enhancing packaging functionality and improving user experience (Brown, 2020).

Currently, many takeaway packages lack sustainable design principles, leading to material waste, limited functionality, and difficulties in post-use recycling. Thus, the core challenge lies in how to innovate from the perspectives of material selection and functional design. This research aims to explore material innovations and functional design for takeaway food packaging under the guidance of sustainable development principles, to provide feasible design solutions to address the environmental issues caused by takeaway packaging and to contribute to the promotion of green design and a circular economy.

¹ International College, Dhurakij Pundit University, Email: lin.zhu@dpu.ac.th.

Literature Review

The Origin and Development of The Sustainable Design Concept

The concept of sustainable design originated in the 1960s and gained momentum with the environmental movement of the 1970s, in response to the negative impacts of industrialization, such as excessive resource consumption and environmental degradation. The United Nations Brundtland Commission's 1987 report, *Our Common Future*, formally defined "sustainable development" as meeting present needs without compromising the ability of future generations to meet theirs. Initially, sustainable design was prominent in architecture, focusing on energy efficiency through optimized building materials and designs, such as the "Passive House," which minimizes energy use through natural ventilation and insulation (Bhamra, 2007). The concept then expanded to industrial design, emphasizing waste reduction, energy efficiency, and recyclability. Today, sustainable design is applied to consumer goods and packaging, covering the entire product lifecycle from materials to disposal. Designers consider renewable sourcing, low-carbon production, product longevity, and recyclability. In recent years, innovations in biodegradable and recycled materials have made significant advances in packaging design. However, takeaway food packaging, with its high consumption and short lifespan, poses sustainability challenges. Thus, integrating sustainable design principles into takeaway packaging is critical to reducing environmental impact, optimizing materials, and promoting eco-friendly practices.

Analysis of the Current Situation and Problems of Takeaway Food Packaging

Over the past decade, the takeaway industry has rapidly grown, catering to consumers' needs for convenient dining, especially in urbanized and digital societies. However, this growth has led to a surge in the use of disposable packaging, resulting in significant environmental concerns (Smith, 2019). Current takeaway packaging materials, including plastic, paper, and aluminum foil, are mostly single-use and non-degradable, contributing to substantial waste accumulation. Plastic packaging although cost-effective and functional (waterproof, oil-resistant, and well-sealed), is problematic due to its long degradation period, which can last hundreds of years. Research indicates that about 40% of the global annual plastic production is for disposable packaging, much of which ends up in oceans, forming "plastic garbage islands" that threaten marine ecosystems (George, 2020). In China, the booming takeaway platforms Meituan, Ele.me, and Baidu Waimai handle over 20 million daily orders, using more than 60 million containers each day. The widespread use of plastic bags has resulted in severe environmental pollution. The plastic bags used could cover an area of 1.2 million square meters. For example, Figure 1 Photos of takeaway plastic boxes and bags, resulting in significant environmental pollution and recycling challenges. Many current packaging designs fail to consider reducing volume and weight, which could lower resource consumption and transportation costs. Therefore, there is an urgent need to balance functionality (e.g., waterproofing, oil-proofing, insulation) with sustainability. Future research should focus on selecting eco-friendly materials, simplifying packaging, and enhancing recyclability to address the environmental impacts of takeaway packaging.



Figure 1. Photos of China's Massive Use of Plastic Takeaway Boxes and Bags, Which Contributes to Serious Waste Pollution.

Source: <https://cn.nytimes.com/china/20190528/china-food-delivery-trash/>

Trends In Innovative Design for Takeaway Food Packaging

Guided by sustainable development principles, researchers and designers are increasingly exploring innovative packaging materials to reduce environmental impact. Key trends include the use of biodegradable plastics, edible packaging, and reusable containers. Biodegradable plastics are common alternatives that can decompose into harmless substances under specific conditions, thus reducing long-term pollution. However, they face challenges such as high production costs and the need for specific environments (e.g., industrial composting) for proper degradation, limiting their practical application in some areas (Lee, 2021). Edible packaging, made from natural ingredients like starch, seaweed, and gelatin, is gaining attention for its potential to reduce packaging waste. Some research teams are developing plant-based films that can serve as food packaging, but issues such as moisture resistance and food safety need further improvement (Zhang & Wang, 2020). Overall, the trends in takeaway packaging design focus on integrating new materials with functional designs. Designers must consider user experience, cost, and environmental impact, with innovations like biodegradable plastics, edible materials, and modular, foldable designs leading the way towards more eco-friendly solutions.

Research On the Multifunctional Design of Take-Out Food Packaging

Takeaway packaging must meet essential requirements like sealing, freshness, and transportability, while also addressing user needs for convenience, insulation, aesthetics, and enhanced user experience. Designing multifunctional packaging to minimize resource waste and enhance reusability is a key research focus. Thermal insulation is critical, especially for long deliveries. Studies suggest that adding insulating layers or using thermal materials can extend heat retention, ensuring food arrives at an optimal temperature (Smith, 2021). Portability is another essential feature, as consumers seek easy-to-carry packaging that simplifies their experience. Foldable or compressible designs are popular, as they can be reduced in size after use, easing transportation and disposal. As shown in Figure 2, Tomorrow Machine's foldable, eco-friendly noodle bowl is made from paper-based materials that are lightweight, antibacterial, and resistant to grease and moisture, allowing it to be transported flat and saving on space and costs (Brown, 2020). Recent innovations like modular and foldable designs optimize packaging structures, improving resource efficiency. Multifunctional designs integrate these features to expand packaging utility while emphasizing sustainability and enhancing user convenience.



Figure 2. Swedish Creative Design Company Tomorrow Machine Has Developed A Completely Biodegradable, Foldable, And Eco-Friendly Instant Noodle Bowl Using A Paper Coating Method.

Source: https://www.sohu.com/a/252405226_655569

Methodology

Literature Review: The study systematically reviews both domestic and international academic literature on takeaway packaging, sustainable materials, and functional innovations. This helps identify current trends and achievements, focusing on sustainable and eco-friendly designs, forming the theoretical framework for the study.

Case Study Method: By analyzing representative cases of innovative takeaway packaging, particularly those using biodegradable or renewable materials, the study highlights practical solutions for material selection and functional design. These cases demonstrate how sustainability principles are applied in real-world designs, offering insights for future projects.

Market Research: The method involves investigating current packaging categories, materials, and functions within the takeaway market. This analysis identifies existing problems and needs, leading to design solutions that align with sustainable development principles. The research also explores the potential for innovative, eco-friendly designs in the market.

Experimental & Design Practice: Guided by sustainable development concepts, the study conducts design experiments using biodegradable materials and innovative functional features. These prototypes are tested for performance (e.g., insulation, durability, convenience) and environmental impact, offering a comprehensive evaluation of their practicality and sustainability.

Result and Discussion

Based on thorough research and analysis of the takeaway food packaging market domestically and internationally, the functional design of takeaway food packaging under the concept of sustainability should focus on safe and convenient packaging structures, eco-friendly degradable materials, and visual designs that align with ecological concepts. In summary, the design of takeaway food packaging under the sustainable development concept can be optimized in three aspects: safety, portability, and ease of use in structural design, ecological material application, and visual guidance in design language.

Safety, Portability, and Ease of Use in Structural Design

Takeaway food packaging should fully consider the convenience and safety for consumers before and after dining. Regardless of the structural design, it must functionally meet the requirements of good sealing, leak resistance, and ease of opening, avoiding issues such as spills, wet hands, and stained clothing while ensuring the safety of the food during transportation.

Secure Sealing

To ensure safe delivery, packaging must prevent spillage and unauthorized access. For example, soup containers use durable PP materials with tight, pressure-resistant lids to avoid leakage, even if inverted. Easy-open slots can enhance convenience. A cost-effective solution is using staples to seal paper bags, providing tamper-evident security by showing if the package has been opened during transit.

Convenient Opening Mechanism

An easy-to-open design is crucial for enhancing user experience in takeaway packaging. Solutions include adding guiding notches or handles to lids for quick access, while still ensuring proper sealing. For paper boxes, thicker edge seals improve insulation, and a double-layer vent design can prevent opening difficulties due to pressure. These structural improvements make packages more user-friendly and efficient.

Structural Design for Reduced Material Use

For both consumers and businesses, the primary consideration when choosing or selling takeout is economic factors, so cost reduction can be targeted. Meeting basic product protection needs while ensuring economic feasibility and cost efficiency through moderate packaging is key. In actual production, reducing packaging layers, minimizing volume, or utilizing innovative structural designs can achieve cost reduction, resulting in streamlined packaging.

Ecological and Sustainable Application of Materials

The choice of takeaway packaging materials is one of the key elements of sustainable design. The sustainability of takeaway packaging materials primarily means that, under safety principles, these materials do not affect human health, contaminate food, and meet green packaging standards. The characteristics of ecological and sustainable materials include: (1) environmental friendliness, i.e., recyclable, reusable, and biodegradable materials; (2) comfort in use; (3) advanced performance of the materials themselves. Based

on the analysis of major takeaway packaging materials, achieving ecological and sustainable goals can be approached from two main aspects: paper materials and plastic materials.

Use and Development of New Paper-Based Packaging Materials

Paper-based packaging is eco-friendly, easy to recycle, and highly versatile. Five types of paper materials stand out for their sustainability:

Kraft Paper: Known for its strength, durability, and natural appearance, kraft paper is commonly used for bags and wraps. It can be treated with water- and oil-resistant coatings, making it suitable for greasy foods. It is highly recyclable and decomposes quickly, enhancing its eco-friendly appeal.

Corrugated Cardboard: With a layered, cushioned structure, it offers excellent protection for items like pizza and bento boxes. Corrugated cardboard is recyclable, customizable, and can include inner coatings for added water and oil resistance.

Coated Paper: This paper features waterproof or oil-resistant layers, making it ideal for wrapping fried foods. Increasingly, biodegradable coatings are replacing traditional chemical ones, reducing environmental impact.

Uncoated Food-Grade Paper: Free from chemical additives, it is fully biodegradable and suitable for wrapping bread and pastries. While not water or oil-resistant, it can be paired with other materials to enhance functionality.

Plant Fiber Paper: Made from renewable resources like bamboo or sugarcane bagasse, this biodegradable material can be treated for water and oil resistance. It is an emerging option for eco-friendly packaging solutions.

In conclusion, selecting appropriate paper materials for takeaway packaging involves balancing strength, safety, and sustainability. Traditional materials like kraft paper remain popular, while plant fiber paper presents a promising eco-friendly alternative.

Use of Biodegradable Plastic Materials

The Biodegradable materials are designed to break down naturally, reducing environmental impact. Four common types of biodegradable plastics with sustainability benefits include:

Polylactic Acid (PLA): Made from renewable resources like corn starch and sugarcane, PLA decomposes into water and CO₂ under industrial composting conditions. It is often used for disposable cutlery and cups but requires specific high-temperature environments to degrade efficiently.

Polyhydroxyalkanoates (PHA): Produced by bacteria, PHA is biodegradable in various environments, including oceans and soil. It is more eco-friendly than PLA and is suitable for use in cutlery and food packaging.

Starch-Based Bioplastics: These are created by blending natural starch with other polymers, decomposing quickly under industrial composting. Commonly used for takeaway containers, their primary advantage is that they are made from renewable resources, though they need modifications to enhance strength and water resistance.

Cellulose-Based Plastics: Derived from the most abundant natural polymer, cellulose, these plastics are fully biodegradable and often used for films and linings to improve water resistance.

In conclusion, biodegradable plastics derived from biomass are increasingly used in takeaway packaging to meet functional requirements while minimizing environmental impact. They can break down into harmless

substances, offering a sustainable alternative to traditional plastics.

Visual Guidance of Packaging Design Language

Visual language plays a key role in takeaway packaging, as it forms the first impression for consumers and conveys important product and brand messages. Under sustainable development, visual design encourages consumers to adopt eco-friendly practices. The design elements include:

Pattern Design: Patterns can effectively communicate sustainability. For instance, Green Rebels United uses footprint designs and strong contrasts to promote environmental consciousness, urging consumers to adopt a low-carbon lifestyle. as shown in Figure 3

Text Design: Clear, minimalistic text on packaging can convey sustainability without overwhelming consumers. An example is ice cream packaging featuring "00:00," symbolizing urgency in environmental protection and reflecting on issues like climate change. as shown in Figure 4

Color Design: Simple, natural colors promote sustainability. Sushi Junction's packaging, made from kraft paper, uses a minimalistic approach with its natural texture and a simple black logo, emphasizing eco-friendliness. as shown in Figure 5

In conclusion, by integrating sustainable concepts through patterns, text, and colors, brands can align with consumers on environmental goals, encouraging active participation in recycling and sustainable practices.

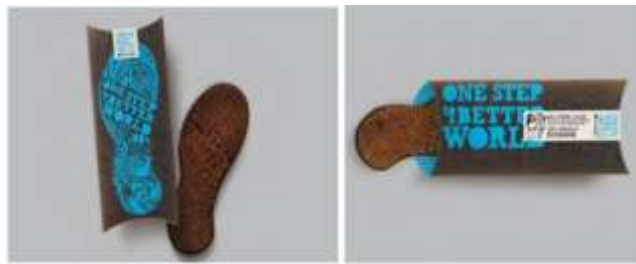


Figure 3. Green Rebels United Sustainable Chocolate Packaging Design

Source: Light Industry Science and Technology Journal

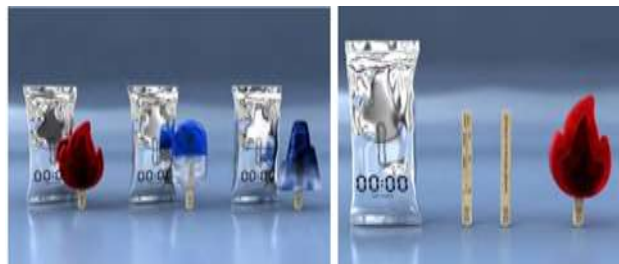


Figure 4. Ice Cream Environmental Protection Concept Packaging Design

Source: Light Industry Science and Technology Journal



Figure 5. Sushi Junction Kraft Paper Environmentally Friendly Packaging Design

Source: Light Industry Science and Technology Journal

Analysis and Display of Innovative Design Results of Take-Out Food Packaging

This research focuses on sustainable innovation in Chinese takeaway food packaging, addressing existing issues and material selection. Chinese takeaways, which often have higher oil and water content, typically use plastic containers, while Western takeaways, with lower moisture content, use paper packaging more frequently. Currently, around 80% of takeaway packaging relies on plastic, with paper packaging less commonly used. Among Chinese fast food, plastic usage is particularly high, highlighting a critical need for eco-friendly innovations in packaging design to reduce environmental impact and promote sustainability in the takeaway industry. According to the different characteristics of takeaway food, packaging can be roughly categorized into five types, as shown in Table 1.

Table1. Takeaway Food Packaging Categories

categories	Examples	Packaging material	Takeaway packaging bags
No oil, no soup	Sushi, pancakes or baked sweet potatoes, corn, etc.	Paper and plastic boxes	Disposable white plastic bag
Less oil and no soup	Steamed buns, dumplings, fried noodles, fried rice, etc.	Disposable plastic boxes and bowls	Disposable white plastic bag
Deep-fried without soup	French fries, hamburgers, fried chicken, pizza, fried dough sticks, etc.	Paper bags and boxes	Paper bags
Less oil, more soup	Noodle soup, wonton, porridge, etc.	Disposable plastic boxes and bowls	Disposable white plastic bag
Lots of oil and soup	Stir-fry, hot pot, spicy hot pot, etc.	Disposable plastic boxes and bowls	Disposable white plastic bag

Based on the categorization of takeaway food packaging, I will conduct sustainable innovation design for Chinese takeaway packaging. In the sustainable innovation design of Chinese takeaway packaging, the choice of materials and functional design should be optimized according to the food's oiliness and amount of soup. When designing the packaging, I mainly focus on material selection and functional design. Aside from the recyclable resource logo, there are no excessive designs or printed colors, primarily emphasizing the concept of sustainable development in takeaway packaging. Below are the material choices, functional designs, and final packaging design renderings for four types of Chinese takeaway food:

- *Packaging Design for Oil-Free and Soup-Free Chinese Takeaway Food*

For packaging oil-free and soup-free takeaway foods like sushi or roasted sweet potatoes, lightweight and eco-friendly materials are recommended. Kraft paper and corrugated cardboard are ideal due to their recyclability, strength, and cost-effectiveness. They effectively support dry foods without risk of seepage.

Additionally, PLA-coated paper can enhance moisture resistance while remaining biodegradable. The functional design emphasizes three key aspects: portability (lightweight and easy to carry), modularity (multi-layer design for varied foods), and foldability (compact and waste-reducing). Based on these findings, kraft paper and corrugated cardboard were chosen for a lightweight, foldable design. The tote bag, also made of kraft paper, is reusable and recyclable, supporting sustainable practices. Below is the rendering of the oil-free, soup-free Chinese takeaway food packaging design:



Figure 6. Oil-Free and Soup-Free Chinese Takeaway Food Packaging and Bag Design

Source: Author design

- *Packaging Design for Low-Oil, Soup-Free Chinese Takeaway Food*

For low-oil, soup-free takeaway foods like buns, dumplings, and fried rice, packaging needs moderate oil resistance without stringent leak-proofing. Three materials are suitable: oil-resistant paper, bamboo fiber paper, and PLA-coated cardboard. Oil-resistant paper prevents oil seepage, while bamboo fiber paper is eco-friendly, renewable, and offers a natural texture, suitable for low-oil foods. PLA-coated cardboard adds oil resistance while maintaining biodegradability. The functional design focuses on three aspects: 1) Oil-proof coating to prevent stains, keeping food clean; 2) Breathability with air holes to retain food texture and prevent sogginess; 3) Environmental protection, ensuring the packaging is easy to disassemble and recycle. Based on the analysis, oil-resistant and bamboo fiber papers were chosen, featuring oil-resistant layers, breathability, and recyclability. The tote bag, made of kraft paper, is reusable, aligning with sustainability goals. Below is the rendering of the low-oil, soup-free Chinese takeaway food packaging design:



Figure 7. Chinese Takeaway Food Packaging and Bag Design with Little Oil and No Soup

Source: Author design

- *Packaging Design for Low-Oil, Soup-Heavy Chinese Takeaway Food*

For soup-based takeaway foods like noodles, porridge, and broth dishes, packaging needs to ensure freshness, maintain temperature, and prevent leakage. Three materials are suitable: 1) Composite cardboard with oil- and water-resistant coatings, which is eco-friendly and prevents leaks; 2) PLA-coated paper, which is biodegradable and resists both water and oil; 3) Transparent PET/PLA soup bowls, which are heat-resistant and leak-proof. The functional design focuses on four aspects: 1) Oil-proof and waterproof coating to prevent seepage and maintain cleanliness; 2) Sealing and leak-proof features, using lock-type lids or sealing strips to avoid leaks during transport; 3) Insulation design with multiple layers to keep food warm; 4) Partition design to separate soup from solid ingredients, preserving taste.

Based on these principles, PLA-coated paper and transparent biodegradable PET/PLA bowls were chosen, featuring sealing and separation. The tote bag comes in two versions: washable fabric for reuse and biodegradable PLA or PHA plastic, designed for insulation and carrying heavy items. Below is the rendering of the low-oil, soup-free Chinese takeaway food packaging design:



Figure 8. Chinese Takeaway Food Packaging and Bag Design with Less Oil and More Soup

Source: Author design

- *Packaging Design for High-Oil, Soup-Heavy Chinese Takeaway Food*

For high-oil, soup-heavy dishes like hotpot and braised foods, packaging must be leak-proof, durable, and well-sealed. Three suitable materials are: 1) Double-layer cardboard with oil- and water-resistant coatings (e.g., PE or PLA) to prevent seepage while maintaining strength; 2) Biodegradable plastics (e.g., PLA or PBAT) for internal containers, which are leak-resistant and eco-friendly; 3) Reusable plastic containers (e.g., PP) for premium takeaway services, allowing for washing and reuse, thus reducing waste. The functional design focuses on three aspects: 1) High-strength sealing to prevent spills during transport, using sealed covers or leak-proof locks; 2) Heat and oil resistance to withstand high temperatures without deformation; 3) Separation design to keep food and soup distinct, preserving taste and improving ease of consumption. Based on these needs, the designs include options for double-layer cardboard with coatings, and biodegradable plastic containers, featuring strong seals, heat resistance, and separation. Tote bags are available in reusable fabric or insulated biodegradable materials. Below is the rendering of the high-oil, soup-heavy Chinese takeaway food packaging design.



Figure 9. Chinese Takeaway Food Packaging and Bag Design with Lots of Oil and Soup

Source: Author design

Conclusions

This study focuses on sustainable material selection and functional design in takeaway packaging, emphasizing minimal design and recyclable resources. By analyzing and innovating packaging for four types of Chinese takeaway food, the research provides insights on optimizing packaging under sustainable principles.

Oil-Free, Soup-Free Foods: For such items, the packaging should prioritize lightweight, eco-friendly materials like biodegradable paper or PLA-coated paper boxes. These materials, being cost-effective and sustainable, offer essential moisture and oil resistance while ensuring breathability and insulation. This reduces material waste while maintaining packaging functionality.

Low-Oil, Soup-Free Foods: Packaging must balance moisture resistance and sealing to maintain food freshness. Coated paper or PLA-coated packaging helps prevent moisture leakage and retains food texture. Foldable designs improve storage and transport efficiency, enhancing user experience.

Low-Oil, Soup-Heavy Foods: For foods containing liquids, water resistance, sealing, and insulation is essential. Packaging options like composite cardboard, PLA-coated containers, or biodegradable plastic bowls with tight-sealing designs prevent soup leakage. Insulation features, such as double-layered structures, help maintain food temperature and taste during delivery.

High-Oil, Soup-Heavy Foods: Packaging materials must be oil and heat-resistant to handle greasy, soup-heavy items. Options include oil-resistant composite paper, aluminum foil, or biodegradable plastic containers with structural separation layers to prevent mixing of ingredients. Thermal materials on inner walls help maintain temperature and flavor during long-distance transport.

Conclusion: The design of Chinese takeaway packaging should be tailored to the food's characteristics, balancing food safety and environmental impact through the use of biodegradable plastics, paper, and composite materials. Future advancements in eco-friendly materials and packaging technologies will further enhance the functionality, sustainability, and intelligence of takeaway packaging, providing consumers with a more convenient and sustainable dining experience. Sustainable design embodies environmental awareness, systematic thinking, and principles of eco-humanism development, integrating resources, environment, society, and economy. By incorporating Sustainable Development Goals (SDGs) into design strategies, designers can innovate takeaway packaging, addressing environmental challenges while promoting social responsibility and green economic growth. This approach ensures a transformative impact, contributing to the alignment of takeaway packaging with global sustainability goals and the broader vision of eco-conscious living.

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