FutureBridge

REPORT

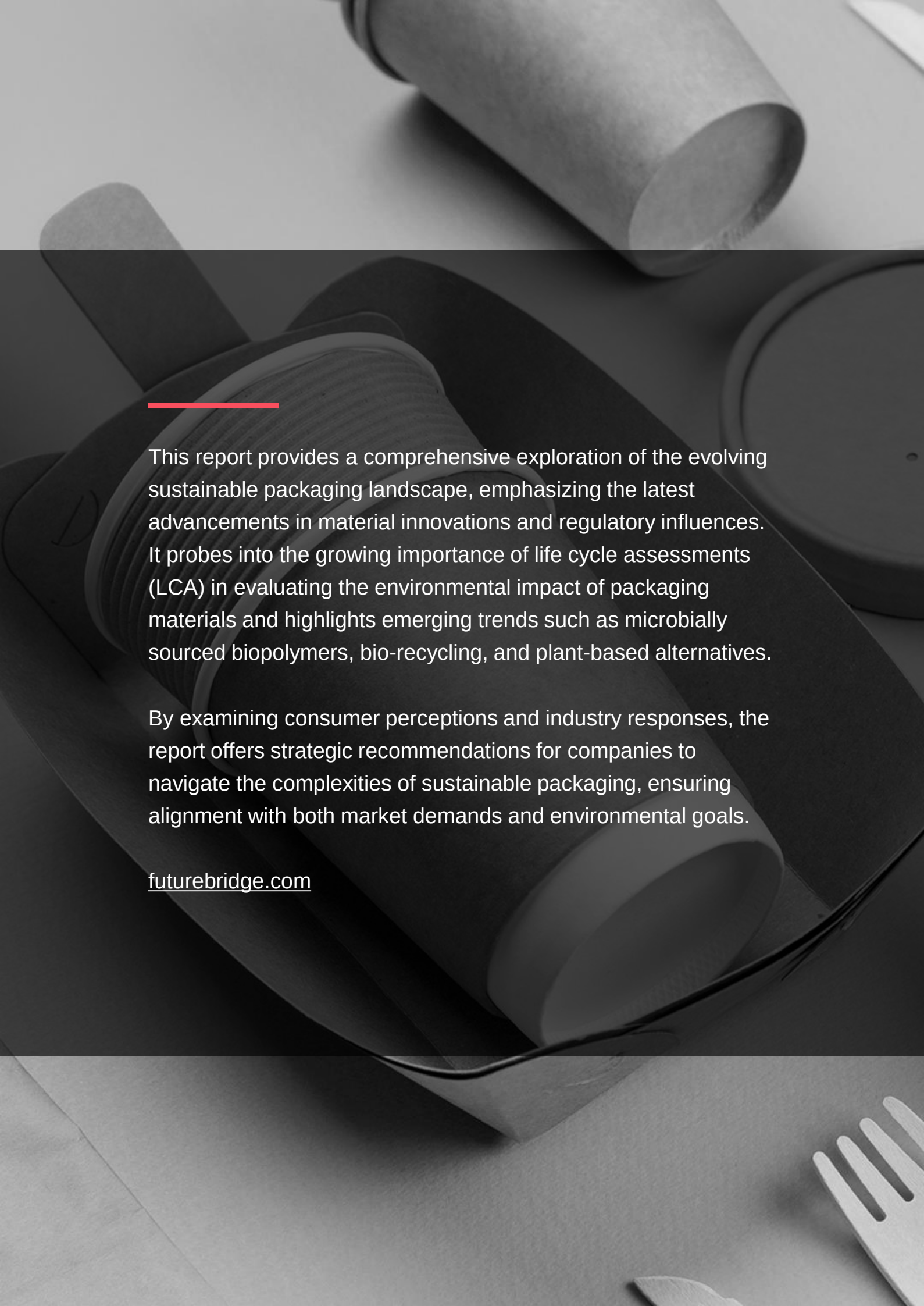
Sustainable Packaging

Emerging Innovations, Opportunities, and Challenges: Now, Next and Future

AUGUST 2024

Edward Bergen
Food & Nutrition

www.futurebridge.com



This report provides a comprehensive exploration of the evolving sustainable packaging landscape, emphasizing the latest advancements in material innovations and regulatory influences. It probes into the growing importance of life cycle assessments (LCA) in evaluating the environmental impact of packaging materials and highlights emerging trends such as microbially sourced biopolymers, bio-recycling, and plant-based alternatives.

By examining consumer perceptions and industry responses, the report offers strategic recommendations for companies to navigate the complexities of sustainable packaging, ensuring alignment with both market demands and environmental goals.

futurebridge.com

Table of Contents

Executive Summary

The sustainable packaging market is witnessing rapid growth as both consumers and governments increasingly prioritize environmental concerns. Companies across various industries face pressure to innovate and adopt packaging solutions that minimize ecological impact while meeting stringent regulatory standards. This report examines the latest trends, material advancements, and strategic opportunities for businesses to stay competitive and aligned with market demands.

Key findings

- **Innovative Materials:** Emerging materials such as microbially sourced biopolymers and plant-based alternatives gaining traction due to their lower environmental impact.
- **Regulatory Influence:** Stricter regulations driving companies to adopt sustainable practices, with life cycle assessments (LCA) becoming essential in evaluating material sustainability.
- **Consumer Expectations:** Growing consumer demand for eco-friendly packaging shaping market trends, pushing companies toward more transparent and sustainable solutions.

Strategic recommendations for Now (0-2 years), Next (2-5 years), and Future (5 years +)

To thrive in this competitive landscape, companies should:

- **Now –** Forge advancements in sustainable packaging by analyzing waste streams, embracing microbially sourced biopolymers, and enhancing post-consumer material recovery through bio recycling processes.
- **Next –** Embrace sustainable packaging by implementing mycelium-based bio foam solutions, incorporating nanoparticles for improved biodegradability, and exploring seaweed-based materials for eco-friendly, edible packaging.
- **Future –** Redefine sustainable packaging with innovations like aerogels and 3D printing, which can reduce packaging weight and streamline the production process.

Introduction

The sustainable packaging sector is at a pivotal moment, driven by increasing environmental concerns and regulatory pressures. As consumers become more environmentally conscious, the demand for packaging solutions that minimize ecological footprints is increasing rapidly. This shift is reshaping the packaging industry, compelling companies to explore new materials and processes that align with sustainability goals. The focus is not only on reducing waste and emissions but also on enhancing recyclability, biodegradability, and overall environmental impact.

Market drivers such as stringent regulations, particularly in regions like Europe and North America, are pushing companies to adopt more sustainable practices. Governments are implementing policies that require reductions in plastic waste, encourage the use of renewable resources, and promote circular economy principles. Additionally, large corporations are setting ambitious sustainability targets, further accelerating the adoption of eco-friendly packaging solutions. These factors are creating a fertile environment for innovation, with a surge in research and development of advanced materials, including bio-based and microbially sourced biopolymers, which offer potential reductions in carbon footprint and enhanced end-of-life disposal options.

Despite promising advancements, innovators in the sustainable packaging sector face significant challenges. The high costs associated with developing and scaling new materials, coupled with the need for infrastructure to support their adoption, pose barriers to widespread implementation. Furthermore, balancing performance, cost, and environmental impact remains a complex task, requiring a holistic approach that considers the entire life cycle of packaging materials. Companies must navigate these challenges while also meeting evolving consumer expectations and maintaining regulatory compliance, making the path to sustainable packaging both challenging and essential for long-term success.

Objectives

This report aims to provide a comprehensive understanding of the sustainable packaging landscape, offering insights into the current market dynamics and future trends. It serves as a strategic guide for stakeholders looking to navigate the complexities of sustainable packaging.

1. **Analyze Market Trends:** Assess the latest developments in sustainable packaging materials, including innovations in biopolymers and plant-based alternatives.
2. **Evaluate Regulatory Impact:** Examine the influence of global regulations on the adoption of sustainable packaging practices and how companies can ensure compliance.
3. **Explore Consumer Perceptions:** Understand consumer expectations and how they are driving the demand for eco-friendly packaging solutions.
4. **Provide Strategic Recommendations:** Offer actionable strategies for companies to successfully implement sustainable packaging solutions while balancing cost, performance, and environmental impact.

Methodology

The analysis implemented employs a detailed approach, examining market trends, technology, consumer perception, regulatory policies, and market dynamics to understand future of functional foods and complexities which includes the following:

- Evaluation scope definition
- Cross-source data analysis
- Expert analysis to identify trends and challenges
- Data analysis using statistical and trend analysis
- Scenario planning to explore potential futures
- Impact assessment on stakeholders and the environment
- Policy analysis to evaluate regulatory landscape
- Commercialized developments highlighting key trends and priorities
- Actionable recommendations for industry stakeholders and policymakers

By conducting a thorough review, validation, and stakeholder engagement, this methodology guarantees a systematic and informed analysis of the evolving functional foods sector, delivering valuable insights to address challenges and capitalize on opportunities in the dynamic food and nutrition landscape.

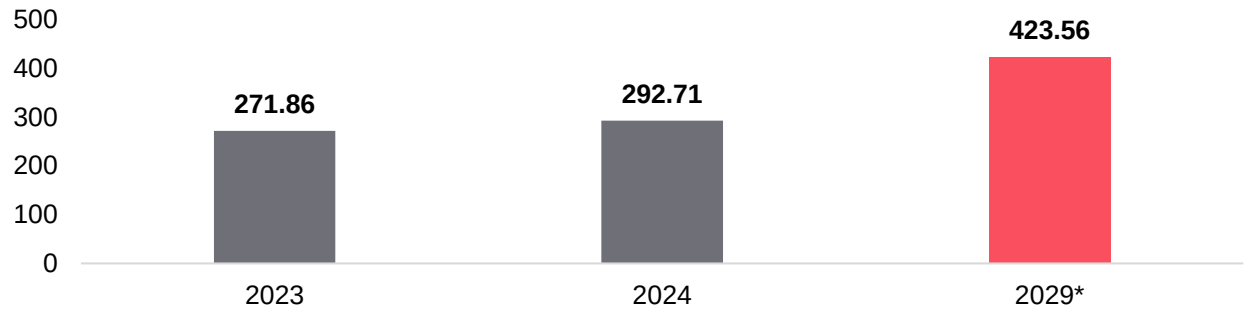
Market Analysis

The sustainable packaging market is exploding

The global packaging industry encompasses a diverse range of materials, including plastic, paper and board, glass, and metals, each offering unique benefits and applications. As sustainability becomes a critical consideration, the industry is increasingly focusing on life-cycle analyses and efficiency optimization to guide packaging decisions and reduce environmental impact. In 2024, the global sustainable packaging market is valued at approximately $292 billion and is projected to surpass $423 billion by 2029.

Several key drivers are propelling the growth of sustainable packaging. The pulp and paper industry, for example, has shifted its focus from declining graphic paper production to expanding its presence in the containerboard market, which is expected to see nearly a 44 percent increase in global demand by 2029. This shift is driven by the need for more sustainable alternatives in response to environmental concerns, such as the sourcing of fibers from recycled materials or sustainable forestry practices. Meanwhile, the plastic packaging industry faces significant pressure to improve its environmental performance, with limited recycling rates prompting consumer criticism and driving innovation. These challenges and opportunities are pushing the packaging industry towards more sustainable solutions, fostering collaboration and innovation as companies seek to meet growing consumer and regulatory demands for environmentally responsible packaging.

EXHIBIT 1: Market value of sustainable packaging [1] worldwide in 2023 and 2024, with a forecast to 2029.



*Global sustainable packaging market, including sustainable glass, plastic, metal, and paper packaging solutions
Source: Statista

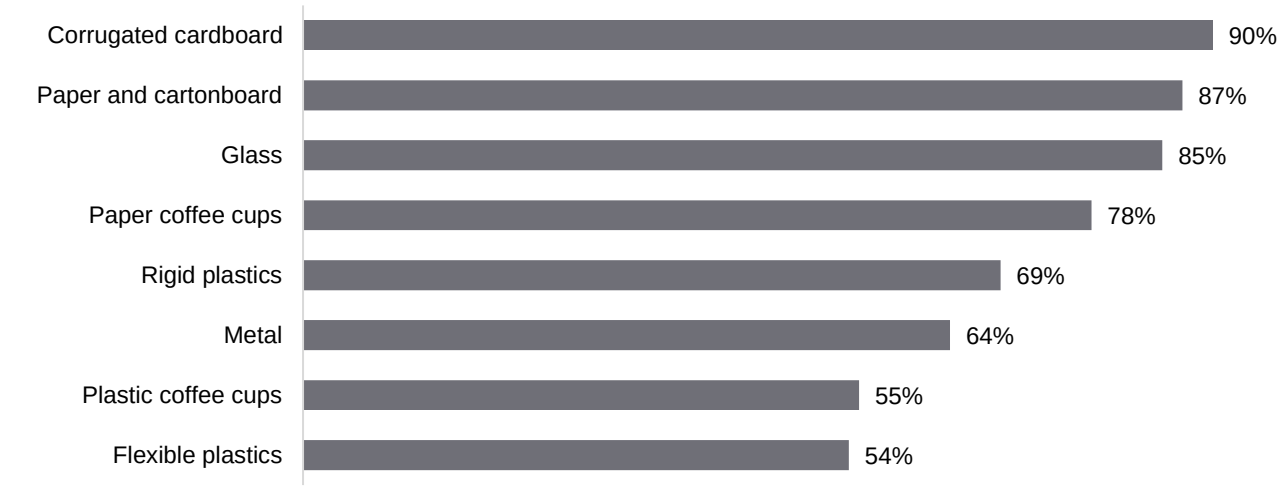
Recyclability defines consumers understanding of sustainable packaging

In the context of ongoing discussions about sustainable packaging in the food industry, a recent survey by packaging company ProCarton on sustainability in packaging emphasizes that no single packaging type stands out for consumers as an absolute leader in sustainability. The findings reveal a varied landscape with positive and negative features across different materials, formats, applications, and regions.

Notably, consumer perceptions of the most desired packaging features diverge globally – between a mix of sustainability desires and convenience. Consumers base their perceptions of sustainability on whether a particular packaging can be recycled. For instance, 70% of EU consumers cite 'easy to recycle' as their top packaging feature, with 'made from renewable materials' (48%) and ‘re-sealability' (44%) as the next desired features.

ProCarton also explores types of materials consumers link to sustainability and recyclability. Unsurprisingly card and paper-based packaging are most heavily linked with recyclability – with consumers expressing more skepticism around plastics.

EXHIBIT 2: Consumer confidence in materials in relation to recyclability



Source: ProCarton

However, the research by YouGov reveals a significant "green trust deficit" among consumers.. A striking 60% [3] of global consumers expressed distrust in brands' environmental, social, and governance (ESG) claims. Therefore, packaging creators must be exceptionally transparent in their communications of materials to meet consumer perceptions.

To address these challenges, the report recommends that companies prioritize sustainability by adopting region-specific strategies that resonate with local consumer preferences while also embracing innovations such as mycelium-based packaging and recycled materials. These approaches not only enhance brand reputation but also contribute to global sustainability goals

Regulations are pushing for sustainable overhaul by the early 2030s

Recent regulatory trends in sustainable packaging have seen a significant increase in both scope and stringency, driven by growing environmental concerns and consumer demand for more sustainable products. Globally, governments are implementing new policies to reduce plastic waste, promote recycling, and encourage the use of sustainable materials.

In European Union, the Single-Use Plastics Directive, effective from July 2021, bans certain single-use plastic products such as straws, cutlery, and plates, while imposing strict requirements on member states to achieve higher recycling rates. Additionally, EU has introduced the Circular Economy Action Plan, which includes measures to ensure that all packaging in EU markets are reusable or recyclable by 2030.

In the United States, several states have enacted their own regulations to address plastic pollution. California, for instance, has passed the Plastic Pollution Prevention and Packaging Producer Responsibility Act in 2021, which requires all packaging in the state to be recyclable or compostable by 2032. Other states like New York and Maine have also implemented extended producer responsibility (EPR) laws, making producers financially responsible for the collection and recycling of packaging waste.

These regulatory developments are pushing companies to innovate and adopt more sustainable packaging solutions. Compliance with these regulations help in reducing environmental impact and enhance brand reputation while meeting the growing consumer demand for sustainable products. As such, businesses in the packaging industry must stay informed and proactive in adapting to these regulatory changes to remain competitive and sustainable.

New sources emerging across the material landscape

Integrating the newly emerging alternative sources can reduce reliance on traditional, less eco-friendly materials, while aligning with consumer demand for greener options. Adopting these materials can improve the brand reputation and contribute to environmental conservation efforts.

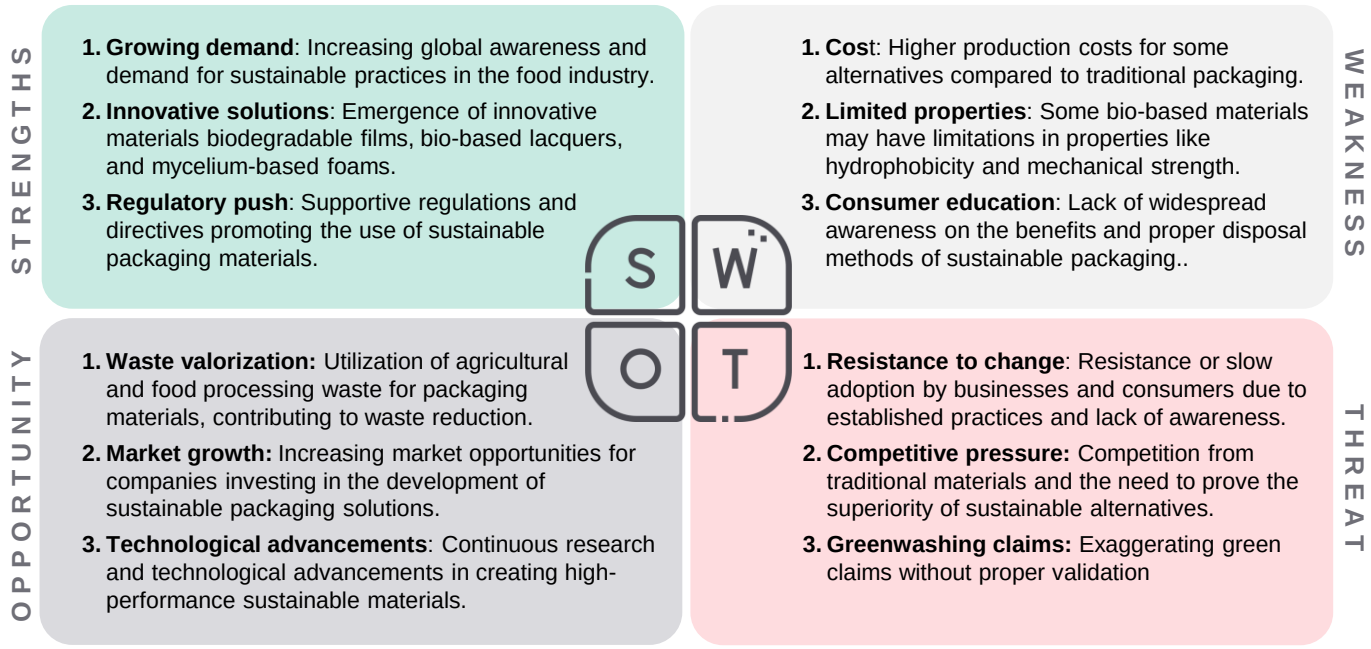
EXHIBIT 3: Player exploration of new sources of packaging material

Source: FutureBridge Analysis

Challenges arise from scalability, regulations, and innovation delays

Address challenges of cost, performance, and adoption by using circular principles and technological advancements

EXHIBIT 4: FutureBridge market SWOT analysis



Source: FutureBridge Food & Nutrition Platform

Key Strategies to Succeed in the Sustainable Packaging Sector

To thrive in the competitive landscape of sustainable packaging, companies must adopt a strategic approach that evolves over time. The following recommendations outline key strategies for success in the immediate, near, and long-term future, providing a roadmap for innovation and sustainability.

- **Now (0-2 years):** Companies should focus on immediate advancements in sustainable packaging by thoroughly analyzing waste streams to identify areas for improvement. Embracing microbially sourced biopolymers can significantly reduce reliance on traditional plastics, offering an eco-friendly alternative. Additionally, enhancing post-consumer material recovery through advanced bio-recycling processes will help close the loop in the lifecycle of packaging materials, promoting a circular economy. Immediate actions will lay the groundwork for more sustainable practices and build consumer trust through visible, impactful changes.
- **Next (2-5 years):** In the next phase, companies should aim to implement innovative materials and technologies that further advance sustainable packaging. Mycelium-based bio foam solutions offer a biodegradable and compostable alternative to traditional foams. Incorporating nanoparticles can improve the biodegradability of packaging materials, making them more efficient in breaking down and reducing environmental impact. Exploring seaweed-based materials for eco-friendly, edible packaging can introduce revolutionary changes in the food packaging sector, offering both sustainability and functional benefits. These innovations will position companies as leaders in sustainability, driving brand differentiation and consumer loyalty.
- **Future (5 years +):** Looking beyond five years, companies should invest in groundbreaking solutions that have the potential to redefine sustainable packaging. The development and application of aerogels can significantly reduce packaging weight while maintaining strength and insulation properties. Furthermore, 3D printing technology can revolutionize the production process, allowing for customizable, on-demand packaging that minimizes waste and maximizes efficiency. By integrating these advanced technologies, companies will not only enhance their sustainability efforts but also drive innovation and efficiency in their packaging processes.

By following these strategic recommendations, companies can successfully navigate the evolving demands of the sustainable packaging market, ensuring long-term competitiveness and environmental stewardship.

Now: Immediate Strategies to Implement

EXHIBIT 5: Transform waste streams into eco-friendly packaging

Repurposing waste streams in food packaging holds significant environmental and economic benefits:

- It contributes to reducing the overall environmental impact by minimizing the burden of waste disposal and promoting a circular economy.
- Utilizing waste materials for packaging mitigates the need for virgin resources, conserving raw materials and energy.
- It addresses the growing concern of plastic pollution by providing sustainable alternatives and fostering an eco-friendlier approach.
- Incorporating waste streams in packaging aligns with increasing consumer demands for environmentally conscious products, enhancing brand reputation and consumer loyalty.
- It serves as a strategic solution for industries to meet sustainability goals and regulatory requirements, aligning with global efforts to combat climate change and promote responsible consumption.

Source	Discarded parts	Percentage of discarded parts
Potato	Peels	5–40%
Mango	Kernel and peels	35–55%
Tomato	Pomace	5–30%
Blueberry	Pomace	20–30%
Apple	Pomace	20–40%
Carrot	Pomace	30–50%

Source: MDPI

Analysis of waste streams and explore collaborations with waste valorization players

Here are some emerging examples utilizing waste coffee grounds:

- Coffeefrom, an Italian startup, develops bio-based thermoplastics. In collaboration with the Department of Chemistry, Materials, and Chemical Engineering Giulio Natta" and Fondazione Politecnico di Milano, the company filed a patent to extract nano cellulose from coffee grounds for developing raw materials with at least 50% coffee grounds for thermoplastic compounds.
- CoffeeBased, a Netherlands-based company, offers a coffee recycling service, collecting coffee grounds from businesses, diverting them from landfills, and rewarding clients with store credits for sustainability efforts. The service, accompanied by a coffee grounds collection bin, promotes a circular economy while strengthening their client's sustainable image, supported by quarterly impact certificates.

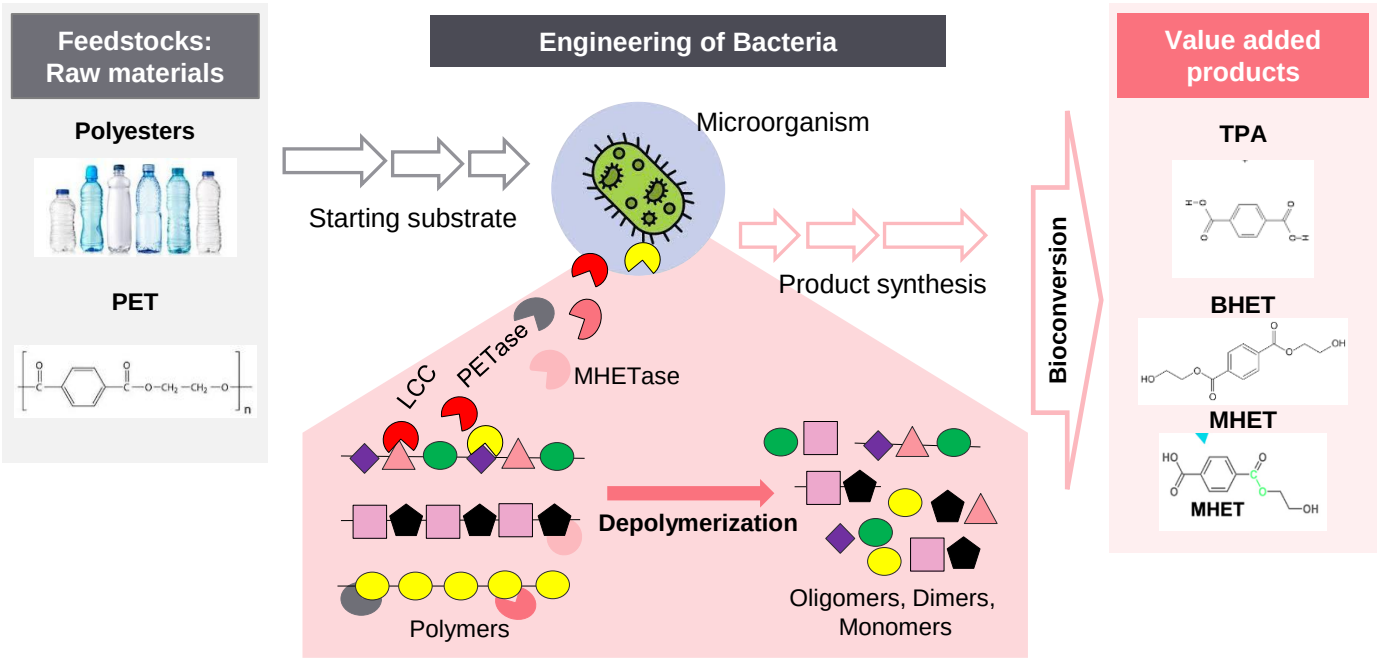
Explore microbially sourced biopolymers to avoid competition in material sourcing

Here are some emerging examples utilizing waste coffee grounds:

- Xampla pioneers a patented technology to engineer natural biopolymers, introducing a new class of plant-based Morro materials. These materials offer high strength, excellent oxygen barriers, and replacements for single-use plastics and microplastics. They are fully biodegradable, tailored for specific solubility and barrier properties, and made from sustainable feedstocks, including potential sources from plant-based waste agricultural biomass.
- LEEF Packaging specializes in natural biopolymers made from fallen palm leaves, providing eco-friendly alternatives to conventional plastic tableware. With a cradle-to-cradle approach, LEEF emphasizes the sustainable lifecycle of its products. Beyond innovation, the company actively contributes to rainforest conservation, making each purchase a step toward protecting endangered ecosystems.

Improve post-consumer material recovery and yield by employing bio recycling process

EXHIBIT 6: Advancing bio recycling — Large-scale degradation of Post-Consumer PET waste through optimized enzymatic processes



Source: Wiley

Recent discoveries in new polyester hydrolases and enzyme engineering strategies have inspired significant research efforts for efficient and large-scale biodegradation of PET. The study focuses on advancing bio-recycling methods for postconsumer waste PET (polyethylene terephthalate), one of the most widely used polyester plastics.

- Genes for key PET-degrading enzymes were optimized, enhancing production in Escherichia coli BL21(DE3).
- A cost-effective approach was employed by fusing a pelB leader sequence, enabling easy enzyme recovery.
- PET binding was improved using a substrate-binding module (PBM) from Alcaligenes faecalis in the enzyme structure.
- The efficiency of enzyme variants and key enzymes (PETase, MHETase) in degrading PET was compared, highlighting their performance.
- A developed fed-batch fermentation process achieved significant enzyme production, paving the way for large-scale availability and supporting a circular economy for PET.

Next: Emerging Strategies to Adopt

Utilize mycelium to replace polystyrene foams and develop bio foam packaging solutions

In the realm of sustainable food packaging, life cycle analysis (LCA) has illuminated a significant environmental contrast between Expanded Polystyrene (EPS) and mycelium-based materials. Mycelium, the root structure of fungi, emerges as a promising candidate for sustainable food packaging due to its biodegradability and versatile applications. **In fact, polystyrene showed 2.3 times higher emissions compared to mycelium packaging.** Researchers are exploring mycelium composite materials by blending it with agricultural waste, resulting in durable and customizable packaging

solutions. Additionally, the development of mushroom-based foam offers lightweight and shock-absorbent materials, ideal for ensuring the safe packaging of fragile items.

Emerging technology leveraging Mycelium

Tetra-laval foam-formed cellulosic fiber is a patented [US11692313B2] invention that involves a method for manufacturing a foam-formed cellulosic fiber material using coarse cellulosic fibers and a cellulose reinforcement fraction. The resulting material has low density, typically below 450 kg/m3, and a relatively high delamination strength, crucial for packaging applications. The coarse cellulosic fibers provide a bulky structure, while the cellulose reinforcement fraction enhances the material's strength and bonding during the papermaking process. Benefits include:

- Enhanced delamination strength in a low-density structure.
- Improved mechanical properties without increasing material density.
- Potential cost savings through down-gauging cellulose-based bulk.

Integrate nanoparticles and nanocomposites to improve biodegradability of packaging

Nanoparticles are extremely small particles, typically ranging from 1 to 100 nanometers in size, that possess unique physical and chemical properties due to their size and high surface area. In the context of sustainable packaging innovation, nanoparticles play a crucial role in enhancing the performance and sustainability of packaging materials.

An emerging technology using nanoparticles

Nano-composite film - the study provides valuable insights into the potential application of nano glass flakes, paving the way for the development of sustainable and high-performance food packaging solutions. Benefits include:

- **Advanced functionalities:** The incorporation of nano glass flakes (NGF) into PLA/PEG films enhances hydrophobicity, oxygen barrier properties, and thermal stability, addressing key challenges in food packaging.
- **Material compatibility:** ATR-FTIR analysis confirms no chemical interaction between the matrix and NGF, ensuring material integrity and reliability in preserving food quality.
- **Optimized performance:** PLA/PEG/NGF1 nanocomposite film stands out, offering superior overall performance with increased transparency and mechanical properties.

Explore seaweed-based materials to formulate edible and plastic free packaging

Seaweed is emerging as a promising resource for sustainable packaging solutions due to its abundant availability, rapid growth, and biodegradability. By harnessing the natural polymers found in seaweed, manufacturers can create eco-friendly packaging materials that reduce reliance on fossil fuels and minimize environmental impact.

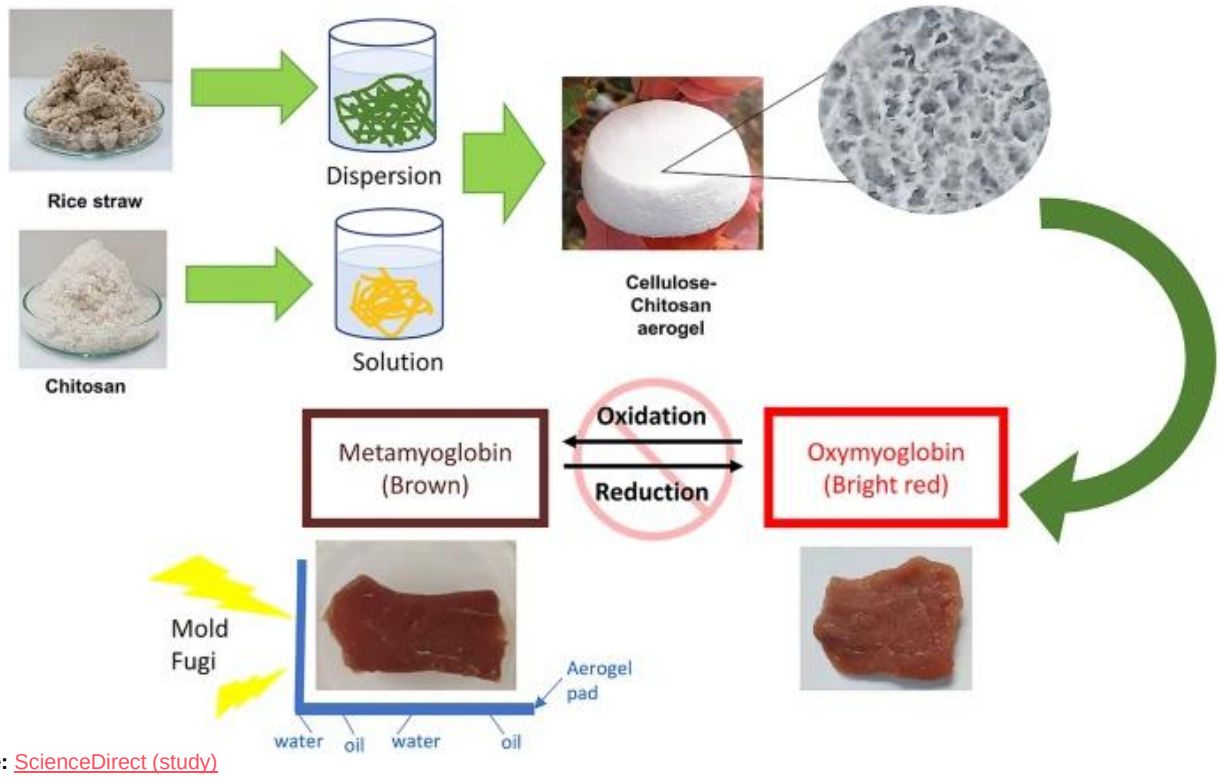
Here are some emerging players who have recently secured funding for seaweed solutions:

- Sway, a bio-materials developer, is set to receive a $272,000 Small Business Innovation and Research grant from the National Science Foundation. The funding aims to scale up the next generation of Sway's biodegradable product, primarily made from seaweed and melt-processable. TPSea offers transformative potential for flexible packaging, seamlessly integrating with plastic processing infrastructure for sustainable solutions.
- FlexSea, an Imperial-based startup, secures £3 million in seed funding to develop sustainable packaging solutions from seaweed derived plastics. These biodegradable materials, sourced from red seaweed, decompose in weeks, countering the longevity of conventional plastics in oceans. Led by Indico Capital, the investment aims to commercialize FlexSea's eco-friendly packaging solutions, supported by £1 million in grants from Innovate UK and other institutions.

Future: Whispering Technologies to Watch

Biodegradable aerogels from natural sources for lightweight and insulating properties

EXHIBIT 6: Cellulose–chitosan aerogels from agricultural waste for sustainable food packaging



Source: ScienceDirect (study)

The cellulose–chitosan aerogel is synthesized via a green method, utilizing rice straw for cellulose recovery and shrimp wastes for chitosan production, avoiding the use of bleaching agents and reducing chemical inputs. Benefits include:

- **Versatile properties:** The aerogel exhibits a low density, high porosity, and high-temperature stability, making it suitable for various applications, with a remarkable oil/water absorption capacity, showcasing its versatility for food packaging needs.
- **Effective preservation:** When applied as an absorbent pad in food packaging, the aerogel demonstrates its ability to inhibit mold growth, reduce lipid oxidation, and preserve the quality of fresh meat, highlighting its effectiveness in extending the shelf life of perishable goods.

3D printing technology for sustainable packaging formulation

Here are some emerging studies utilizing 3D printing technologies to create sustainable packaging:

- 3D printing biodegradable packaging from banana peel powder - This study explores the 3D printability of banana peel powder enriched with guar gum, a byproduct of fruit processing. The findings showcase the potential for converting non-printable banana peel waste into customizable, biodegradable 3D-printed food packaging structures.
- Circular economy model for 3D printing of recycled polymers - This study looks at how 3D printing can be used in a circular economy, which is a way of designing products and systems to reduce waste and make the most of resources. By using recycled plastics in 3D printing, we can create new products more quickly and cheaply. This approach not only helps in cutting down waste but also saves time and money, making it useful in many different fields.

Conclusion

The need for sustainable packaging in the food industry is more pressing than ever, driven by rising consumer demand for environmentally friendly products and increasing regulatory pressures. As the global market shifts towards sustainability, companies must recognize the critical importance of adopting packaging solutions that reduce environmental impact without compromising on functionality or consumer appeal.

New technologies are at the forefront of this transformation, offering innovative materials such as mycelium-based bio foams, biopolymers, and seaweed-based packaging. These advancements not only address current environmental challenges but also pave the way for future innovations that could redefine packaging standards across the industry.

Food and nutrition companies must take proactive steps to integrate these technologies into their packaging strategies. This means investing in research and development, forming strategic partnerships, and aligning with consumer values on sustainability. By doing so, companies can not only meet regulatory requirements but also strengthen their market position in a rapidly evolving landscape.

In conclusion, the future of sustainable packaging lies in the hands of those willing to innovate and adapt. The time to act is now.

Our experts offer clear, actionable analysis and advisory into the functional foods industry, guiding stakeholders through its challenges. Connect with the FutureBridge Food & Nutrition team to innovate, ensure regulatory compliance, and drive sustainable growth.

References

1. Statista
2. ProCarton
3. YouGov
4. Zippia
5. MDPI
6. Science Direct

About the Author

Edward, the Principal Analyst driving insights and strategic marketing in Food & Nutrition at FutureBridge, brings over a decade of hands-on experience in food and nutrition technology. He’s passionate about innovation, particularly in the areas of functional foods and personalized nutrition. Working closely with a team of dedicated analysts and food scientists, Edward develops strategies and insights that keep clients at the cutting edge of the evolving food industry. His approach not only drives innovation but also helps shape the future of food.

NORTH AMERICA

55 Madison Ave, Suite 400
Morristown, NJ 07960
USA

EUROPE

Stadsplateau 7
3521 AZ Utrecht
The Netherlands

Holborn Gate, 330 High Holborn
London, WC1V 7QH
United Kingdom

ASIA PACIFIC

Millennium Business Park
Sector 3, Building # 4, Mahape
Navi Mumbai 400 710
India

About FutureBridge

FutureBridge is a techno-commercial consulting and advisory company. We track and advise on the future of industries from a 1-to-25-year perspective to keep you ahead of the technology curve, propel your growth, Identify new opportunities, markets and business models, answer your unknowns, and facilitate best-fit solutions and partnerships using our platforms, programs, and access to global ecosystems and players.

www.futurebridge.com