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INNOVATIONS IN FOOD PACKAGING: A SYSTEMATIC LITERATURE REVIEW ON MATERIALS, TECHNOLOGIES, AND CONSUMER ADOPTION

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Abstract. Food packaging plays a crucial role in the modern food system by ensuring food safety and quality, balancing consumer requirements, and adhering to legal standards. However, the utilization of commercial packaging materials, particularly petroleum-based materials, causes severe environmental concern due to their non-biodegradability and long-term impact on the environment. Despite the rapid growth of technological research, food packaging is still fragmented across disciplines, suggesting the need for comprehensive and systematic synthesis of recent developments. In this study, a systematic literature review methodology was used to analyze innovative approaches for food industries aimed at enhancing sustainability and reducing the environmental impacts by using alternative packaging materials and methods. A total of 59 eligible research articles between January 2015 and July 2025, were selected based on the inclusion and exclusion criteria from the Scopus database. The review identifies and analyses various novel packaging materials and technologies, along with current trends and barriers to adopt the innovative eco-friendly packaging alternatives, with particular emphasis on consumer perceptions and technological advancement in the packaging sector. Despite the evident benefits of innovative packaging materials and methods, challenges such as financial limitations, regulatory complexities, and gaps in consumer awareness hinder widespread adoption. This review highlights the importance of coordinating efforts among businesses, government, and consumers to enhance the shift towards sustainable packaging solutions across the global food supply chain. Finally, this review provides a unique combination of bibliometric analysis, material innovation, and consumer views and adoption challenges to present a clear and complete overview of research in sustainable food packaging applications.

Keywords: active packaging, consumer, environmental impact, food packaging, intelligent packaging, sustainability, sustainable packaging and systematic literature review.

Introduction. Formulation of the problem

Food packaging is an evolving area due to new food technologies, modification in consumption habits,

and environmental factors [1]. Packaging is considered as a critical component in the food industry. It encompasses various forms such as envelopes, containers, or any type of covering, removable or not,

designed to enclose, protect, extend shelf life, or assist their marketing. Packaging facilitates food safety and quality from manufacturing to consumption by providing protection, shelf life, information, traceability, convenience, and tamper detection [2]. Polyethylene, polypropylene, polyester, and polystyrene are some of the most common petroleum-based polymers employed in plastic packaging. Traditional packaging materials, especially crude oil-derived plastics, are non-biodegradable, resulting in extended degradation periods and deposits in landfills and oceans, leading to adverse effects on environments, marine life, and human health [3]. Although some of these are typically recyclable, several countries face technical and economic barriers to recycling this packaging waste [4]. As a container for the preservation of food products, both structural packaging design and packaging technology play a key role in food waste reduction [5]. Regulation is a major concern when using chemicals in packaging that might come into contact with food [6]. These plastic wastes contribute significantly to environmental pollution.

Only a small fraction of plastic packaging materials is recycled globally, while the remaining are either incinerated or end up in landfills, water bodies, and the environment. In one minute, consumers purchase one million plastic bottles and make use of up to five trillion plastic bags every year, the majority of which are designed for single use. Plastics, particularly microplastics, have already been incorporated into the Earth's fossil record. They have even been associated with the formation of a new marine microbial habitat known as the "plastisphere".

The use and disposal of traditional plastics derived from fossil fuels are projected to account for 19 percent of the worldwide carbon budget by 2040 [7]. The majority of plastic items are used for a shorter span, but a plastic straw can last up to 200 years and plastic bags take approximately 20 years to decompose, whereas PET used in the packaging of food and beverages requires over 500 years to degrade [8]. In 2019, China (20%), India (6%), and other rapidly developing emerging Asian nations accounted for 35% of worldwide plastics usage. It is anticipated that plastics use in India will rise five times between 2019 and 2060, accounting for 13% of global plastics [9]. India banned the manufacturing, distribution, and use of 19 types of disposable plastic products, such as utensils, straws, and polystyrene decorations, on July 1, 2022. Additionally, regulations were put in place to control the thickness of plastic carry bags, setting the limits at 120 and 100 microns, respectively [10].

Edible and biodegradable packaging can reduce environmental pollution triggered by synthetic packaging materials [11]. The government support through policy initiatives is essential to improve waste management regulations and eliminate non-recyclable packing materials in society. Despite the invention of

numerous packaging materials, many food industries have yet to adopt these innovations in their product lines. Although consumers have become more aware of environmental issues, they often lack knowledge about various packaging materials and their potential societal benefits. Most existing reviews focus either on material development or consumer perception, whereas integrated assessments combining technological innovation, adoption barriers, and bibliometric trends remain limited. This article offers an elaborate explanation of the types of packaging materials. Furthermore, it seeks to identify and assess various innovative packaging materials in consideration of their potential for ensuring food safety and avoiding adverse environmental impacts.

Analysis of recent research and publications

Methodology

A systematic literature review (SLR) is a comprehensive academic approach that seeks to identify and assess all relevant literature on a particular topic in order to derive solid conclusions about the specific question under consideration. The SLR approach was employed in writing this review article on innovative packaging techniques, which identified the research gap and formulated research questions for an appropriate solution. The research questions are formulated and given below,

RQ 1. How do consumer perceptions influence the adoption of eco-friendly packaging in the food sector?

RQ 2. What innovative packaging materials are being explored to ensure food safety and reduce environmental impact?

RQ 3. What are the benefits and barriers to adopting innovative packaging in the food industry?

Topic Selection

Choosing the right topic is the most important aspect of writing a strong literature review, and the selected topic should not have been recently published in any journal. In this article, we review 'innovative packaging techniques in the food retail sector', and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) technique was used for the systematic review, which is illustrated in Fig 1. The scope of this study is comparatively broader, comprising brief explanations on consumer perceptions of eco-friendly packaging, various eco-friendly packaging techniques, and especially 'novel packaging techniques' with their benefits and barriers to adoption, which are addressed solely as a sub-topic. The articles were searched in Scopus database. The packaging review covers articles published between January 2015 and July 2025.

Research materials and methods

After topic selection, the next step is to select an online database to search for previous research papers.

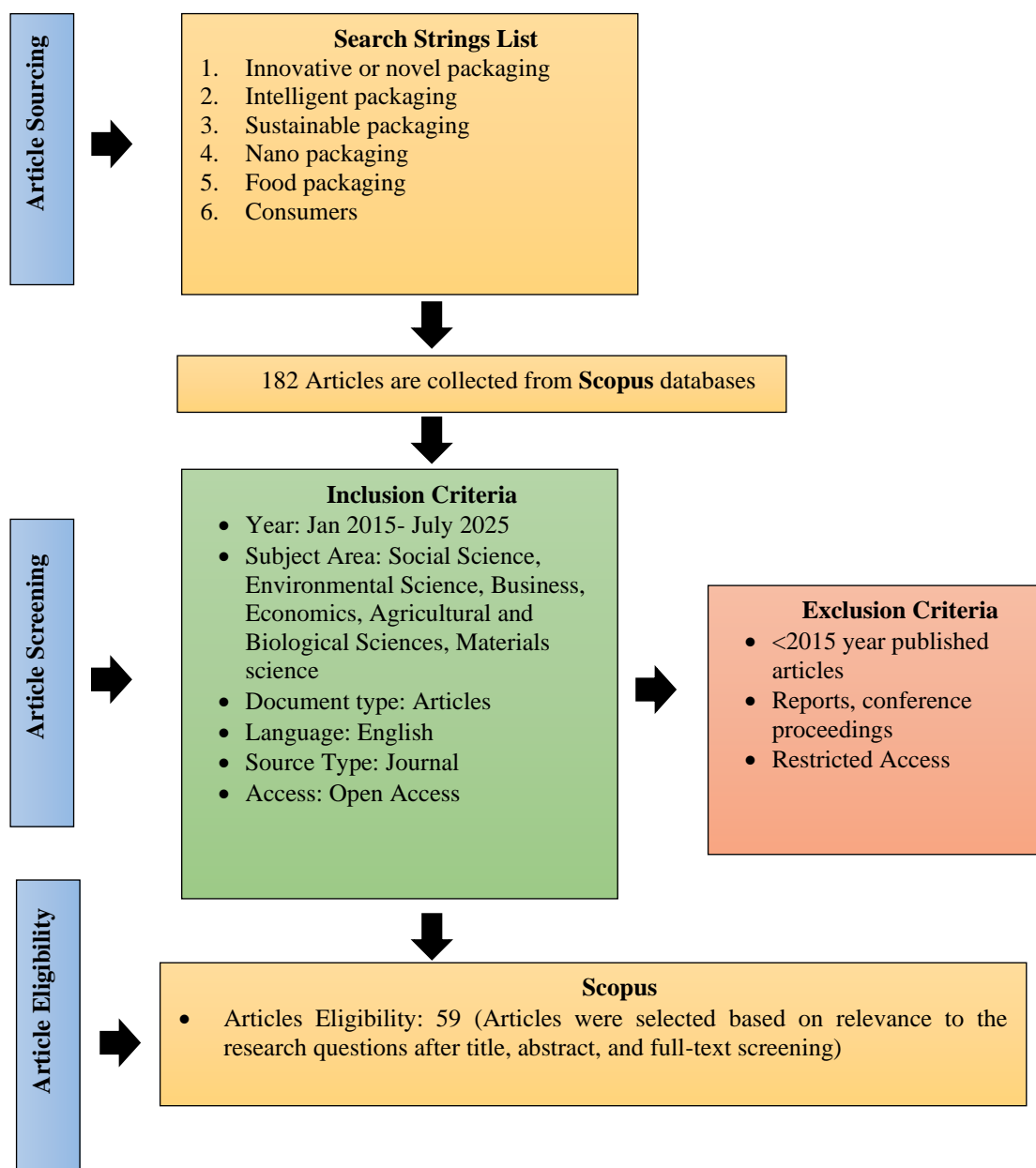


Fig 1: PRISMA Flowchart Diagram

The search strings used in the Scopus database are “Innovative or novel packaging,” “Intelligent packaging,” “Sustainable packaging,” “Nano packaging,” “Food packaging,” and “Consumers.” The article titles that included these search strings in the topic, abstract, or keywords are included in this study. The unwanted articles are excluded, and related articles are included according to the inclusion and exclusion criteria, which are explained in the next section.

Using the search strings, a total of 182 articles are collected from Scopus databases in the article sourcing stage. The next step is to remove the duplicate papers from the total dataset. After screening, no duplicate articles were identified, and so all 182 articles are

allowed for assessment of their suitability for inclusion in the study. In the article screening stage, the articles published between January 2015 and July 2025 were selected from the Scopus database. Regarding subject areas, social science, environmental science, business, economics, agricultural and biological sciences, and materials science are included, and only open-access articles in English are included in the document type in the Scopus database. Articles published before 2015 are excluded. Reports, conference proceedings, and restricted access articles are excluded from the Scopus database. After the inclusion and exclusion criteria, 59 articles are included in the Scopus database and included in the systematic review. From this SLR, we

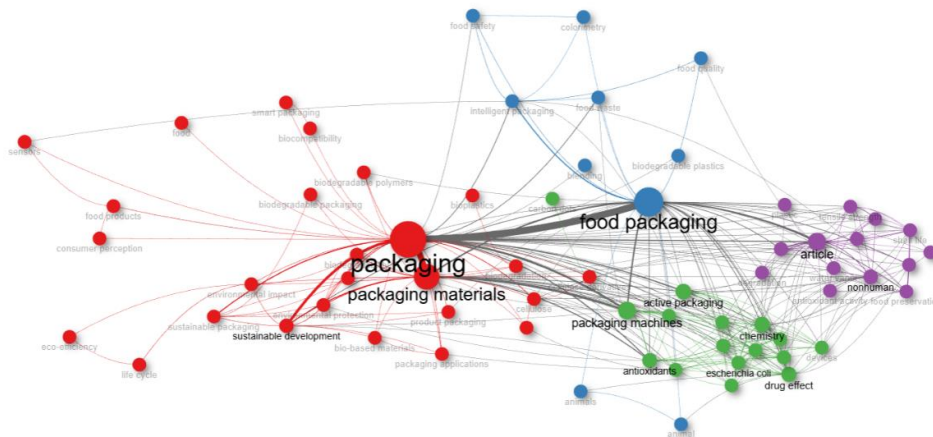


Fig 4. Keyword co-occurrence network

Green cluster represents research on active packaging, particularly focusing on antimicrobial and antioxidant functions. Major keywords include active packaging, antioxidant, *Escherichia coli*, chemistry, drug effect, and devices. Research in the field combines bioactive compounds, nanoparticles, and natural extracts into packaging material to inhibit microbial growth and reduce the oxidative process. The use of microbiological indicators, such as *Escherichia coli*, is commonly employed to confirm antimicrobial effectiveness. Overall, this cluster shows the combined application of chemistry and food microbiology to enhance shelf life and food preservation.

Purple cluster focused on the mechanical and physicochemical characterization of packaging materials, and it includes tensile strength, shear, oxidation, plastic strength, food preservation, and nonhuman stand as major keywords. Analyzing tensile strength, barrier properties, oxidative stability, and degradation of the material during storage forms the core of this research. These studies set performance standards that help ensure the strength and safety of packaging materials. The findings support better mechanical material selection and enhanced design of the packaging system.

Tree Map

The treemap illustration displays how often author keywords appear, enabling the identification of the dominant and emerging research topics in the food packaging system. As shown in Fig 5. “Packaging” is the most common keyword, appearing 26 times (10%), followed by “food packaging” (18; 7%) and “packaging materials” (14; 5%), including a strong focus on packaging material and system. Keywords with moderate frequency, such as “intelligent packaging,” “sustainable development,” and “sustainable packaging” (each 9; 3%), reflect growing interest in smart and environmentally friendly solutions. Topics related to functionality and safety, including active packaging (7; 3%) and environmental impact (6; 2%),

show growing interest in safety and environmental evaluation. Keywords emerge with preservation and material properties, such as antioxidants, tensile strength, food preservation, and biodegradability, appearing around five times each (2%). Overall, the results suggest that food packaging mainly focuses on packaging materials, while interest in sustainable, smart, and active packaging technologies has extended.



Fig 5. Treemap

Three-field plot

The three-field plot map illustrates the relationship between keywords, authors, and countries showing research topics are distributed among contributors and regions. The key topics such as packaging, sustainable packaging, food safety and intelligent packaging are linked to leading authors highlighting broad friendly engagement is shown in the Fig 6. Countries including China, Malaysia, Italy, Brazil, and India are closely connected with these authors, highlighting their significant contributions to the field. The strong link connections between sustainability and safety related keywords, as well as between authors from Asian and European, reflect regional research priorities that align with environmental and food security concerns. Overall, the plot reveals that food packaging research is

internationally distributed, with a strong focus on sustainability and functional packaging systems.

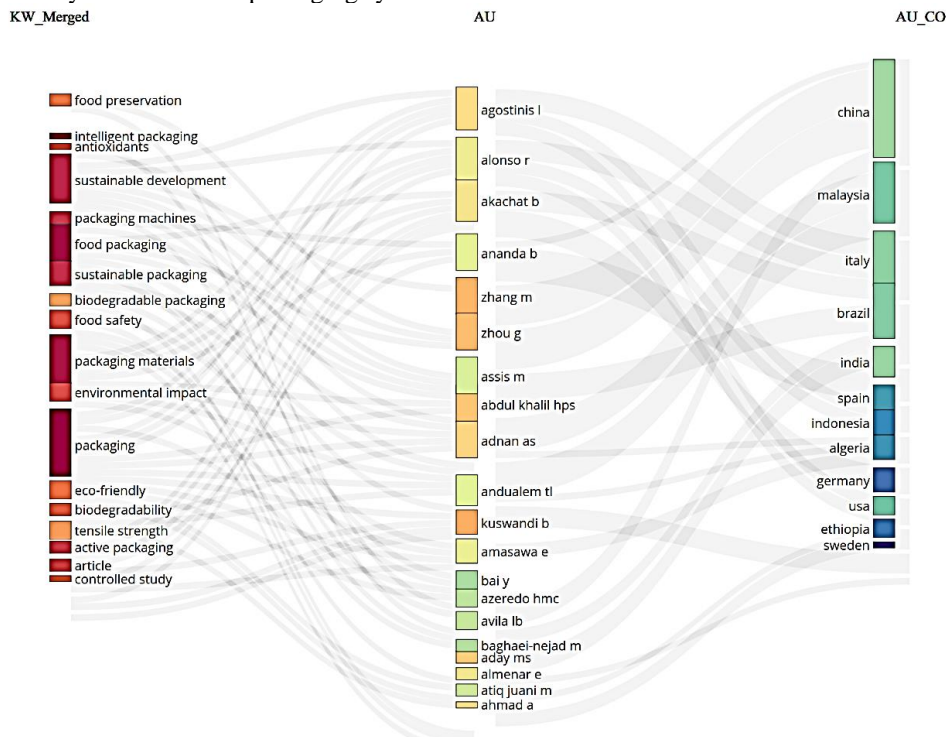


Fig 6. Three-field Plot

Consumer Perception and Attitudes toward Food Packaging

Packaging plays a significant role in shaping consumer perceptions of food quality and influencing purchasing decisions. Understanding consumer attitudes toward emerging packaging techniques is essential for businesses seeking to develop effective marketing strategies, design innovative products, and position them competitively [12]. Modern packaging, particularly when characterized by robust structural and graphical design, fosters consumer engagement, especially among environmentally conscious individuals. These consumers demonstrate heightened attention to sustainable packaging during shopping [13]. Packaging also affects post-purchase behavior; convenient features enhance satisfaction, while informative labelling supports appropriate product use [14,15]. Consumers with favourable perspectives towards protecting the environment are more likely to pay attention to sustainable packaging when making purchasing decisions [16–18]. Preserving food quality through mechanisms such as smart packaging is critical for influencing purchase intentions [19]. Globally, food industries are increasingly implementing proactive environmental initiatives, largely in response to consumer demand [20]. Nevertheless, consumers frequently encounter challenges in identifying eco-friendly packaging, possess limited knowledge of novel materials, and often prioritize price and quality over sustainability. Therefore, consumer education and the

provision of credible environmental information regarding packaging are necessary to foster positive attitudes. When ecological benefits are clearly communicated, positive consumer perceptions increase, whereas ambiguous benefits tend to elicit skepticism [21]. Expanding the availability of sustainable packaging options can mitigate negative perceptions and reinforce favourable ones. Furthermore, consumers generally prefer eco-friendly packaging designs, such as tray packaging for daily convenience, and women tend to exhibit greater concern for environmentally friendly packaging than men [22].

Sustainable Packaging Materials and Strategies

Sustainable packaging methods encompass management and handling activities designed to reduce the environmental impact of packaging materials, product waste, and logistics operations. The primary objective is to enhance the sustainability of packaging. Sustainable packaging materials typically require fewer virgin resources and are composed of recyclable or reusable components [23]. Although some authors contend that achieving sustainability presents significant challenges, they maintain that it is attainable through dedicated effort and innovative approaches [24]. Implementing sustainable packaging can enhance brand reputation and attract environmentally conscious consumers [25]. Additionally, it may lower costs by utilizing more efficient materials and logistics processes. Research indicates that consumers generally accept sustainable materials provided this preserve product quality and extend shelf life. Furthermore,

consumers are receptive to eco-sustainable consumption and may be willing to pay a premium for the advantages offered by innovative packaging [26]. Some of the sustainable packaging materials are bioplastics, wood and plant fibres, mushroom packaging, corrugated cardboard and paper, bamboo, recycled plastics, edible films etc. These packaging materials are discussed below,

Bioplastics are produced from renewable biomass resources, including plant fats and oils, maize starch, woodchips, sawdust, and straw derived from food waste and other organic substances [26]. These materials are processed into various packaging products, such as bags, wraps, and containers, commonly used for fresh food items, including baked goods, fruits, and vegetables. Wood and plant fibres are biodegradable fibre-based packaging materials derived from cellulose and other plant fibres [26]. These fibres are utilised in the production of paper and cardboard boxes for snack products, moulded pulp containers for eggs, compostable trays and plates for ready-to-eat foods, and wrapping materials for sandwiches. Mushroom packaging, a biodegradable and compostable material, is produced from mycelium, the root-like structure of mushroom [27]. This material is applied in the packaging of baked products, meat, and seafood. Corrugated cardboard and paper are made from recycled materials, offering robust, durable options for shipping and packaging. While traditionally used for dry foods, their applications have recently expanded to include fatty and wet food products.

Bamboo is a sustainable, renewable raw material with the potential to replace plastic in packaging applications [28]. Bamboo-based materials are commonly used in restaurants, cafes, food stalls, and food trucks, serving as takeout containers, plates, bowls, and trays for both hot and cold beverages and baked goods. Additionally, bamboo products offer the benefit of reusability for dining purposes [29]. Recycled plastic, derived from post-consumer and post-industrial waste, is also used to produce new packaging, including bottles, trays, wraps, tubs, and jars for sauces, yoghurts, dips, spreads, and ready-to-eat meals. Edible packaging encompasses films, coatings, and containers made from seaweed, plant-based fibres, and food starches, used for packaging candies, desserts, fruits, and vegetables [30]. Furthermore, biopolymer films represent innovative, environmentally friendly, and sustainable materials designed to cover or wrap food products, thereby extending shelf life and providing protection [26].

Intelligent Packaging Technologies for Food Quality and Safety

Intelligent packaging represents a significant advancement in protecting and managing food products. Intelligent packaging is designed to extend shelf life, enhance safety, and preserve food quality. Technologies utilized in this context include barcodes, sensors, freshness indicators, and other advanced interactive

functional solutions [31]. Intelligent packaging systems monitor external variables that influence food quality [32]. Nowadays, there are different types of intelligent packaging materials are widely used in most of the countries such as sensors, indicators and data carriers [33,34]. The classification of smart packaging technologies including sensors, indicators, and data carriers with their functions in monitoring food quality, safety and storage conditions were explained in Fig 7. Sensors is used to monitor food quality and safety by detecting physiological changes from microbial and chemical deterioration during storage and transportation. Indicators use colorimetric or fluorescent dyes to inform customers about food quality by detecting the presence, interaction, or concentration of substances. Data carriers store and transfer product information to manage the supply chain, ensuring traceability, automatization, theft prevention, and counterfeit protection [35].

Active Packaging Systems for Food Preservation

Active packaging goes beyond simply containing food by interacting with both the product and environment to improve freshness and safety. These systems use special agents that absorb or release substances such as oxygen, moisture or antibacterial compounds [36]. Examples include packaging films containing antioxidants, antimicrobial agents, or moisture regulators that release protective substances inside the package. As a result, active packaging inhibits microbial growth, delays spoilage, and reduces contamination, thereby maintaining the quality and safety of food products. Modified atmosphere packaging (MAP) operates by changing the gas composition within the package through the balance between the film's gas permeability and the product's respiration. This approach reduces unwanted physiological, biochemical, and physical changes in food products [36]. It limits the microbial growth and mitigates product contamination. Active packaging, such as oxygen absorbers or moisture control packets, interacts with the environment in order to enhance shelf life or improve food safety.

Functional and Nano Packaging

Functional packaging represents a rapidly expanding sector that increases product value and influences consumer purchasing decisions at the point of sale by providing enhanced usability, convenience, and sustainability. Common examples include flexible pouches and stick packs, which frequently incorporate pressure-sensitive closures. The following section outlines several important functional and nano packaging materials. Microwaveable containers are packaging materials that can be safely used in microwave ovens for heating food [37]. Nanomaterials used in food packaging exhibit distinctive and captivating properties, including enhanced antibacterial activity, thermal conductivity, and catalytic activity

[38]. Functional nanoparticles have been produced for food nano-packaging, which increase the release of antioxidants, antimicrobials, flavours, enzymes, and nutraceuticals, enhancing shelf life and food quality [39]. Nanocomposite technology has been shown to enhance the material properties of both biopolymers and

synthetic thermoplastics. Bio-nanocomposite films enhance sustainability and provide improved capabilities by combining nanotechnology with intelligent functional features [40]. Nano-sensors and nanodevices are made to detect freshness and track changes in packaging integrity [41].

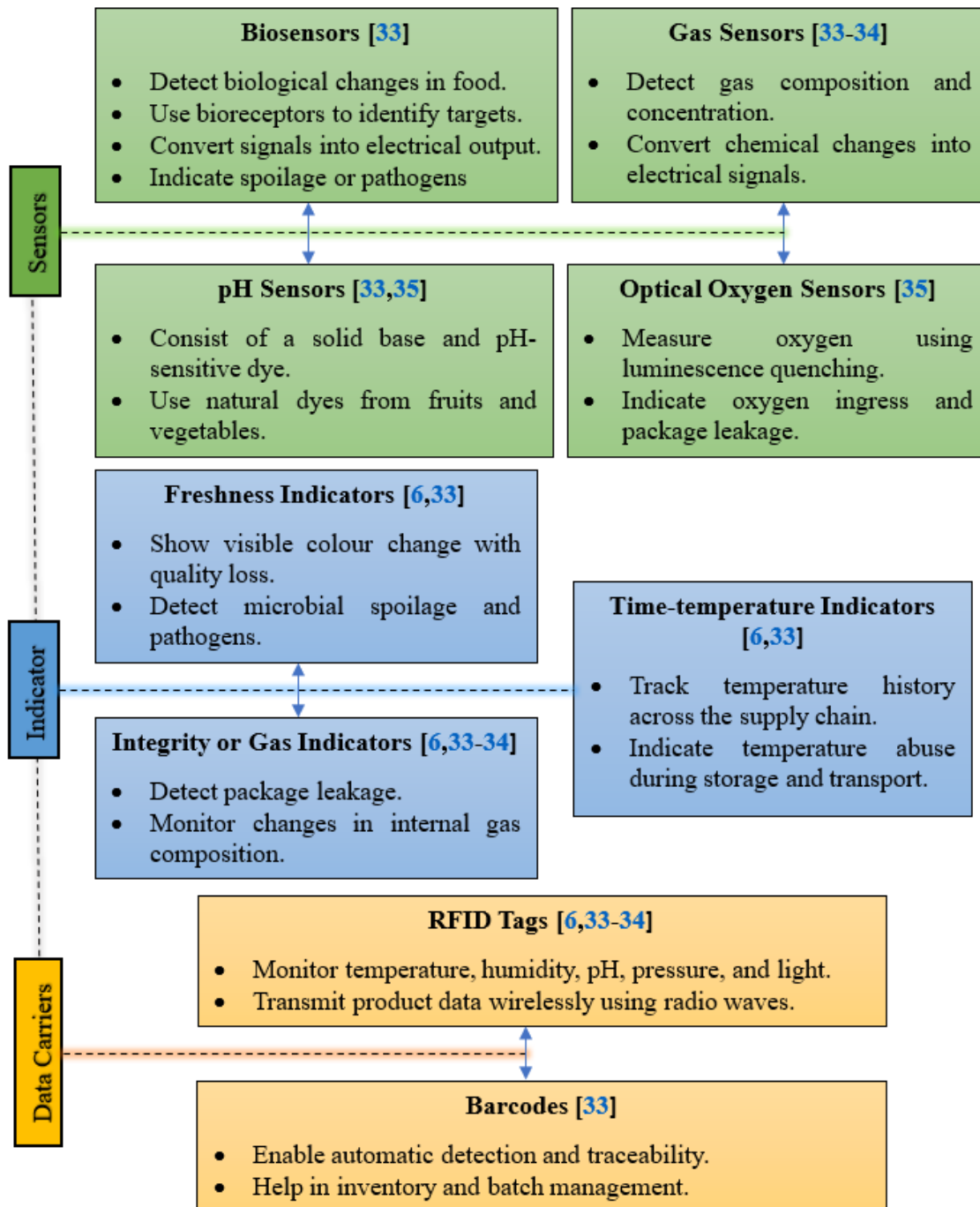


Fig. 7. Overview of smart packaging elements such as sensors, indicators, and data carriers used to monitor food quality and safety

Recent Innovative Packaging Materials

Evolving lifestyles and the increasing demand for convenient, shelf-stable foods have prompted the development of advanced packaging technologies that prioritize consumer health and food security. Food quality and safety are often evaluated by consumers based on visual appearance and packaging. Recent

innovations in food packaging provide access to critical information, including raw material sources, manufacturing processes, and shelf life, thereby enhancing product safety and consumer trust. In the Table 1, recent innovative packaging materials are described.

Table 1- Novel food packaging materials developed by different authors

	Material	Material Type	Function	Key Property	Sustainability contribution	Application	Main Advantage	Ref.
1	Metallyte 28UBW-ES	Multilayer polymer film	Sustainable & Functional	High seal strength, contamination resistance	Not biodegradable	General food products	Improved package integrity	[42]
2	Carrageenan film with jaboticaba additive	Biopolymer composite	Active & Intelligent	Antioxidant, colour response	Biodegradable, bio-based	Fresh foods	Spoilage indication	[43]
3	Smart packaging systems	Hybrid packaging system	Active + Intelligent	Monitoring & protection	Depends on materials used	Wide range of foods	Real-time quality monitoring	[44]
4	PBAT, PHA, PLA, PVAc blends	Biodegradable polymers	Sustainable packaging	Comparable barrier to plastics	Bio-based, biodegradable	General food packaging	Plastic replacement	[13]
5	Banana plant waste packaging	Waste-derived biopolymer	Sustainable packaging	Biodegradability	Waste valorisation, renewable	General foods	Sustainable raw material	[3]
6	Anthocyanin/curcumin/PVA films	Natural additive biopolymer films	Intelligent packaging	pH-sensitive colour change	Biodegradable, bio-based	Meat, fish, perishables	Visual freshness indicator	[35]
7	Modified Atmosphere Packaging (MAP)	Gas-control technology	Active packaging	Oxygen and CO ₂ regulation	Reduces food waste	Meat, fruits, bakery	Delayed spoilage	[45, 46]
8	Edible/biodegradable coatings	Natural polymer films	Sustainable packaging	Moisture and oxygen barrier	Fully biodegradable, edible	Fruits, confectionery	Eliminates plastic waste	[11]
9	Plant-based & whey-based packaging	Agro-industrial waste polymers	Sustainable packaging	Film-forming ability	Renewable, waste-based	Dairy and dry foods	Circular economy approach	[13]
10	Virgin pulp packaging	Cellulosic material	Sustainable packaging	Strength and printability	Renewable resource	Boxes, cartons	High-quality paper packaging	[28]
11	Anthocyanin indicator labels	Pigment-polymer composite	Intelligent packaging	pH-responsive colour shift	Bio-based	Meat and seafood	Rapid freshness detection	[47]
12	Chitin nanofiber + anthocyanin films	Bio-nanocomposites	Active & Intelligent packaging	Antibacterial, antioxidant, colour response	Biodegradable	Meat products	Multi-functional freshness monitoring	[40]
13	Cellulose nanofibers	Natural nanomaterial	Sustainable, Active and Functional	High strength, renewability	Renewable, biodegradable	Films and coatings	Mechanical improvement	[48]
14	Nano-bio composites	Polymer-nanoparticle blends	Active packaging	Antimicrobial, barrier	Reduced plastic usage	Various foods	Enhanced shelf life	[49]
15	Aseptic packaging	Sterile processing system	Functional packaging	Microbial elimination	Reduces preservatives	Liquid foods	Long shelf life	[5]
16	Vacuum packaging	Air-removal technology	Functional packaging	Oxygen elimination	Reduces food waste	Meat, cheese	Slows oxidation	[5]
17	Carbon dot-based films	Fluorescent nanocomposites	Intelligent packaging	Spoilage sensing, anti-counterfeiting	Low material usage	Meat and dairy	Quality monitoring & security	[50]

Completion Table 1- Novel food packaging materials developed by different authors

18	Corn husk MCC-carrageenan films	Waste-derived biopolymer	Sustainable packaging	Improved strength and stability	Agricultural waste valorisation	Dry and semi-moist foods	Strong biodegradable films	[51]
19	Active zein films	Protein-based biopolymer	Active packaging	Antioxidant release	Bio-based, biodegradable	Snacks, cereals	Natural preservation	[52]
20	Chili pomace chitosan-CNF films	Bio-nanocomposites	Active packaging	Antioxidant, antimicrobial, UV blocking	Food waste utilization	Perishables	Extended freshness	[53]
21	Lignin-loaded gelatin nanofibers	Biopolymer nanofibers	Active packaging	Antimicrobial, antioxidant	Bio-based additives	Meat and seafood	Multifunctional protection	[54]
22	Cassava starch + green ZnO films	Biopolymer nanocomposites	Active packaging	Antimicrobial	Renewable, green synthesis	Perishable foods	Shelf-life extension	[55]
23	Essential oil rice starch films	Biopolymer active films	Active packaging	Antimicrobial vapor release	Renewable materials	Fried foods	Flavour and microbial control	[56]
24	Spirulina biopolymer films	Algae-based composites	Active packaging	Antioxidant, light protection	Renewable biomass	Light-sensitive foods	Oxidation prevention	[57]
25	Biomimetic multilayer films	Advanced composite films	Sustainable & Functional packaging	High gas and water resistance	Reduced material usage	Broad food products	Food waste reduction	[58]
26	Avocado seed starch + enset cellulose films	Waste-reinforced bioplastics	Sustainable packaging	UV blocking, strength	Agro-waste utilization	Light-sensitive foods	Plastic alternative	[59]
27	Chitosan + plant protein films	Biopolymer composites	Active packaging	Antimicrobial	Fully biodegradable	Fruits and fresh produce	Post-harvest protection	[60]
28	Banana peel bioplastics	Waste-based biopolymers	Sustainable packaging	Antibacterial	Food waste valorisation	General packaging	Low-cost sustainability	[61]
29	Chitosan + carbon dot films	Intelligent nanocomposites	Intelligent packaging	Fluorescent pH sensing	Biodegradable	Milk and dairy	Spoilage detection	[62]

The materials reviewed highlight a clear shift toward bio-based, biodegradable, and multifunctional food packaging, with a focus on waste-derived polymers, natural additives, and nanocomposites. Several innovations focusing on active packaging functions such as antibacterial and antioxidant efficiency, to extend the shelf life and enhance the food safety concern. Intelligent packaging has emerging towards natural pigments and carbon dots for real time monitoring freshness. The additive of agricultural and food processing wastes such as banana peel and corn husk establishes a commitment to circular economy principles. Biomimetic multilayer films and advanced barrier designs enhance the mechanical properties and gas resistance of biopolymers. Overall, sustainability, enhanced functionality, and smart monitoring are the leading trends in next-generation food packaging research.

Benefits of Adopting Innovative Food Packaging Materials

Implementing advanced packaging approaches such as active, intelligent and smart packaging improves the interaction between the food and its environment while supporting consumer health [16]. The adoption of biodegradable and edible packaging in the food sector

contributes to multiple UN Sustainable Development Goals, including Responsible Consumption and Production (Goal 12), Climate Action (Goal 13), Sustainable Cities and Communities (Goal 11), Life Below Water (Goal 14), and Life on Land (Goal 15). These practices help to reduce waste, reduce greenhouse gas emissions, protect ecosystem from plastic pollution. Moreover, the environmental benefits, sustainable packaging enables economic advantages for companies by low cost, sales boosting, enhancing operational efficiency and strengthening brand image. Although it improves the consumer experience, ensures regulatory compliance and meets consumer expectations regarding materials and production methods [63]. Clear labelling on eco-friendly packaging can positively influence purchasing decisions by communicating environmental benefits [2]. There is increasing demand from consumers, businesses, and food processors for innovative smart packaging that ensures quality, safety and product traceability. Furthermore, nanotechnology is being increasingly applied to enhance packaging functions, including food safety, preservation, marketing and consumer engagement [64].

Barriers to Adopting Innovative Food Packaging Materials

Adopting sustainable packaging possesses several challenges for food companies. Internally, firms often face financial constraints, lack of motivation, and difficulties in communicating the benefits of innovative packaging materials to consumers which slows market acceptance and adoption. Externally, companies may encounter limited incentives such as financial support or regulatory measures to invest in new eco-friendly material [15]. Fabricating and managing environmentally friendly packaging is specifically challenging in the food industry, where packaging is need for product protection, handling and transportation. Striking a balance between these functional requirements and environmental recognition such as the use of biodegradable or recyclable materials, remains a significant obstacle [65]. Additionally, the food traceability system pressures because of their common safety incidents, which undermine consumer trust, cause economic loss and place demands on regulatory authorities [66]. Barriers to adopting sustainable packaging often involving trade-off between economical goals and practical needs, including marketing, visibility and handling. While company focus to reduce environmental impacts they must also ensure packaging meets functional and commercial needs making the transition to sustainable alternatives a complex challenge for the industry.

Conclusion

In summary, the shift towards eco-friendly packaging is driven by environmental awareness and consumer demand for sustainable products. Alternative material such as edible films, bioplastics, and nanocomposites enables practical solutions to replace traditional plastics and conserve resources. However,

challenges like high cost, regulatory hurdles and limited consumer acceptance remain limited. To overcome these challenges the requirement of collaborative research, supportive policies, and educating consumers about the benefits of sustainable packaging. The use of advancing technologies including intelligent packaging and functional nanomaterials can further enhance both performance and environmentally friendly. Adjusting economic incentives with environmental goals will enable stakeholders to create a strong and sustainable food packaging sector that supports global sustainability targets.

Limitations and Future research directions

This review only involves peer-reviewed articles in English-language from the Scopus database, so studies published in other languages or databases may have been excluded. Additionally, differences in experimental conditions and testing methods also make it hard to directly compare the performance of material. Future work should develop common testing protocols, evaluate large-scale industrial scale, and assess the long-term safety and migration risk of nano-enabled packaging materials. Studies that include life cycle assessment, consumer education strategies, and supportive policies will be important for increasing the use of sustainable food packaging.

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