Technological Evolution and Innovation Trends in Biodegradable and Compostable Packaging: A Patent Landscape Analysis Based on Simple Patent Families

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***Abstract*– The increasing generation of plastic waste has driven the development of biodegradable and compostable packaging; however, its inventive evolution and technological configuration still require an integrated characterization. This study analyzed the technological evolution and innovation trends in this field through a patent landscape analysis. The search was conducted in Lens.org using terms related to biodegradable and compostable packaging and the CPC filter Y02W90/10. Of the 2,956 records retrieved, 1,757 simple patent families were selected to avoid duplication. Temporal evolution, protection jurisdictions, leading applicants, and CPC domains were examined; additionally, a term co-occurrence network was constructed using VOSviewer. The results revealed accelerated growth between 2016 and 2023, with China as the leading jurisdiction and low individual shares among the leading applicants. The predominant domains encompassed biodegradable materials, polymer films, formulations, and multilayer structures. The conceptual structure revealed three clusters related to biodegradability and polyesters, polysaccharides and plasticizers, and coatings and barrier properties. Overall, innovation is evolving toward more complex functional systems whose environmental contribution will depend on their design, certification, and compatibility with waste treatment infrastructure.**

***Keywords*– Biodegradable Packaging, Compostable Packaging, Patentometrics, Patent Families, Technology Intelligence.**

I. Introduction

The production and consumption of plastics have increased because of their versatility, durability, low weight, processability, and relatively low cost [1]. In 2019, global plastic use reached 460 million tonnes, while plastic waste generation amounted to 353 million tonnes. Of this volume, only 9% was effectively recycled, 19% was incinerated, approximately 50% was disposed of in landfills, and 22% was inadequately managed [1]. Furthermore, between 19 and 23 million tonnes of plastic waste entered aquatic ecosystems in 2016 [2]. This accumulation represents a systemic pressure whose rate of increase exceeds the global capacity to assess, monitor, and control its risks [3]. Without additional policies, plastic use and waste could nearly triple by 2060, highlighting the inadequacy of current mitigation commitments [2], [4].

Within this context, packaging is a priority concern because of its high demand and short service life, accounting for approximately 40% of global plastic waste [1]. However, packaging performs essential containment, protection, preservation, and transportation functions; therefore, its substitution cannot be assessed solely based on the amount of material used [5]. In food applications, packaging protects products against physical damage, microorganisms, oxygen, and moisture while extending shelf life and reducing food losses [6]. Consequently, alternative materials must retain adequate mechanical, thermal, sealing, and barrier properties [7]. Moreover, the transition toward circularity requires a combination of reduction, reuse, substitution, recycling, and controlled waste management, since no single intervention can eliminate plastic pollution [8], [9].

In this context, biodegradable and compostable packaging has gained relevance as an alternative for certain short-lived applications, although it does not constitute a universal solution to waste generation or inadequate waste management [10]. Its assessment requires a distinction among the concepts of biobased, biodegradable, and compostable. A biobased plastic is manufactured wholly or partly from biological resources, but its renewable origin does not guarantee biodegradability [11]. Biodegradability depends on the polymer structure and on conditions such as temperature, moisture, oxygen availability, and microbial activity [12]. Compostability further requires defined levels of biodegradation and disintegration, the absence of ecotoxic effects, and compliance with conditions established by standards or certification schemes [13]. Therefore, some biobased plastics are non-biodegradable, whereas some biodegradable polymers are derived wholly or partly from fossil resources [11], [12].

Industrial interest in these technologies has increased alongside the development of new polymers, blends, films, coatings, and multilayer structures. Global bioplastics production capacity was estimated at 2.47 million tonnes in 2024 and was projected to reach 5.73 million tonnes by 2029, although these figures refer to installed or planned capacity and not necessarily to actual production [14]. Packaging accounted for approximately 45% of this capacity in 2024, making it the leading application segment [14]. However, these figures include both non-biodegradable biobased polymers and biodegradable materials and should not be attributed entirely to compostable packaging [12]. The expansion of the sector is driven by regulation, corporate demand, the search for renewable raw materials, and the need for alternatives for short-lived products [15].

The main technological pathways include biodegradable polyesters such as polylactic acid (PLA), polyhydroxyalkanoates (PHAs), and poly(butylene adipate-co-terephthalate) (PBAT), as well as materials based on starch, cellulose, chitosan, and proteins [7]. Although these materials offer potential advantages, they may exhibit brittleness, moisture sensitivity, low thermal resistance, or insufficient barrier properties [7], [15]. In response, innovation has focused on polymer blends, plasticizers, reinforcing agents, coatings, and multilayer structures capable of combining structural support, sealability, and protection against oxygen, water vapor, and fats [5], [16]. These architectures improve performance; however, incorporating different polymers, adhesives, and layers may also hinder the recycling, separation, or composting of the complete package [16].

Biodegradability does not automatically guarantee a lower environmental impact, because performance depends on raw materials, the production process, the application, the required durability, and post-consumer management [10]. Compostable materials require separate collection and facilities capable of maintaining controlled conditions, but such infrastructure remains insufficient in many countries [10], [11]. Without these conditions, degradation may be slow or incomplete [13]. Barriers related to cost, scalability, stability, safety, migration, and compatibility with industrial equipment also remain [6], [15]. These challenges are compounded by consumers' limited understanding of the differences among biobased, biodegradable, and compostable materials and of the appropriate disposal pathways [6].

The literature has extensively examined biodegradable packaging materials, their properties, processing methods, and applications, particularly in food preservation [5], [7]. Likewise, bibliometric studies have identified scientific trends associated with biopolymers, coatings, films, and the valorization of agricultural waste [17]. However, scientific publications primarily reflect the generation and dissemination of academic knowledge, whereas patents provide information on protected inventions, rights holders, and technology protection strategies [18], [19]. Consequently, analyses based exclusively on scientific publications cannot comprehensively characterize inventive activity, protection jurisdictions, leading applicants, or protected technological domains [20]. Within the literature reviewed for this study, patent-based analyses specifically addressing biodegradable and compostable packaging remain limited, and no study was identified that jointly examines its temporal evolution, jurisdictions of protection, leading applicants, CPC domains, and conceptual structure using simple patent families.

Patent documents contain data on priority dates, applicants, jurisdictions, classifications, and technical content, enabling the identification of technological trajectories, relevant actors, and concentrations of inventive activity [19], [20]. Patent landscapes integrate these indicators with technological classifications and conceptual networks to support technology monitoring and intelligence [21]. However, a single invention may generate several patent publications across different jurisdictions; therefore, the use of patent families reduces double counting and provides a more consistent unit of analysis [19]. Accordingly, this study aims to analyze the technological evolution and innovation trends in biodegradable and compostable packaging through a patent landscape based on simple patent families. Its contribution lies in integrating temporal, geographical, organizational, classificatory, and conceptual dimensions within a single analytical framework. To this end, temporal evolution, jurisdictions of protection, leading applicants, CPC domains, and the conceptual structure derived from a term co-occurrence network are examined.

II. Methodology

A. Research Design

This study adopted a quantitative, descriptive, and exploratory approach based on patentometric and technology intelligence methods. The patentometric analysis characterized the temporal evolution of inventive activity, protection jurisdictions, leading applicants, and technological domains defined through the Cooperative Patent Classification (CPC). In addition, the technology intelligence analysis examined the conceptual structure of the field through co-occurrence relationships among terms found in patent titles and abstracts.

Patent documents contain structured information on inventions, rights holders, priority dates, jurisdictions, and technical fields, enabling the identification of emerging technologies, active organizations, and concentrations of inventive activity [19]. Patent landscapes also provide evidence to support research, investment, and technology transfer decisions [21].

The procedure comprised six stages: selection of the information source, record retrieval, consolidation into simple patent families, data cleaning and preprocessing, patentometric analysis, and technology intelligence analysis. Fig. 1 presents the methodological workflow.

B. Information Source and Patent Retrieval

The information was retrieved from Lens.org, a platform that integrates patent data from different authorities and provides access to the bibliographic and textual fields of patent documents. The search was conducted on July 14, 2026, in the title, abstract, and claims fields, without temporal restrictions, using the following search equation:

Title: ((compostable OR biodegradable) AND packaging) OR abstract: ((compostable OR biodegradable) AND packaging) OR claim: ((compostable OR biodegradable) AND packaging)

The initial search strategy retrieved 10,508 records related to biodegradable or compostable packaging. Subsequently, the CPC filter Y02W90/10, corresponding to biopackaging technologies, including packaging manufactured from renewable resources or bioplastics, was applied. This criterion reduced the dataset to 2,956 records.

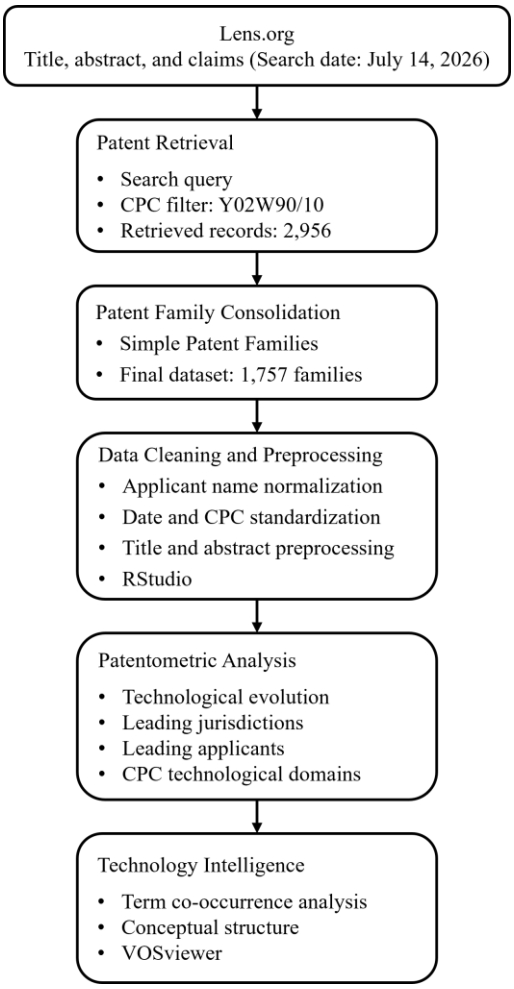


Fig. 1 Workflow of the patentometric and technology intelligence methodology.

The text-based search identified documents containing expressions directly related to biodegradable or compostable packaging, whereas the CPC filter restricted the results to the technological domain of biopackaging. The combination of both criteria was adopted to prioritize thematic precision and reduce the inclusion of documents in which the terms appeared incidentally or outside the field under study. However, this delimitation may exclude relevant inventions classified exclusively under other packaging- or polymer-related CPC codes without an assigned Y02W90/10 code. Accordingly, the resulting dataset represents a technologically delimited patent landscape based on the defined search criteria rather than an exhaustive representation of all inventions potentially related to biodegradable and compostable packaging.

C. Consolidation into Simple Patent Families

A single invention may generate multiple applications or publications when protection is sought in different jurisdictions; therefore, analyzing individual documents may result in duplication. To control for this effect, the simple patent family was adopted as the unit of analysis.

Patent families group related documents according to their priority data and provide a consolidated representation of the same invention protected through multiple publications. This procedure reduces double counting and makes the indicators more closely reflect the number of distinct technological developments [19], [21]. Family consolidation was performed using the simple patent family grouping provided by Lens.org, according to which documents sharing the same set of priorities belong to the same family. Therefore, the reduction from 2,956 patent records to 1,757 simple patent families resulted from family-level consolidation rather than from the manual exclusion of duplicate documents. The 1,757 simple patent families constituted the final unit of analysis and the final corpus.

D. Data Cleaning and Preprocessing

The records corresponding to the 1,757 simple patent families were exported from Lens.org in CSV format. The exported fields included titles, abstracts, applicants, priority dates and years, jurisdictions, and CPC codes. All families contained the information required for the analyses; therefore, no records were excluded because of missing data. The dataset was processed in RStudio to review and standardize the exported fields. For the conceptual analysis, the titles and abstracts were restructured in RStudio into a format compatible with VOSviewer.

Spelling variants, abbreviations, punctuation differences, and applicants' legal designations were consolidated under standardized names to prevent a single organization from being counted as different entities. CPC codes were disaggregated and organized according to their hierarchical structure to identify the predominant technological subgroups.

For the temporal analysis, the earliest priority year of each family was used as a proxy for the emergence of the invention. For the geographical analysis, the jurisdictions in which each family contained protection documents were considered; therefore, this indicator represents territories of protection and not necessarily countries of origin.

Titles and abstracts were preprocessed using a thesaurus file. This file made it possible to merge synonyms, singular and plural forms, abbreviations, and spelling variants, as well as to exclude general terms derived from conventional patent language that did not provide distinctive technological information.

E. Patentometric Analysis

The patentometric analysis comprised four dimensions: technological evolution, leading jurisdictions, leading applicants, and technological domains according to the CPC. Technological evolution was examined through the annual distribution of simple patent families according to their earliest priority year. The stages were delineated interpretively through visual examination of changes in the annual trajectory. No formal change-point or growth-rate analysis was performed; therefore, these stages were used as descriptive periods rather than statistically identified phases.

Jurisdictions were analyzed by counting the families associated with each territory of protection. Because a family may contain documents from several jurisdictions, the categories were not mutually exclusive and were interpreted as indicators of interest in securing protection in specific markets.

Leading applicants were determined according to the number of families associated with each rights holder after their names had been normalized. This analysis identified the companies, universities, research centers, and other organizations with the highest levels of patenting activity.

Technological domains were identified through the frequency of the CPC codes assigned to the families. This classification organizes technologies into standardized hierarchical units and enables the identification of the technical fields associated with inventions [21]. Because a family may contain multiple codes, the counting was non-exclusive, and the sum of the frequencies may exceed the total corpus. The interpretation focused on the most frequent classifications related to the materials, structures, properties, processes, and applications of biodegradable and compostable packaging.

F. Technology Intelligence Analysis

The conceptual structure was examined through a term co-occurrence analysis conducted in VOSviewer using the representative titles and abstracts of the simple patent families. Binary counting was applied; therefore, each term was counted only once per document, regardless of its frequency within that document.

A minimum threshold of 40 occurrences was established to retain recurrent terms while maintaining the interpretability of the network. During preprocessing, a lower threshold of 35 occurrences was initially evaluated; however, it produced a denser network containing a larger number of generic or weakly informative terms. Therefore, the threshold of 40 occurrences was selected to reduce terminological noise without restricting the analysis to only the most frequent concepts. A total of 55 terms met this criterion, of which VOSviewer selected 33 for network construction. After applying the thesaurus to merge equivalent expressions and remove generic terms or terms lacking specific technological meaning, the final network comprised 23 terms organized into three clusters.

In the network, node size represents term frequency, and links indicate co-occurrence relationships. Proximity indicates a stronger association, whereas colors identify clusters of terms exhibiting related patterns. These clusters were interpreted as the main conceptual cores of the technological field [22].

III. Results

A. Technological Evolution

For descriptive interpretation, the annual evolution of the 1,757 simple patent families was divided into four stages: emergence, initial development, consolidation, and rapid expansion. As shown in Fig. 2, the first families appeared in the late 1960s, although activity remained at minimal levels for approximately two decades.

The emergence stage, corresponding to 1968–1989, exhibited incipient and discontinuous activity. The initial development stage, between 1990 and 2000, recorded the first visible increase in the annual number of families, followed by fluctuations and a gradual recovery toward the end of the period.

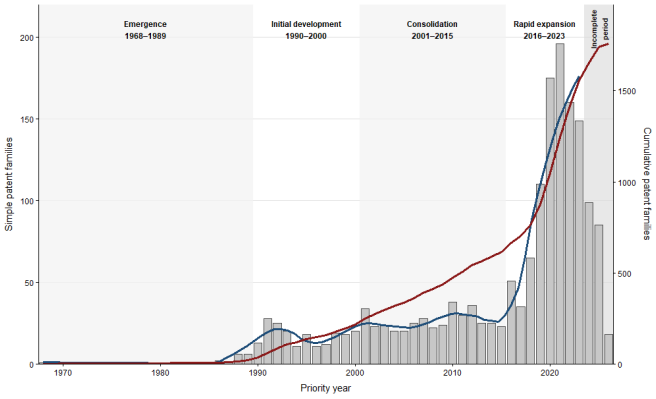


Fig. 2 Technological evolution of simple patent families by priority year.

The interpretative consolidation stage covered the period from 2001 to 2015, during which activity remained above the initial levels and the cumulative trajectory continued to increase. The rapid expansion stage, corresponding to 2016–2023, exhibited the most pronounced increase in the series. The annual number of families increased particularly from 2018 onward and peaked around 2021. The cumulative curve shows that a considerable proportion of the corpus was concentrated in recent years.

Patent applications are generally published approximately 18 months after the priority date [19]. Consequently, the 2024–2026 period was considered incomplete because some applications from these years may not yet have been published or incorporated into the database at the time of retrieval. To reduce the effect of this temporal truncation, 2023 was treated as the latest complete year for interpreting the technological trajectory. Therefore, the apparent decline after 2023 cannot be interpreted as a contraction in inventive activity.

B. Distribution by Jurisdiction and Leading Applicants

Fig. 3 shows that the families were concentrated in a limited number of jurisdictions. China ranked first with 786 simple patent families, followed by the United States with 261 and Japan with 196. International applications published through the World Intellectual Property Organization (WO) accounted for 149 families, whereas the European Patent Office (EP) recorded 99.

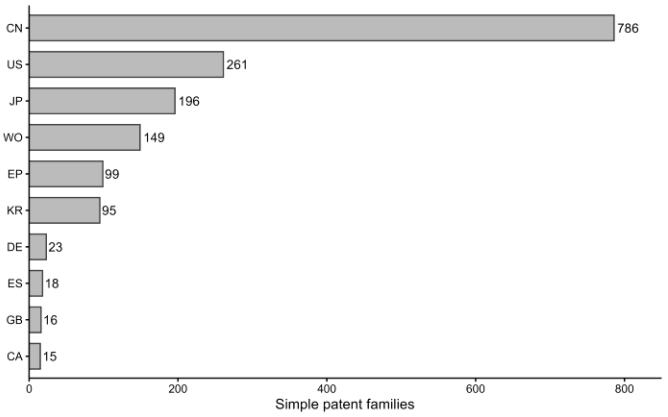


Fig. 3 Leading jurisdictions by number of simple patent families.

China recorded approximately three times the number of families reported for the United States and four times the number reported for Japan. The Republic of Korea ranked sixth with 95 families. The remaining jurisdictions exhibited considerably lower values: Germany recorded 23 families; Spain, 18; the United Kingdom, 16; and Canada, 15.

A patent family may contain documents filed in more than one jurisdiction. Therefore, the categories are not mutually exclusive, and the sum of their frequencies does not necessarily correspond to the total of 1,757 families. The values represent the territories in which protection was sought rather than the countries of origin of the inventions.

Fig. 4 presents the leading applicants. Toppan Printing Co. Ltd. ranked first with 22 simple patent families, followed by Xiamen Changsu Industrial Co. Ltd. with 15. Nestlé S.A. and Huhtamaki Molded Fiber Technology B.V. shared third place, with 11 families each.

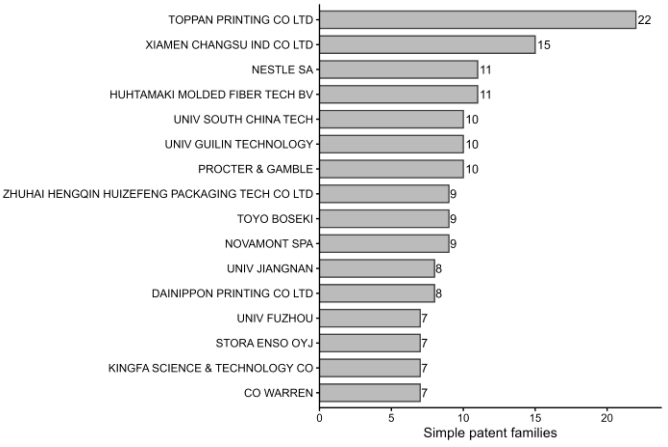


Fig. 4 Leading applicants by number of simple patent families.

South China University of Technology, Guilin University of Technology, and Procter & Gamble recorded 10 families each. Zhuhai Hengqin Huizefeng Packaging Technology, Toyobo, and Novamont reported nine families, whereas Jiangnan University and Dainippon Printing each accounted for eight. Fuzhou University, Stora Enso, Kingfa Science & Technology, and Warren recorded seven families each.

The leading applicant represented approximately 1.3% of the corpus, whereas the 16 applicants included in the figure collectively accounted for approximately 9.1%. These low shares indicate that patenting activity among the leading applicants was distributed across industrial companies, universities, packaging manufacturers, food and consumer goods companies, and organizations specializing in films, fibers, and polymeric materials.

C. Main Technological Domains According to the CPC

Table I presents the ten most frequent CPC codes after excluding Y02W90/10, which was used as a mandatory retrieval criterion and was present in every family within the corpus.

The most frequent code was B65D65/466, identified in 553 families, equivalent to 31.5% of the corpus. This code corresponds to biodegradable or photodegradable packaging materials. C08J5/18 ranked second and was related to the manufacture of polymeric films or sheets; it was present in 265 families, equivalent to 15.1%.

The Y02A40/90 code appeared in 226 families, equivalent to 12.9%, and encompasses climate change adaptation technologies related to agriculture, livestock, and the agri-food industries. B32B2307/7163, corresponding to layered products characterized by biodegradable properties, was identified in 199 families, equivalent to 11.3%.

Among the classifications related to layered products, B32B27/36, referring to synthetic resin layers characterized by polyesters, appeared in 182 families, whereas B32B27/08, associated with layers containing polyolefins, was present in 136. The B32B2439/70 code, specifically related to food packaging, was identified in 114 families, equivalent to 6.5% of the corpus.

The C08L2201/06 code, corresponding to biodegradable macromolecular compositions, appeared in 164 families. Likewise, C08J2367/04, associated with films or sheets involving polyesters derived from hydroxy acids, was present in 103 families. Finally, B65D65/40, related to the use of laminates in wrappers or flexible packaging materials, was identified in 101 families.

TABLE I.

MAIN TECHNOLOGICAL DOMAINS IDENTIFIED THROUGH CPC CODES

Rank	CPC	Patent families	Technological Interpretation
1	B65D65/466	553	Bio- or photodegradable packaging materials, representing the central application domain of the retrieved technologies.
2	C08J5/18	265	Manufacture of polymeric films or sheets, including processing routes applicable to biodegradable packaging materials.
3	Y02A40/90	226	Climate-change adaptation technologies related to agriculture, livestock and agro-food industries.
4	B32B2307/7163	199	Layered products characterized by biodegradable properties.
5	B32B27/36	182	Layered products comprising synthetic resins characterized by polyesters.
6	C08L2201/06	164	Macromolecular compositions characterized by biodegradable properties.
7	B32B27/08	136	Layered products comprising synthetic resins characterized by polyolefins.
8	B32B2439/70	114	Layered products specifically intended for food-packaging applications.
9	C08J2367/04	103	Film or sheet technologies involving polyesters derived from hydroxycarboxylic acids, including polylactic-acid-related materials.
10	B65D65/40	101	Applications of laminates as wrappers or flexible packaging materials.

CPC code Y02W90/10 was excluded because it was incorporated as a mandatory retrieval criterion and was therefore present in all patent families.

Collectively, the most frequent codes covered biodegradable packaging materials, film manufacturing, polymeric compositions, layered products, polyesters, polyolefins, laminates, and food applications. Because a single family may contain several CPC codes, the frequencies are not mutually exclusive, and their sum exceeds the total corpus.

D. Conceptual Structure and Technological Clusters

The co-occurrence analysis identified three interrelated clusters, as represented in Fig. 5. The terms exhibiting the largest size and greatest centrality were biodegradability, starch, barrier property, coating, and polylactic acid.

The green cluster was organized around biodegradability and included terms such as polylactic acid, PLA, PBAT, mechanical property, composite material, and food packaging. Within this cluster, biodegradability occupied the most central position and was linked to polymeric materials, mechanical properties, and packaging applications. The term food packaging was associated with biodegradability, composite material, mechanical property, PLA, and PBAT.

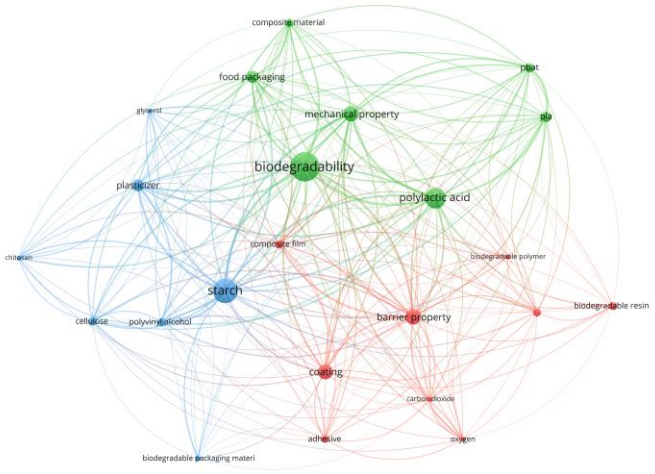


Fig. 5 Conceptual structure of biodegradable packaging technologies based on term co-occurrence.

The blue cluster was structured around starch and included the terms chitosan, cellulose, glycerol, plasticizer, polyvinyl alcohol, and biodegradable packaging material. The most visible connections linked starch to plasticizers, glycerol, and other polymers used to produce films and composite materials.

The red cluster was structured primarily around barrier property and coating. It also included adhesive, oxygen, carbon dioxide, biodegradable polymer, biodegradable resin, and composite film. The relationships among barrier property, oxygen, and carbon dioxide indicate the presence of terms associated with controlling gas transfer, whereas coating and adhesive were linked to films and composite structures.

The three clusters exhibited cross-connections. Starch was associated with biodegradability, composite materials, and barrier properties; PLA and PBAT were linked to coatings and films; and mechanical properties were associated with both natural and synthetic materials. Overall, the network was organized around three dimensions: biodegradable materials, polysaccharide-based formulations, and functional performance through coatings and barrier properties.

The presence of food packaging in the network and code B32B2439/70 in Table I confirms that food packaging is part of the corpus. However, both results show that this application constitutes a specific domain within the broader field of biodegradable and compostable packaging.

IV. Discussion

The results show that biodegradable and compostable packaging evolved from incipient inventive activity into a rapidly expanding technological field. The acceleration recorded between 2016 and 2023 coincides with increasing regulatory and corporate pressure to reduce short-lived plastic waste, particularly packaging waste, which accounts for approximately 40% of global plastic waste [1]. It is also consistent with the growth in bioplastics production capacity and the position of packaging as its leading application segment [14]. The identified trajectory further corresponds with the evolution of research from environmental assessment toward composite materials and functional solutions [17]. However, growth in patenting activity does not, by itself, demonstrate a reduction in pollution, since no material alternative alone can offset the projected increase in consumption and waste without complementary measures involving reduction, reuse, recycling, and end-of-life management [9], [10].

China's leading position and the presence of Japan and the Republic of Korea indicate a high concentration of protection in Asian jurisdictions. This distribution corresponds with the participation of Chinese companies and universities, as well as Japanese companies specializing in printing, films, and laminates. Nevertheless, the low individual shares of the leading applicants suggest a dispersed competitive structure comprising material and packaging manufacturers, food and consumer goods companies, universities, and specialized organizations. This interpretation is descriptive and is based on the observed shares of the leading applicants rather than on a formal market-concentration index. The diversity of actors indicates that inventive activity is distributed throughout the value chain and is not limited to polymer synthesis. This finding demonstrates the usefulness of patents for identifying organizations and protection strategies that are not necessarily observable through the analysis of scientific publications [19], [20]. It is also consistent with the industrial perspective that scaling up bioplastics depends on integrating scientific knowledge, industrial processing, infrastructure, regulation, and market access [15].

The indicators used in this study measure the volume and distribution of inventive activity and patent protection. The number of simple patent families does not, by itself, indicate technological influence, invention quality, legal strength, commercial success, or market adoption. Patent citations, legal status, claim breadth, licensing, and commercial exploitation were not examined. Therefore, the rankings of jurisdictions and applicants should be interpreted as indicators of patenting and protection activity rather than as measures of technological or market performance.

The distribution of CPC codes indicates that inventive activity is concentrated at three complementary levels: the formulation of biodegradable materials, film manufacturing, and the development of laminated or multilayer structures. The predominance of B65D65/466 shows that biodegradability is a central attribute of a substantial proportion of the inventions, whereas C08J5/18 and the codes within class B32B demonstrate the importance of converting polymers into functional films and structures. This orientation is consistent with the literature, according to which materials based on PLA, PBAT, starch, cellulose, and chitosan often require blends, plasticizers, reinforcing agents, or coatings to improve their mechanical and barrier properties [5], [7]. Multilayer structures make it possible to combine functions that would be difficult for a single material to provide; however, they also increase end-of-life complexity when they incorporate incompatible polymers, adhesives, or layers [16].

The conceptual network reinforces this interpretation through three closely connected cores: biodegradability and polyesters; polysaccharides and plasticizers; and coatings and barrier properties. The centrality of biodegradability shows that end-of-life behavior structures the field, whereas its association with mechanical property and barrier property indicates that inventive activity seeks to combine degradability with performance during use. The presence of PLA, PBAT, starch, cellulose, and chitosan is consistent with the main material families described in recent reviews [7], [12]. Likewise, the association among coating, oxygen, carbon dioxide, and adhesive demonstrates the importance of controlling permeability and preserving packaged contents, particularly in food applications [5], [6]. Collectively, the clusters show that innovation is directed not only toward obtaining degradable materials but also toward developing

systems that integrate strength, flexibility, and protective capacity.

The presence of the term food packaging and CPC code B32B2439/70 demonstrates that food packaging constitutes a relevant trajectory within the corpus, although it is not its only application. This finding supports the scope of the study as a technological landscape of biodegradable and compostable packaging and avoids attributing all patent families to the food sector. In this field, material substitution must be assessed alongside the ability of the packaging to protect the product and extend its shelf life, because inadequate performance could increase food losses and diminish part of the expected environmental benefit [5], [6]. Therefore, innovation in food packaging must reconcile biodegradability, safety, stability, and adequate mechanical and barrier properties.

Finally, the expansion of patenting activity does not automatically constitute evidence of sustainability. A biobased origin does not guarantee biodegradability, which depends on the material structure, environmental conditions, and treatment conditions [11], [12]. Compostable materials require separate collection systems and facilities capable of maintaining controlled conditions, but such infrastructure remains insufficient in many countries [10]. Furthermore, multilayer structures and combinations with adhesives, coatings, or conventional polymers may hinder the complete degradation of the packaging [16]. Consequently, the identified trajectories represent opportunities for innovation, but their environmental contribution will depend on compatibility among design, application, certification, and effective waste management. Biodegradable and compostable packaging should be regarded as a selective alternative within a broader circular strategy rather than as a justification for maintaining widespread single-use models [8], [9], [10].

V. Conclusions

The analysis of 1,757 simple patent families demonstrated that biodegradable and compostable packaging constitutes an expanding technological field, with particularly rapid growth between 2016 and 2023. China was the leading jurisdiction of protection; however, the low individual shares among the leading applicants suggest a dispersed competitive landscape involving companies, universities, and specialized manufacturers.

The CPC codes and co-occurrence network showed that innovation is concentrated on biodegradable formulations, polymeric films, multilayer structures, and coatings designed to reconcile biodegradability, mechanical strength, and barrier properties. Food packaging represents a relevant, although not exclusive, application within the corpus.

Overall, the identified trends reveal an evolution from solutions focused primarily on degradability toward more complex and functional packaging systems. Nevertheless, their environmental contribution will depend on material compatibility, certification, treatment infrastructure, and actual end-of-life conditions. This study provides a foundation for guiding future research, investment decisions, and innovation strategies in biodegradable and compostable packaging.

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