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# PACKAGING SCIENCE

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*Pubblicazione bimestrale in cui sono presentati 7 articoli multidisciplinari, afferenti al packaging, selezionati da diverse riviste del mondo scientifico digitale.*

*Packaging Science attraverso le tematiche sempre attuali ed aggiornate dei suoi articoli in diverse discipline, concorre ampiamente alla promozione e all'evoluzione della corretta cultura del packaging e dei **10 Valori della Carta Etica** per accompagnare il packaging verso un futuro più consapevole.*

## Packaging cosmetico: aspetti normativi europei e sostenibilità.

Questa revisione mira a fornire una panoramica completa di vari aspetti relativi al packaging dei prodotti cosmetici, evidenziando sia i progressi che le sfide nel settore. Inizialmente, offre una descrizione generale dei principali materiali utilizzati nei contenitori per cosmetici, tra cui plastica, vetro, carta e alluminio. Segue un'analisi dei quadri legislativi esistenti dell'UE che regolano il packaging cosmetico, comprese le normative in materia di sostanze chimiche, alimenti e rifiuti. Il documento discute anche le recenti proposte normative dell'UE e le linee guida delle associazioni di categoria volte a migliorare la sostenibilità dei materiali di imballaggio cosmetico. Inoltre, viene analizzato il ruolo dei materiali di imballaggio riciclati e a base biologica nella promozione della sostenibilità ambientale.



Review

### Cosmetic Packaging: European Regulatory Aspects and Sustainability

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**Abstract:** This review aims to provide a comprehensive overview of various aspects related to cosmetic product packaging, highlighting both advancements and challenges in the field. Initially, it offers a general description of the main materials used in cosmetic containers, including plastic, glass, paper, and aluminum. This is followed by an analysis of the existing EU legislative frameworks that govern cosmetic packaging, encompassing chemical, food, and waste regulations. The paper also discusses recent EU regulatory proposals and guidelines from trade associations aimed at enhancing the sustainability of cosmetic packaging materials. Additionally, the role of recycled and bio-based packaging materials in promoting environmental sustainability is analyzed. Overall, this review aims to provide insights for experts in the field on how to balance safety, functionality, and environmental responsibility in cosmetic packaging.

**Keywords:** cosmetic packaging; EU legislation; guidelines; container materials; sustainability

## Sviluppo di film in bolla multistrato composti PBS/Nano a base di PHB con proprietà migliorate per applicazioni di imballaggio alimentare.

Le plastiche a base biologica e biodegradabili sono emerse come alternative promettenti alle plastiche convenzionali, offrendo il potenziale per ridurre l'impatto ambientale promuovendo al contempo la sostenibilità. Questo studio si concentra sulla produzione di film in bolla multistrato con proprietà funzionali migliorate adatte per applicazioni di imballaggio alimentare. I film sono stati sviluppati attraverso la coestrusione in una configurazione a tre strati, con polibutilene succinato (PBS) e polibutilene succinato adipato (PBSA) rispettivamente come strati esterno e interno. Lo strato funzionale era costituito da poliidrossibutirrato (PHB) potenziato con nanoargille Cloisite 30B a rapporti di peso variabili



Article

### Development of PBS/Nano Composite PHB-Based Multilayer Blown Films with Enhanced Properties for Food Packaging Applications

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**Abstract** Biobased and biodegradable plastics have emerged as promising alternatives to conventional plastics offering the potential to reduce environmental impacts while promoting sustainability. This study focuses on the production of multilayer blown films with enhanced functional properties suitable for food packaging applications. Films were developed through co-extrusion in a three-layer film configuration, with Polybutylene Succinate (PBS) and Polybutylene Succinate Adipate (PBSA) as the external and internal layers, respectively. The functional layer consisted of Polyhydroxybutyrate (PHB) enhanced with nanoclays Cloisite<sup>®</sup> 30B at varying weight ratios. Films were also processed by manipulating the extruder screw speed of the functional layer to investigate its impact on the functional properties. Rheology, mechanical strength, and barrier performance were characterised to establish correlations between processing conditions and functional layer blends (Cloisite<sup>®</sup> 30B/PHB) on the properties of the resultant films. Rheological test results indicated that the system with 5% Cloisite<sup>®</sup> had the best polymer/nanofiller matrix dispersion. Mechanical and permeability tests showed that by varying the process conditions (the alteration of the thickness of the functionalized layer) resulted in an improvement in mechanical and barrier properties. Furthermore, the addition of the nanofiller resulted in a stiffening of the film with a subsequent decrease in permeability to oxygen and water vapour.



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## Minerali argillosi e biopolimeri nella progettazione di film: panoramica delle proprietà e delle applicazioni.

La ricerca per sostituire le plastiche a base di petrolio è stata piuttosto impegnativa. Attualmente, c'è molto interesse per i biopolimeri come alternativa. Tuttavia, i biopolimeri non hanno proprietà meccaniche adeguate quando sono in forma di film, il che ne limita le applicazioni. Per risolvere questo problema, i minerali argillosi vengono incorporati come strategia. I minerali argillosi offrono ai film buone proprietà barriera, termiche, reologiche, ottiche e meccaniche. Questa breve rassegna si concentra sull'incorporazione di minerali argillosi con altri nanofiller e bioattivi per migliorarne le caratteristiche fisiche, chimiche e funzionali. La sinergia di questi materiali conferisce ai film proprietà eccezionali e li rende adatti ad applicazioni come rivestimenti alimentari, materiali di confezionamento, medicazioni e bendaggi per il trattamento delle ferite cutanee.



Review

### Clay Minerals and Biopolymers in Film Design: Overview of Properties and Applications

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**Abstract:** Research to replace petroleum-based plastics has been quite challenging. Currently, there is a lot of interest in biopolymers as an alternative. However, biopolymers do not have suitable mechanical properties when in film form, which limits their applications. To resolve this issue, clay minerals are being incorporated as a strategy. Clay minerals offer the films good barrier, thermal, rheological, optical, and mechanical properties. They can also work with other additives to promote antioxidant and antimicrobial activity. This brief review focuses on incorporating clay minerals with other nanofillers and bioactives to improve their physical, chemical, and functional characteristics. The synergy of these materials gives the films exceptional properties and makes them suitable for applications such as food coatings, packaging materials, dressings, and bandages for treating skin wounds.

**Keywords:** clay minerals; biopolymer; film formation; nanofillers; food packaging; wound dressing

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## Soluzioni al plasma a pressione atmosferica fredda per imballaggi alimentari sostenibili.

Il quarto stato del materiale, composto da elettroni, ioni, radicali liberi, specie eccitate, radiazioni ultraviolette (UV) e campi elettromagnetici, è chiamato plasma. L'aumento del numero di batteri resistenti al trattamento è una delle principali cause di morte in tutto il mondo. Vari studi hanno dimostrato che il plasma atmosferico freddo può uccidere questi batteri attraverso diversi meccanismi, rendendo il plasma freddo uno strumento promettente per disattivare i batteri. Questa nuova tecnologia può essere efficacemente utilizzata nell'industria alimentare perché ha il potenziale per inattivare microrganismi come spore e tossine microbiche e aumentare la bagnabilità e la stampabilità dei polimeri per confezionare alimenti freschi e secchi. Può anche aumentare la durata di conservazione degli alimenti senza lasciare residui o effluenti chimici. Questo documento esamina il potenziale, i vantaggi e gli svantaggi del plasma freddo nell'industria alimentare e nella sterilizzazione.



Review

### Cold Atmospheric Pressure Plasma Solutions for Sustainable Food Packaging

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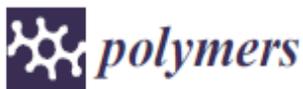
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**Abstract:** Increasing the number of resistant bacteria resistant to treatment is one of the leading causes of death worldwide. These bacteria are created in wounds and injuries and can be transferred through hospital equipment. Various attempts have been made to treat these bacteria in recent years, such as using different drugs and new sterilization methods. However, some bacteria resist drugs, and other traditional methods cannot destroy them. In the meantime, various studies have shown that cold atmospheric plasma can kill these bacteria through different mechanisms, making cold plasma a promising tool to deactivate bacteria. This new technology can be effectively used in the food industry because it has the potential to inactivate microorganisms such as spores and microbial toxins and increase the wettability and printability of polymers to pack fresh and dried food. It can also increase the shelf life of food without leaving any residue or chemical effluent. This paper investigates cold plasma's potential, advantages, and disadvantages in the food industry and sterilization.

**Keywords:** cold atmospheric plasma; sterilization; bacterial inactivation; food packaging

## Una panoramica del packaging alimentare antimicrobico avanzato: enfasi sugli agenti antimicrobici e sui film a base polimerica.

L'industria alimentare è sempre più concentrata sul mantenimento della qualità e della sicurezza dei prodotti alimentari, poiché i consumatori stanno diventando più attenti alla salute e cercano alimenti freschi e minimamente trasformati. L'imballaggio attivo, compreso l'imballaggio antimicrobico, ha guadagnato una notevole attenzione tra gli attuali metodi di confezionamento alimentare grazie all'ampia gamma di materiali utilizzati, ai metodi di applicazione e alla loro capacità di proteggere vari prodotti alimentari. Questa revisione completa si concentra sulle sostanze antimicrobiche naturali e sintetiche e sui film a base polimerica, nonché sui loro meccanismi e applicazioni nei sistemi di imballaggio.



Review

### An Overview of Advanced Antimicrobial Food Packaging: Emphasizing Antimicrobial Agents and Polymer-Based Films

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**Abstract:** The food industry is increasingly focused on maintaining the quality and safety of food products as consumers are becoming more health conscious and seeking fresh, minimally processed foods. However, deterioration and spoilage caused by foodborne pathogens continue to pose significant challenges, leading to decreased shelf life and quality. To overcome this issue, the food industry and researchers are exploring new approaches to prevent microbial growth in food, while preserving its nutritional value and safety. Active packaging, including antimicrobial packaging, has gained considerable attention among current food packaging methods owing to the wide range of materials used, application methods, and their ability to protect various food products. Both direct and indirect methods can be used to improve food safety and quality by incorporating antimicrobial compounds into the food packaging materials. This comprehensive review focuses on natural and synthetic antimicrobial substances and polymer-based films, and their mechanisms and applications in packaging systems. The properties of these materials are compared, and the persistent challenges in the field of active packaging are emphasized. Specifically, there is a need to achieve the controlled release of antimicrobial agents and develop active packaging materials that possess the necessary mechanical and barrier properties, as well as other characteristics essential for ensuring food protection and safety, particularly bio-based packaging materials.



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## Lo sviluppo di materiali biocompositi sostenibili a base di acido polilattico e Silverskin, un sottoprodotto dell'industria del caffè, per applicazioni di imballaggio alimentare.

In linea con i principi dell'economia circolare e con l'obiettivo di produrre materiali ecocompatibili per applicazioni di imballaggio alimentare, sono stati sviluppati film biocompositi sostenibili a base di acido polilattico (PLA) e silverskin di caffè (SS). Il silverskin del caffè è un sottoprodotto del processo di tostatura del caffè, mentre il PLA è uno dei polimeri a base biologica più promettenti. Diversi compositi sono stati preparati con diversi carichi di SS, che vanno dal 2,5 al 20 in peso, tramite il metodo della colata in soluzione. I risultati hanno indicato che l'efficace dispersione della pelle argentata del caffè nel PLA è stata realizzata con successo e che un trattamento sbiancante del filler porta a una migliore interazione interfacciale..



Article

### The Development of Sustainable Biocomposite Materials Based on Poly(lactic acid) and Silverskin, a Coffee Industry By-Product, for Food Packaging Applications

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**Abstract:** Aligned with the principles of the circular economy and aiming at the production of environmentally friendly materials for food packaging applications, sustainable biocomposite films based on poly(lactic acid) (PLA) and coffee silverskin (SS), were developed. Coffee silverskin is a by-product of the coffee roasting process, while PLA is one of the most promising bio-based polymers. Several composites were prepared with different loadings of SS, ranging from 2.5 to 20 wt%, via the solution casting method. The findings indicated that the effective dispersion of coffee silverskin in PLA was successfully accomplished and that a bleaching treatment of the filler leads to better interfacial interaction. The addition of silverskin, in any proportion, did not affect the melting point and glass transition temperature of the polymer matrix or the oxygen permeability of the film. Moreover, the degree of swelling was increased, more so for the films with modified particles, whereas the water vapor transmission rate and permeability increased only after the addition of high amounts (>10%) of surface-treated silverskin. A gradual decrease in color lightness was measured with the increasing concentration of silverskin, and the color was more intense in the untreated samples. The antioxidant activity of the films increased gradually with increasing additions of coffee silverskin due to the presence of compounds such as polyphenols. The chemical treatment of coffee silverskin resulted in the films having improved mechanical properties, as the chemical treatment facilitated stronger bonding between the base material and the additive. Therefore, sustainable composites with enhanced antioxidant activity can be produced by the incorporation of a food industry by-product into a PLA matrix.



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## Il pericolo della plastica: microplastiche atmosferiche in ambienti esterni, interni e remoti.

Le crescenti applicazioni commerciali, industriali e mediche delle materie plastiche non possono essere fermate nei prossimi anni. Le microplastiche sono una nuova classe di inquinanti plastici che sono emerse come crescenti minacce ambientali. La persistenza, gli effetti e la rimozione delle MP presenti nel suolo, nell'acqua e in numerosi organismi sono diventate un importante campo di ricerca. Tuttavia, le microplastiche atmosferiche (AMP), che sono suddivise in depositate e sospese, rimangono in gran parte inesplorate. Questa rassegna presenta i recenti sviluppi e le sfide legate alla piena comprensione degli AMP sospesi e depositati.



Review

### The Peril of Plastics: Atmospheric Microplastics in Outdoor, Indoor, and Remote Environments

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**Abstract** The increasing commercial, industrial, and medical applications of plastics cannot be halted during the coming years. Microplastics are a new class of plastic pollutants which have emerged as escalating environmental threats. The persistence, effects, and removal of MPs present in soil, water, and numerous organisms have become an important research field. However, atmospheric microplastics (AMPs), which are subcategorized into deposited and suspended, remain largely unexplored. This review presents the recent developments and challenges involved in fully understanding suspended and deposited AMPs. The evaluation of indoor suspended MP fibers needs to be critically investigated to understand their implications for human health. Furthermore, the transportation of AMPs to isolated locations, such as cryospheric regions, requires immediate attention. The major challenges associated with AMPs, which have hindered advancement in this field, are inconsistency in the available data, limited knowledge, and the lack of standardized methodologies for the sampling and characterization techniques of AMPs.



Citation: Borah, S.J.; Gupta, A.K.; Kumar, V.; Jhajharia, P.; Singh, P.P.; Kumar, P.; Kumar, R.; Dubey, K.K.; Gupta, A. The Peril of Plastics Atmospheric Microplastics in Outdoor, Indoor, and Remote Environments. *Sustain. Chem.* **2024**, *5*.

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