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# PACKAGING SCIENCE

*E' la Rassegna Scientifica Internazionale della **Fondazione Carta Etica del Packaging**.*

*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.*

## Migrazione chimica dai materiali a contatto con il vino.

La qualità e la sicurezza del vino sono influenzate dai materiali utilizzati a contatto con gli alimenti (MOCA). Il presente lavoro distingue le sostanze chimiche che migrano da quelle di (i) origine industriale con potenziali effetti sulla sicurezza e da quelle di (ii) presenza naturale, principalmente nel sughero (es. tannini) con effetti sulla qualità organolettica. La revisione si concentra sulla migrazione di contaminanti chimici industriali. Le sostanze migranti identificate includono sostanze autorizzate come plastificanti ftalati, monomeri (bisfenolo A), antiossidanti (Irganox 1010), sostanze note ma non autorizzate (butilparabene), prodotti di degradazione, prodotti di ossidazione (nonilfenolo), sottoprodotti di adesivi poliuretanici, oligomeri, fotoiniziatori di inchiostri ed elementi inorganici.



Review

## Chemical Migration from Wine Contact Materials

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**Abstract** Wine quality and safety is affected by the food contact materials (FCMs) used. These materials are expected to protect the beverage from any chemical, physical, or biological hazard and preserve its composition stable throughout its shelf-life. However, the migration of chemical substances from FCMs is a known phenomenon and requires monitoring. This review distinguishes the migrating chemical substances to those of (i) industrial origin with potential safety effects and those of (ii) natural occurrence, principally in cork (ex. tannins) with organoleptic quality effects. The review focuses on the migration of industrial chemical contaminants. Migration testing has been applied only for cork stoppers and tops, while other materials like polyethylene terephthalate (PET) bottles with aluminum cups, paperboard cartons, stainless steel vats, and oak casks have been examined for the presence of chemical migrating substances only by wine analysis without migration testing. The dominant analytical techniques applied are gas and liquid chromatography coupled to mass spectrometry (MS) for the determination of organic compounds and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) and ICP-MS for elemental analysis. Targeted approaches are mostly applied, while limited non-target methodologies are reported. The identified migrating substances include authorized substances like phthalate plasticizers, monomers (bisphenol A), antioxidants (Irganox 1010), known but non-authorized substances (butylparaben), break-down products, oxidation products (nonylphenol), polyurethane adhesive by-products, oligomers, ink



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# Valutazione dell'esposizione agli analoghi del bisfenolo attraverso il consumo di pasti in scatola e pronti al consumo e dei loro possibili effetti sulla pressione sanguigna e sulla frequenza cardiaca.

I bisfenoli sono sostanze chimiche che alterano il sistema endocrino, utilizzate nelle materie plastiche e nelle resine per gli imballaggi alimentari. Questo studio mira a valutare l'esposizione al bisfenolo A (BPA), al bisfenolo S (BPS) e al bisfenolo F (BPF) associati al consumo di pasti freschi, in scatola e pronti e a determinare gli effetti dei bisfenoli sulla pressione sanguigna e sulla frequenza cardiaca.



Article

## Evaluation of Exposure to Bisphenol Analogs through Canned and Ready-to-Eat Meal Consumption and Their Possible Effects on Blood Pressure and Heart Rate

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**Abstract** Bisphenols are endocrine-disrupting chemicals used in plastics and resins for food packaging. This study aimed to evaluate the exposure to bisphenol A (BPA), bisphenol S (BPS), and bisphenol F (BPF) associated with the consumption of fresh, canned, and ready-to-eat meals and determine the effects of bisphenols on blood pressure and heart rate. Forty-eight healthy young adults were recruited for this study, and they were divided into the following three groups: fresh, canned, and ready-to-eat meal groups. Urine samples were collected 2, 4, and 6 h after meal consumption, and blood pressure and heart rate were measured. The consumption of ready-to-eat meals significantly increased urine BPA concentrations compared with canned and fresh meal consumption. No significant difference in BPS and BPF concentrations was observed between the groups. The consumption of ready-to-eat meals was associated with a significant increase in systolic blood pressure and pulse pressure and a marked decrease in diastolic blood pressure and heart rate. No significant differences were noted in blood pressure and heart rate with canned and fresh meal consumption. It can be concluded that total BPA concentration in consumed ready-to-eat meals is high. High BPA intake causes increase in urinary BPA concentrations, which may, in turn, lead to changes in some cardiovascular parameters.

**Keywords:** bisphenol A; bisphenol F; bisphenol S; blood pressure; canned food; ready-to-eat meal



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# Gestione dei rifiuti solidi urbani in Laos: analisi comparativa dell'impatto ambientale, delle pratiche e delle tecnologie con le regioni ASEAN e il Giappone.

La gestione dei rifiuti solidi urbani nei paesi in via di sviluppo deve essere soggetta a limitazioni, in particolare per quanto riguarda le tecnologie per il trattamento e lo smaltimento, che sono fondamentali per raggiungere gli obiettivi di sostenibilità ambientale ed economica. Questo articolo indaga la gestione dei rifiuti solidi urbani in Laos, rispetto alle regioni ASEAN-Giappone, concentrandosi su informazioni di base, caratteristiche dei rifiuti, impatto ambientale e tecnologie di trattamento per l'utilizzo delle risorse. I risultati indicano un continuo aumento della produzione di rifiuti urbani in Laos, in particolare nella capitale Vientiane, da 0,21 milioni di tonnellate nel 2012 a 0,37 milioni di tonnellate nel 2021.



Review

## Municipal Solid Waste Management in Laos: Comparative Analysis of Environmental Impact, Practices, and Technologies with ASEAN Regions and Japan

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**Abstract** Municipal solid waste management in developing countries faces limitations, especially concerning technologies for treatment and disposal, which is crucial for achieving environmental and economic sustainability goals. This paper investigates municipal solid waste management in Laos, compared with the ASEAN-Japan regions, focusing on background information, waste characteristics, environmental impact, and treatment technologies for resource utilization. The findings indicate a continuous rise in municipal waste generation in Laos, particularly in the capital Vientiane, from 0.21 million tons in 2012 to 0.37 million tons in 2021. Treatment methods include unsanitary landfilling, basic recycling, and open dumping, as well as burning or discharge into rivers, posing potential risks to the environment and human health. Japan and Singapore have shown decreasing trends, with Japan reducing from 45.23 million tons in 2012 to 40.95 million tons in 2021 and Singapore from 7.27 million tons in 2021 to 6.94 million tons in 2021. Laos encounters challenges in managing municipal waste, especially in waste recovery and waste-to-energy practices, crucial elements of integrated solid waste management aimed at promoting environmental and economic sustainability. Enhancing waste management in Laos involves developing a waste management act with segregation, recycling, and extended producer responsibility policies. Implementing mechanical biological



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## Sviluppo di pellicole o rivestimenti commestibili composti funzionali per la conservazione della frutta con aggiunta di nanoemulsione a base di olio di sansa per proprietà barriera migliorate e caffeina per attività antiossidante migliorata.

La sicurezza alimentare è una questione critica per l'industria moderna. I film e i rivestimenti commestibili semplici, realizzati con un unico materiale di base, soddisfano determinati requisiti, come le proprietà barriera, l'aspetto attraente dei prodotti, l'aumento della loro durata di conservazione, ecc. Lo scopo di questo studio è stato quello di sviluppare film o rivestimenti commestibili composti funzionali per la conservazione della frutta mediante l'aggiunta di componenti bioattivi in combinazioni che non sono state ancora studiate a fondo, secondo la letteratura pertinente. I film commestibili erano inizialmente composti da (i) chitosano (CH), nanocristalli di cellulosa (CNC) e beta-ciclodestrina (CD) (rapporto 50%-37,5%-12,5%), e (ii) idrossipropilmetilcellulosa (HPMC), nanocristalli di cellulosa (CNC) e beta-ciclodestrina (CD) (rapporto 50%-37,5%-12,5%).



Article

### Development of Functional Composite Edible Films or Coatings for Fruits Preservation with Addition of Pomace Oil-Based Nanoemulsion for Enhanced Barrier Properties and Caffeine for Enhanced Antioxidant Activity

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**Abstract** The aim of this study was to develop functional composite edible films or coatings for fruit preservation by the addition of bioactive components in combinations that have not yet been thoroughly studied, according to the relevant literature. Edible films were initially composed of (i) chitosan (CH), cellulose nanocrystals (CNC) and beta-cyclodextrin (CD) (50%-37.5%-12.5% ratio), and (ii) hydroxypropyl methylcellulose (HPMC), cellulose nanocrystals (CNC) and beta-cyclodextrin (CD) (50%-37.5%-12.5% ratio). The bioactive components incorporated (5, 10 and 15% *v/v*) were as follows: (i) pomace oil-based nanoemulsion (NE) aiming to enhance barrier properties, and (ii) caffeine (C), aiming to enhance the antioxidant activity of films, respectively. Indeed, NE addition led to very high barrier properties (low oxygen and water vapor permeability), increased flexibility and reduced color. Furthermore, the contribution of these coatings to fresh strawberries' preservation under cold storage was investigated, with very promising results concerning weight loss, color difference, and preservation of fruit moisture and quantity of O<sub>2</sub> and CO<sub>2</sub> inside the packages. Additionally, C addition led to very high antioxidant activity, reduced color and improved barrier properties. Finally, the contribution of these coatings to avocado's preservation under cold storage was investigated, with very encouraging results for color difference, hardness and peroxide value of the fruit samples.



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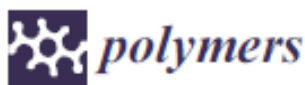
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## Film intelligenti a base di biopolimeri: nuove soluzioni promettenti per le applicazioni di imballaggio alimentare.

Lo sviluppo di film a base di biopolimeri rappresenta una direzione promettente nell'industria del packaging che risponde a stringenti esigenze di sostenibilità, riducendo l'impatto ecologico. I polimeri tradizionali di origine fossile presentano grandi preoccupazioni a causa del loro lungo tempo di decomposizione e del loro contributo significativo all'inquinamento dell'ambiente. Al contrario, i biopolimeri come il chitosano, il PVA e il PLA offrono valide alternative. Questo studio mirava a ottenere un indicatore di pH innovativo per il packaging intelligente utilizzando un colorante analogo sintetico non tossico degli antociani incorporato in film a base biologica per indicare la freschezza e la qualità della carne. Questo studio può essere il punto di partenza per creare soluzioni di imballaggio più durevoli che portino a un'economia circolare.



Article

### Intelligent Biopolymer-Based Films: Promising New Solutions for Food Packaging Applications

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**Abstract:** The development of biopolymer-based films represents a promising direction in the packaging industry that responds to stringent needs for sustainability, reducing the ecological impact. Traditional fossil-derived polymers present major concerns because of their long decomposition time and their significant contribution to the pollution of the environment. On the contrary, biopolymers such as chitosan, PVA, and PLA offer viable alternatives. This study aimed to obtain an innovative pH indicator for smart packaging using a synthetic non-toxic anthocyanin analogue dye incorporated in bio-based films to indicate meat freshness and quality. The pH-responsive color-changing properties of the dye make it suitable for developing intelligent films to monitor food freshness. The obtained polymeric films were characterized by FT-IR and UV-VIS spectroscopy, and their thermal properties were assessed using thermogravimetric methods. Moisture content, swelling capacity, and water solubility of the polymeric films were also evaluated. The sensitivity of the biopolymer-flavylium composite films to pH variations was studied in the pH range of 2 to 12 and noticeable color variations were observed, allowing the monitoring of the meat's quality damage through pH changes. The pH-responsive films were applied directly on the surface or in the proximity of pork and chicken meat samples, to evaluate their colorimetric response to fresh and spoiled meat. This study can be the starting point for creating more durable packaging solutions leading to a circular economy.

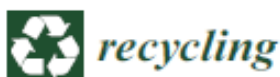
*Polymers* **2024**, *16*, 2256. <https://doi.org/10.3390/polym16162256>

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## Recenti sviluppi nella tecnologia per lo smistamento della plastica per il riciclo: l'emergere dell'intelligenza artificiale e l'ascesa dei robot.

Il riciclo della plastica è una componente importante dell'economia circolare. Nel riciclo meccanico, il recupero di plastica di alta qualità per il successivo ritrattamento richiede che i rifiuti di plastica vengano prima selezionati per tipo, colore e dimensione. Nel riciclo chimico, alcuni tipi di plastica dovrebbero essere rimossi per primi in quanto influiscono negativamente sul processo. Tale smistamento di oggetti in plastica presso gli impianti di recupero dei materiali (MRF) si basa sempre più su una tecnologia automatizzata. Fondamentale per qualsiasi selezione è la corretta identificazione del tipo di plastica. A tal fine viene utilizzata la spettroscopia, sempre più potenziata dall'apprendimento automatico (ML) e dall'intelligenza artificiale (AI). Qui vengono evidenziati i recenti sviluppi nell'applicazione del ML/AI nel riciclo della plastica e viene presentato lo stato dell'arte nell'identificazione e nello smistamento della plastica.



Article

### Recent Developments in Technology for Sorting Plastic for Recycling: The Emergence of Artificial Intelligence and the Rise of the Robots

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**Abstract** Plastics recycling is an important component of the circular economy. In mechanical recycling, the recovery of high-quality plastics for subsequent reprocessing requires plastic waste to be first sorted by type, color, and size. In chemical recycling, certain types of plastics should be removed first as they negatively affect the process. Such sortation of plastic objects at Materials Recovery Facilities (MRFs) relies increasingly on automated technology. Critical for any sorting is the proper identification of the plastic type. Spectroscopy is used to this end, increasingly augmented by machine learning (ML) and artificial intelligence (AI). Recent developments in the application of ML/AI in plastics recycling are highlighted here, and the state of the art in the identification and sortation of plastic is presented. Commercial equipment for sorting plastic recyclables is identified from a survey of publicly available information. Automated sorting equipment, ML/AI-based sorters, and robotic sorters currently available on the market are evaluated regarding their sensors, capability to sort certain types of plastics, primary application, throughput, and accuracy. This information reflects the rapid progress achieved in sorting plastics. However, the sortation of film, dark plastics, and plastics comprising multiple types of polymers remains challenging. Improvements and/or new solutions in the automated sorting of plastics are forthcoming.



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## Valorizzazione degli scarti di frutta e verdura in materiali sostenibili e a valore aggiunto.

Questa revisione mira a semplificare l'approccio alla valutazione dei metodi di valorizzazione più utilizzati per i rifiuti ortofrutticoli (FVW) che siano ecologici, economici e sostenibili in un quadro di economia circolare. Vengono evidenziate le tecnologie di lavorazione ecologiche per l'estrazione di composti bioattivi da FVW, le loro applicazioni e la valutazione tecnico-economica della bioraffineria FVW a supporto dell'economia circolare. Importanti prodotti a valore aggiunto generati dalla FVW includono composti bioattivi, pectina, isolati proteici, come la soia, pigmenti naturali come antociani, chinoni, carotenoidi, betalaine e clorofilla. In questo momento, le prospettive di utilizzo di FVW sono aumentate nei settori degli integratori alimentari, degli imballaggi alimentari bioattivi e commestibili, dell'agricoltura, dell'energia e della depurazione dell'acqua.



Review

## Valorization of Fruit and Vegetable Waste into Sustainable and Value-Added Materials

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**Abstract:** This review aims to streamline the approach to assessing the most used valorization methods for fruit and vegetable waste (FVW) that are eco-friendly, cost-effective, and sustainable within a circular economy framework. Green processing technologies for the extraction of bioactive compounds from FVW, their applications, and the technico-economical assessment of FVW biorefinery to support circular economy are highlighted. Important value-added products generated by FVW include bioactive compounds, pectin, protein isolates, such as soy, natural pigments such as anthocyanins, quinones, carotenoids, betalains, and chlorophyll. At this time, the prospects of using FVW have increased in the food supplements, bioactive and edible food packaging, agriculture, energy, and water purification fields. The findings report that proper management of FVW not only minimizes their addition to landfills in the absence of composting, but also promotes the efficient utilization of resources for the development of innovative materials with a wide range of beneficial applications. Implementing the possible solutions described in this paper would not only reduce environmental impact, but also open up new economic opportunities through the valorization of FVW.

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