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Natural substances as protective agents against photodegradation

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Introduction

Durability of polymeric materials have made them indispensable in various applications, from packaging, arts to construction. When exposed to environmental factors, these materials are not immune to degradation. Sunlight, in particular, plays a significant role in triggering chemical reactions that weaken polymers, compromising their performance over time. Understanding the mechanisms of polymer degradation, particularly under outdoor conditions, is crucial for developing materials that can withstand harsh environments and maintain their integrity for longer periods. Polymers and organic materials exposed to sunlight undergo photo-oxidation, through various mechanisms involving UV radiation, oxygen, temperature, and humidity, leading to the degradation of their physical properties .

Problem Description

When UV radiation acts on the surface of a material, it can cause the formation of reactive species such as free radicals, peroxides, and ozone, leading to the degradation of the polymer. Recent attention has focused on polymer photostabilization to effectively inhibit photochemical degradation. UV absorbers act as protective additives that prevent polymer damage caused by ultraviolet (UV) radiation. They function by absorbing the energy of UV radiation and converting it into less harmful thermal energy, thus preventing UV radiation from causing chemical changes in the polymers. Plants have withstood varying levels of UV radiation since the beginning of their existence by developing a range of protective mechanisms. These include the production of UV-absorbing compounds. Thus, plants should be the inspiration when designing UV protective films and materials. These compounds, along with antioxidants protect plants by reducing UV transmittance in leaves. Antioxidants play a crucial role in photoprotection by neutralizing reactive oxygen species generated from both endogenous and exogenous sources, including ultraviolet radiation.

Table 1
Properties and general applications of antioxidants

Antioxidant	Properties	Application
Vitamin C	Powerful antioxidant, supports the immune system, improves iron absorption, involved in collagen synthesis	Dietary supplements, cosmetics (for skin radiance and health), pharmaceuticals, prevention of oxidative stress.
Vitamin E	Protects cells from oxidative damage, improves skin health, supports the immune system.	Cosmetics (skin care and anti-aging products), dietary supplements, pharmaceuticals, functional foods.
Vitamin A	Supports vision, skin health, and immune function, essential for reproductive health.	Dietary supplements, cosmetics (anti-aging and regenerative products), pharmaceuticals.
Carotenoids	Precursors of vitamin A, antioxidant properties, support eye and skin health.	supplements, functional foods, cosmetics (skin and hair protection products).
Polyphenols	Anti-inflammatory and antioxidant properties, reduce the risk of chronic diseases, protect cardiovascular health.	Food (teas, wine, fruits), cosmetics, pharmaceuticals, dietary supplements.
Anthocyanin	Potent antioxidant, gives red, purple, and blue colors to fruits, has anti-inflammatory and anticancer properties.	Food (juices, functional drinks), dietary supplements, cosmetics (for skin brightening, anti-aging).

Discussion

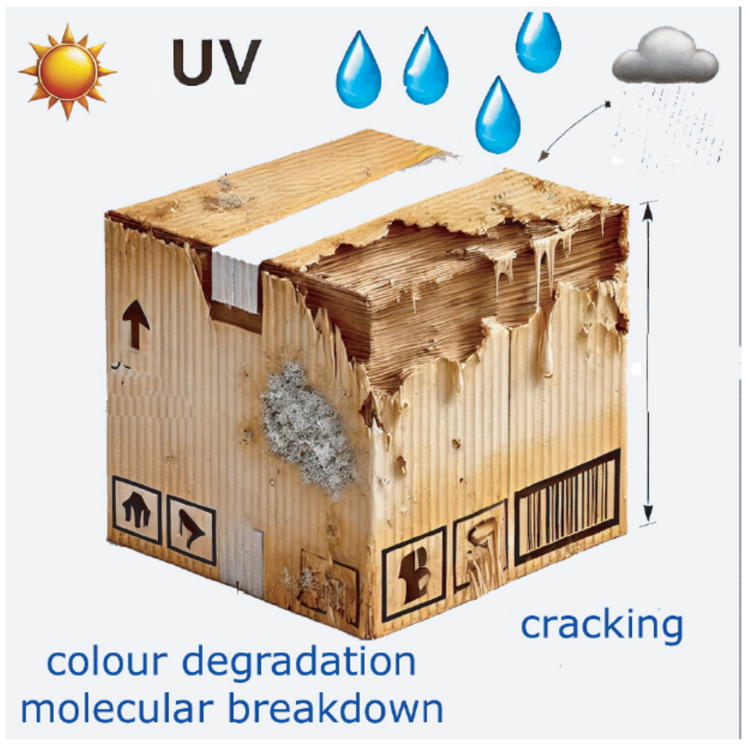

Figure 1
Visual representation of materials degradationa during exposure to different environmental conditions

Table 2
Residues as a source of antioxidant compounds

Waste type	Active compound
Fruit peels (orange, lemon, apple, banana	vitamin C and polyphenols
Grape seeds and skins	resveratrol
Vegetable peels (carrot, potato, cucumber)	carotenoids and flavonoids
Coffee grounds	polyphenols and other
Olive oil production residues	Polyphenols (hydroxytyrosol and oleuropein)
Cocoa production waste	flavonoids
Nut shells	phenolic compounds
Tomato and pepper skins	lycopene and carotenoids

Every year, large amounts of agricultural waste, such as peels, pomace, seeds, leaves, resin, and other residues, are generated and often improperly disposed of, leading to serious environmental pollution. However, these residues represent a significant and cost-effective source of antioxidant compounds, including terpenes, phytosterols, phenolic substances, and peptides, which can have beneficial applications across various industries (Table 2). In recent years, the application of innovative or eco-friendly extraction methods for obtaining antioxidant compounds from agricultural waste has grown significantly. These approaches aim to maximize the value of such waste by producing high-quality extracts, while minimizing environmental impact. They also prioritize safety, reduce energy use and solvent consumption, and enhance the efficiency and yield of the final product.

Conclusion

Integration of circularity and green chemistry is essential for developing sustainable industrial processes that protect both human health and the environment. By prioritizing the use of waste materials as alternative sources for new products, we reduce the reliance on virgin resources and minimize environmental degradation. This approach, inspired by nature's inherent resilience, aligns with the Sustainable Development Goals and promotes innovative solutions for photodegradation and material protection. Drawing from natural mechanisms, such as plants' ability to adapt to UV exposure, we can design durable, eco-friendly materials that extend product lifecycles while preserving biodiversity and reducing pollution. Combining scientific innovation with traditional knowledge allows us to create safer, more sustainable products for future generations. The future research should examine the potential of using natural UV stabilizers ad antioxidants in formation of durable polymer materials.

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