Sustainable, high-performance paper coating material could reduce microplastic pollution

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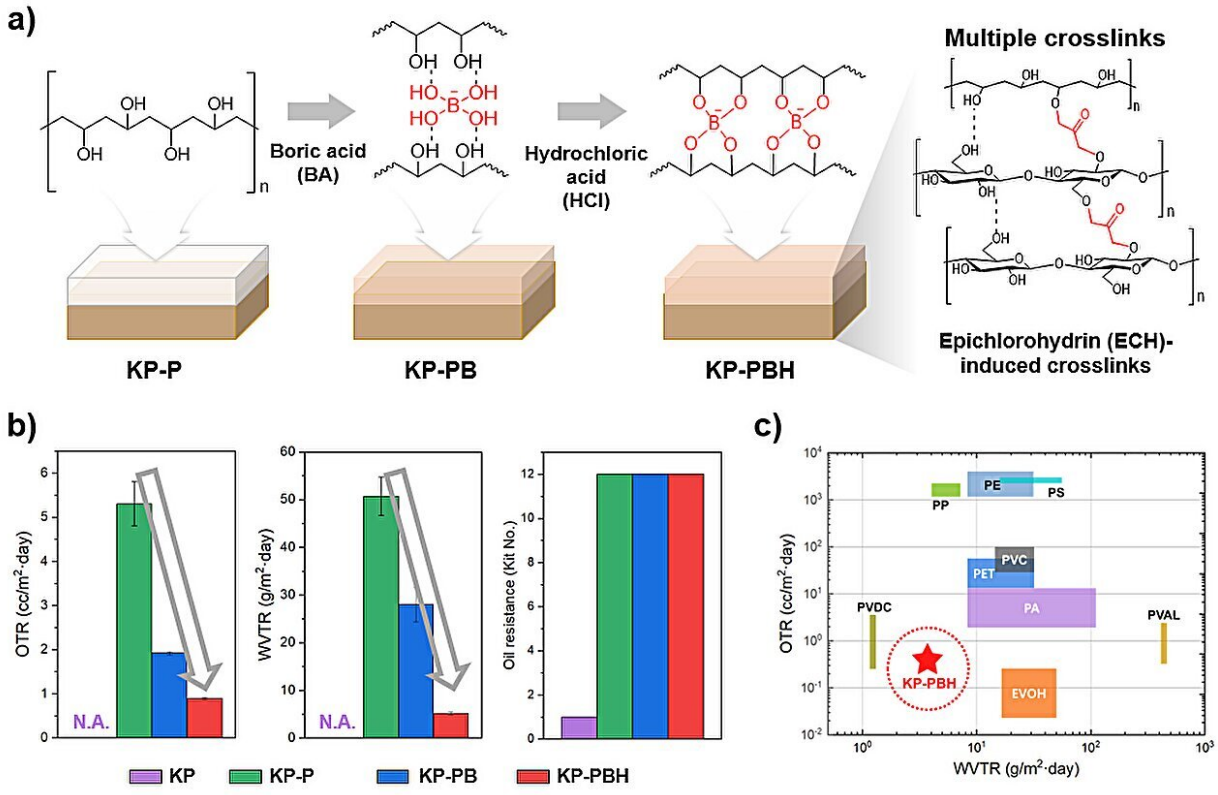


(a) Chemical structure of boric acid-crosslinked poly(vinyl alcohol) coating on paper, (b-c) Oxygen and water vapor barrier properties, (d-f) Tensile strength in dry and moist conditions. OTR: Oxygen transmission rate, WVTR: Water vapor transmission rate. Credit: The Korea Advanced Institute of Science and Technology (KAIST)

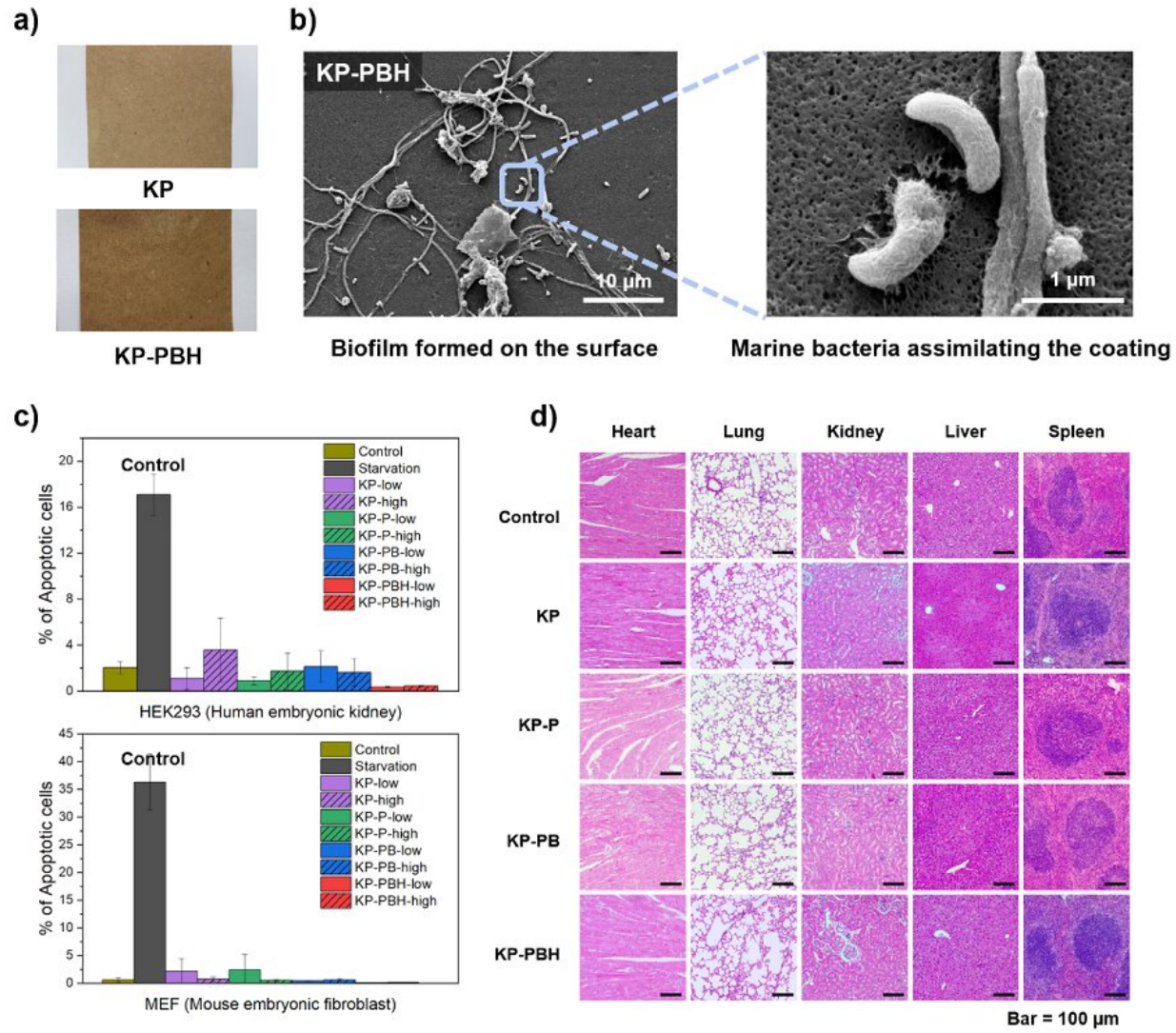
Plastic pollution presents a global challenge that must be solved. In particular, packaging accounts for 30–50% of the total plastic consumption. While paper packaging is eco-friendly, it lacks crucial functionalities like moisture resistance and strength. Traditional coating materials exacerbate plastic pollution, prompting the need for sustainable alternatives.

Polyethylene (PE) and ethylene vinyl alcohol (EVOH) are typically used as coating materials to improve the low barrier properties of paper packaging, but these substances do not decompose and worsen microplastic pollution when disposed of in the natural environment.

In response to this problem, packaging materials made from bio-based substances and biodegradable plastics have been developed, but in most cases, as the packaging performance improves, the biodegradability diminishes rapidly.

A joint research team led by Professor Jaewook Myung of the Department of Civil and Environmental Engineering, Professor Hanseul Yang of the Department of Life Sciences, and Professor Jongcheol Seo of the Department of Packaging and Logistics at Yonsei University tackled the challenge of balancing packaging performance and sustainability. They successfully developed a sustainable, marine biodegradable, high-performance paper coating material.

The work was published in the journals *Green Chemistry* and *Food Chemistry*.



(a) Normal paper and boric acid-crosslinked poly(vinyl alcohol) coated paper, (b) Biodegradation of the coated paper by marine bacteria, (c) Result of cytotoxicity test using human embryonic kidney and mouse embryonic fibroblast cells. (d) Vital organs after one-month exposure of the coated papers to mice. Credit: The Korea Advanced Institute of Science and Technology (KAIST)

The team utilized boric acid-crosslinked poly(vinyl alcohol) (PVA), a biodegradable plastic, to coat the paper, thereby enhancing its biodegradability, barrier properties, and strength. The resulting coated

paper exhibited superior performance compared to conventional plastics, with excellent barrier properties and physical strength, even in humid conditions.

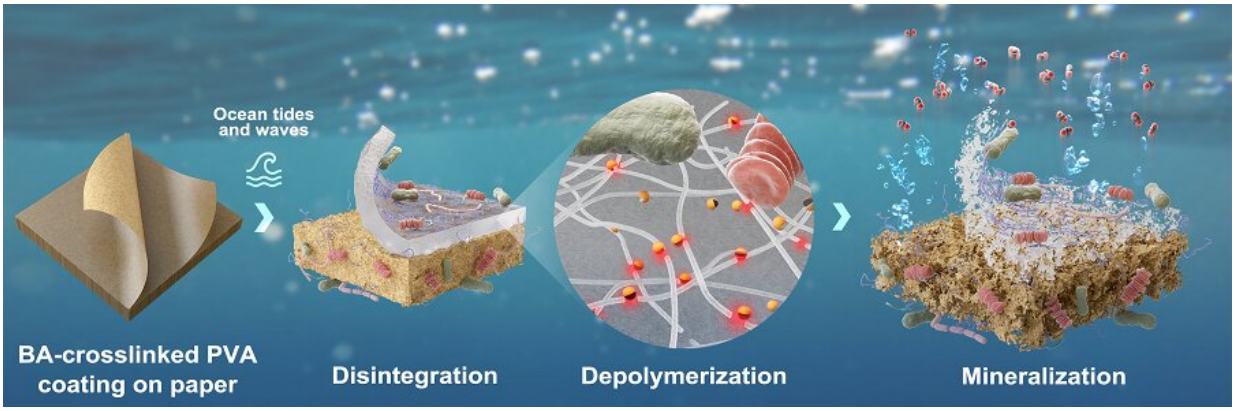
The team also conducted an in-depth examination of biodegradation and biocompatibility to systematically evaluate the sustainability of the newly developed coated paper. Biodegradation was assessed by simulating the marine environment, known for its challenging biodegradability conditions.

The team employed a respiratory system-based bioreactor to measure the degree of carbon mineralization into carbon dioxide. After 111 days of biodegradation, it was found that the coated papers achieved 59–82% biodegradation depending on the coating component.

The phenomenon in which marine bacteria are decomposing the coating material was captured through a scanning electron microscope. In addition, in vitro biocompatibility was confirmed through human embryonic kidney and mouse embryonic fibroblast cells, as well as high in-vivo biocompatibility of the coated paper was verified through mouse experiments.

Through this study, the joint research team proposed a coating strategy that can improve packaging performance while upholding sustainability to address the drawbacks of paper packaging. The boric acid-crosslinked PVA-coated paper eliminates the need for artificial composting conditions or sewage treatment facilities.

Being biodegradable in natural environments and characterized by low toxicity, this newly coated paper does not exacerbate environmental pollution when accidentally discarded. Thus, it presents a sustainable substitute for plastic packaging materials.



End-of-life scenario of papers coated by BA-crosslinked PVA in the marine environment. The coated papers potentially be disintegrated by marine microorganisms and ocean waves and tides. The depolymerization of PVA coating and paper is then mediated by extracellular depolymerases such as oxidases and cellulases, after which the small subunits (oligomers and monomers) are assimilated by microbial cells. The carbon components in the coated papers are ultimately mineralized into CO_2, posing no harm in the ocean. Credit: The Korea Advanced Institute of Science and Technology (KAIST)

Professor Jaewook Myung at KAIST, who led the sustainability study of coated paper, said, "The development of a marine biodegradable high-performance paper coating is the result of combining the innovative technologies of three leading research teams in each field. We will continue to develop sustainable materials with excellent performance."

Professor Jongchul Seo of Yonsei University, who led the research on the development of high-performance paper coating, said, "Through this research, we have developed a sustainable paper packaging technology that can replace non-degradable plastic packaging, and we expect the research outcome will be applied in industry."

More information: Shinhyeong Choe et al, Boric acid-crosslinked poly(vinyl alcohol): biodegradable, biocompatible, robust, and high-barrier paper coating, *Green Chemistry* (2024). DOI: 10.1039/D4GC00618F

Kitae Park et al, Effect of epichlorohydrin treatment on the coating process and performance of high-barrier paper packaging, *Food Chemistry* (2024). DOI: 10.1016/j.foodchem.2024.138772

Provided by The Korea Advanced Institute of Science and Technology (KAIST)