Effect of Encapsulated Essential Oils and $KMnO_4$-Activated White Charcoal on the Properties of Natural Rubber Sheets for Active Packaging of Climacteric Fruits

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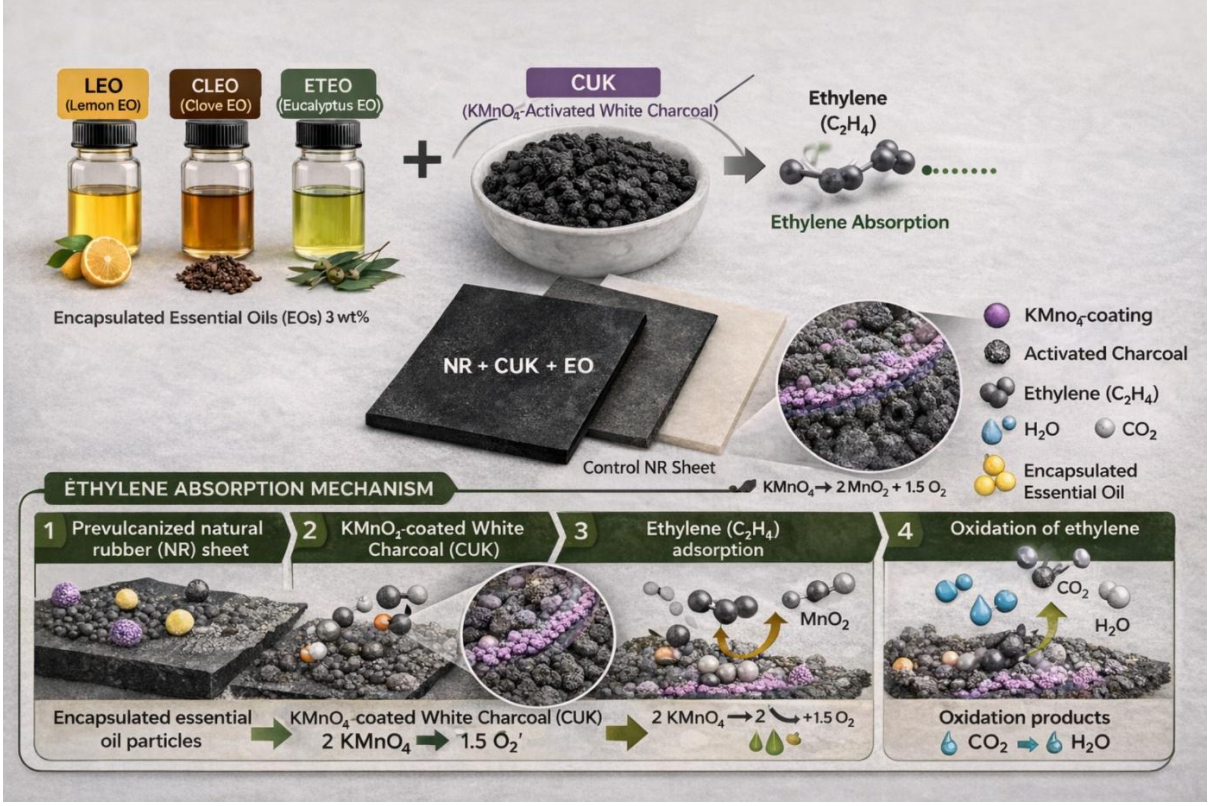
Natural rubber (NR) absorber sheets are gaining increasing attention for active packaging applications due to their flexibility and biodegradability. However, the incorporation of functional additives to impart ethylene-absorbing and insect-repelling properties often affects the mechanical performance of the material, limiting its practical use. To date, the addition of functional fillers and bioactive compounds into rubber matrices has been considered a promising approach to develop multifunctional materials while maintaining structural integrity.

We believe that incorporating potassium permanganate–activated white charcoal (CUK) and encapsulated essential oils (EOs) into prevulcanized natural rubber latex (PNR) is an effective approach to fabricate active rubber sheets for climacteric fruit applications. In this study, three encapsulated essential oils, lemon (LEO), clove (CLEO), and eucalyptus (ETEO) were incorporated at 3 wt%. The NR rubber sheets were prepared through mixing, casting, and drying processes. The resulting NR sheets were characterized in terms of chemical structure, crosslink density, swelling behavior, water vapor permeability, mechanical properties, surface morphology, and ethylene absorption efficiency.

The results indicated that the incorporation of CUK combined with encapsulated eucalyptus or lemon essential oil slightly increased the crosslink density compared to the control. The sheet containing encapsulated lemon essential oil exhibited the highest tear strength. Notably, all essential oils showed no significant effect on modulus or elongation at break. These findings indicate that the developed NR sheets retain adequate mechanical properties and have strong potential for use as active packaging materials for climacteric fruits.

Scheme I



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