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Porous Modified Calcium Carbonate as an Efficient Carrier for Gallic and Ascorbic Acids in Humidity-Activated Oxygen Scavenging Systems

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Abstract:

Modified calcium carbonate (MCC) is a porous mineral material with a large specific surface area. In this study, MCC was investigated as a solid carrier for two natural oxygen-scavenging compounds, gallic acid (GA) and ascorbic acid (AA) to develop humidity-activated oxygen scavenging systems for food packaging applications. MCC was loaded with GA (9–20 wt%) and AA (9–25 wt%) and structurally characterized by mercury intrusion porosimetry, nitrogen adsorption (BET) and scanning electron microscopy. Oxygen scavenging activity was evaluated under controlled relative humidity (37%–100% RH) and temperature (5°C–30°C). MCC largely preserved its porous structure after loading, although pore volume and surface area decreased with increasing loading. Intermediate loadings of 13 wt% GA or AA provided the most efficient scavenger utilization. Under humid conditions (≥ 87% RH), 13 wt% GA-loaded MCC reduced the oxygen concentration in modified atmosphere packages (2 vol-% O_2) to below 0.01 vol-% within 27 days at 21°C, with oxygen scavenging rates reaching 14.1 mL O_2 d^{-1} gGA^{-1} at 30°C. AA-loaded MCC showed lower activity, with maximum scavenging rates of 4.5 mL O_2 d^{-1} gAA^{-1} under comparable conditions. No measurable oxygen scavenging occurred below 67% RH. Temperature primarily influenced reaction kinetics, with GA-loaded MCC remaining effective under refrigerated storage, albeit with reduced rates. Long-term tests under normal atmosphere revealed oxygen absorption capacities exceeding 300 mL O_2 gGA^{-1} and 100 mL O_2 gAA^{-1}. Overall, the results demonstrate that MCC is an effective porous carrier for humidity-activated oxygen scavengers, offering a platform for high-moisture packaging applications. Porous MCC is presented as an efficient carrier for humidity-activated oxygen scavengers based on GA and AA. The porous MCC structure preserves high accessibility of the active compounds, enabling effective oxygen scavenging under high relative humidity, with performance governed by loading level, temperature and carrier accessibility. The results demonstrate a rational carrier-based approach for designing bio-based oxygen scavenging systems for high–water activity packaging applications.

Keywords: active packaging, ascorbic acid, gallic acid, modified calcium carbonate, oxygen scavenger