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Micro and mesoporous materials with essential oils as sustainable biocide materials

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Over the last few years policy is shifting towards more sustainable models, and agriculture is changing together. Legislative changes in the use of pesticides lead to the search for new materials that guarantee the needs of the present without compromising future generations. Consequently, there is an increasing necessity to develop new sustainable materials with fungicidal properties to preserve the quality of fresh horticultural produce during storage. Postharvest diseases of citrus fruits, mainly caused by wound pathogens such as *Penicillium digitatum* (PD), *Penicillium italicum* (PI) and *Geotrichum citri-aurantii* (GC), can produce large economic losses [1]. Many studies have been conducted to find biocide materials that may control the development of these fungi. It has been reported that silver-functionalised zeolitic materials are effective to reduce decay on oranges infected by these fungi [2], but the release of silver may be a problem due to strict regulations associated with food products. An alternative can be the use natural substances as thyme and cinnamon essential oils supported on zeolites as biocidal agents against PD, PI and GC. *In vitro* studies using Faujasite zeolites impregnated with essential oils at different concentrations showed a significant fungal growth inhibition, obtaining the best results with thyme essential oil. In subsequent *in vivo* studies, LTA and MCM-22 zeolites synthesized from silica extracted from rice husks, SiO_2 and a pillared clay with 20% by weight of thyme essential oil were applied to oranges artificially inoculated with each fungus. Results showed that the antifungal activity highly depended on the fungus and the material used. LTA zeolite with 20% thyme essential oil was the most active antifungal material. As another alternative, silica mesoporous materials were synthetised and impregnated with pomegranate peel extract (PPE) in aqueous or methanolic medium. In *in vitro* studies, these materials inhibited the growth of PD by 80% compared to the control without functionalised silica. Furthermore, *in vivo* studies with oranges artificially inoculated with each fungus showed the biocidal activity of the PPE-functionalised materials, especially against PD and PI. Nevertheless, optimization of these materials is still necessary to improve their disease control and general performance.

[1] L. Palou, *Postharvest Decay. Control Strategies.* **2014**, 45-102.
[2] J. L. Cerrillo, A.E. Palomares, F. Rey, S. Valencia, L. Palou, M.B. Pérez-Gago, *Microporous and Mesoporous Mater.*, **2017**, *254*, 69-76.