

ABSTRACT

The approaches that enhance essential oils (EOs) characteristics for their suitability as biorational pesticides have been regarded more precisely. In stored grain pest management, to facilitate and develop the applicability of the EOs, the essential oils nanoformulation (EONF) is a promising strategy. In this study, the repellent and toxicity effects of turmeric (*Curcuma longa*) EO and its PEs was evaluated against *Tribolium Castaneum* (Herbst), the red flour beetle. The turmeric rhizomes produce 0.75% of oil by hydrodistillation. GC-MS characterization of TEO confirmed the presence of potent constituents important for pest control. The FT-IR spectra of Cellulose Nanocrystals (CNC) ensured the presence of cellulose, confirming its efficient extraction. Characterization of the Pickering emulsions, included assessments of zeta potential, Polydispersity index (PDI) and particle size, revealed a stable formulation suitable for effective oil retention. Characterization of alginate beads using X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and FTIR, elucidated their structural integrity and morphological features. UV-Vis spectrophotometry calculated the encapsulation efficiency of the nano-encapsulated TEO, exploring a high retention rate within the alginate matrix. The insecticidal efficacy was rigorously evaluated through both repellency and contact toxicity assays. The percentage repellency (PR) of 100% was recorded against *T. Castaneum* after 1, 3, and 6 hours of exposure period at 0.45% concentration. Notably, the encapsulated hydrogel beads with LC50 and LC90 value 640 and 993 $\mu\text{l/ml}$, respectively demonstrated significantly enhanced contact toxicity ($P < 0.001$) compared to the pure TEO with LC50/LC90 value 79.8 /140 $\mu\text{l/ml}$, respectively achieving remarkable mortality rates in *T. Castaneum*. The overall findings of this research suggest that the TEO PEs encapsulated beads can be used as eco-friendly and sustainable strategy for an efficient control of *T. Castaneum*.