

# Effects of mandarin (*Citrus reticulata*) peel essential oil as a natural antibiofilm agent against *Aspergillus niger* in onion bulbs

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## Abstract

The efficacy of the mandarin peel essential oil (MPEO) was evaluated for antibiofilm activity against *A. niger* with the effect on the development of black mold in onion bulbs in both curative and preventive applications. The detection of *A. niger* biofilm in onion bulbs by scanning electron microscopy (SEM), and fluorescence microscopy (FM) was performed for the first time. Twelve constituents were identified in the MPEO by GC–MS analysis, and the predominant compound was limonene by 75.16%. The concentration of 30.72 mL L<sup>-1</sup> of MPEO completely inhibited the planktonic growth of *A. niger* as well as the formation and eradication of *A. niger* biofilm. The changes in the biofilm morphology treated with MPEO were observed using scanning electron microscopy (SEM), including loss of ability to biofilm formation, absence of extracellular polymeric substances (EPS) and collapse of hyphae. Also, transmission electron microscopy (SEM) observations revealed ultrastructural alterations, including the disintegration of cytoplasmic organelles and folding of the cell membrane at various sites. Also, the fungal cell membrane integrity was affected by MPEO as detected by FM. Furthermore, the MPEO caused a considerable reduction in the development of black mold in onion bulbs inoculated with *A. niger* in the curative and preventive applications. The MPEO and its active components could be effective natural agent as an alternative to synthetic fungicides against *A. niger* in both planktonic and biofilm form.