

## Licorice-garlic-fennel essential oils composite nanoparticles as natural food preservatives

Maral Zahedi

*Department of Chemical Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran.*

*E-mail: [docmaral@yahoo.com](mailto:docmaral@yahoo.com)*

Behnaz Memar Maher\*

*Department of Chemical Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran.*

*E-mail: [b\\_maher@iau-ahar.ac.ir](mailto:b_maher@iau-ahar.ac.ir)*

Navideh Anarjan

*Faculty of Engineering, Islamic Azad University, Tabriz Science and Research Branch, Tabriz, Iran.*

*Email: [anarjan@gmail.com](mailto:anarjan@gmail.com)*

Hamed Hamishekar

*Pharmaceutical Technology Laboratory, Drug Applied Research Center, Tabriz University of Medical, Tabriz, Iran.*

*Email: [hamishehkar.hamed@gmail.com](mailto:hamishehkar.hamed@gmail.com)*

### Antibacterial activities

The antibacterial activities of macro-sized and nano-sized essential oils, individual or in three-component combination (optimum formulation) are shown in figures S1-S8.

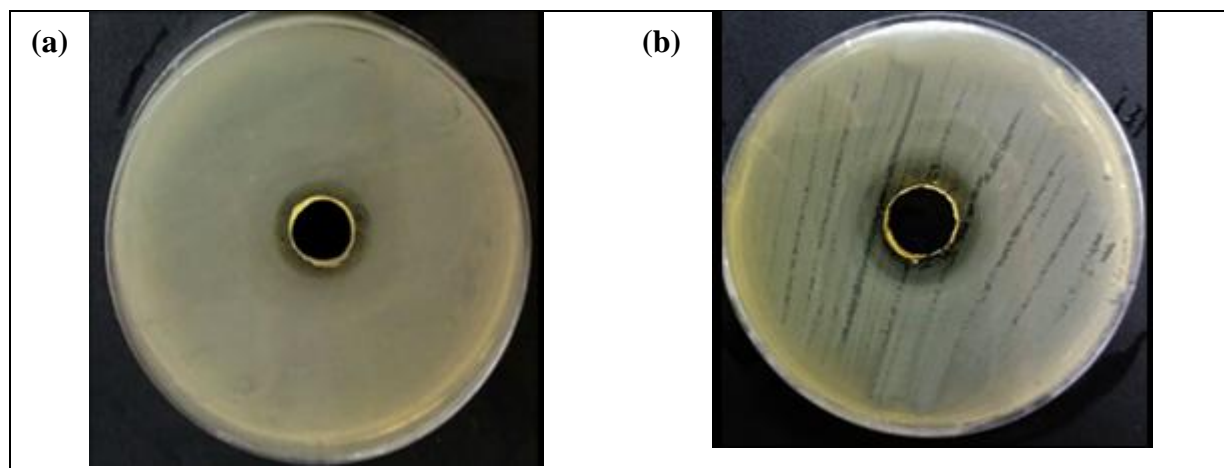


Figure S1. Antibacterial inhibitory zone against *S. aureus* (mm) of Licorice essential oil (a) and Licorice essential oil nanoemulsion (b).

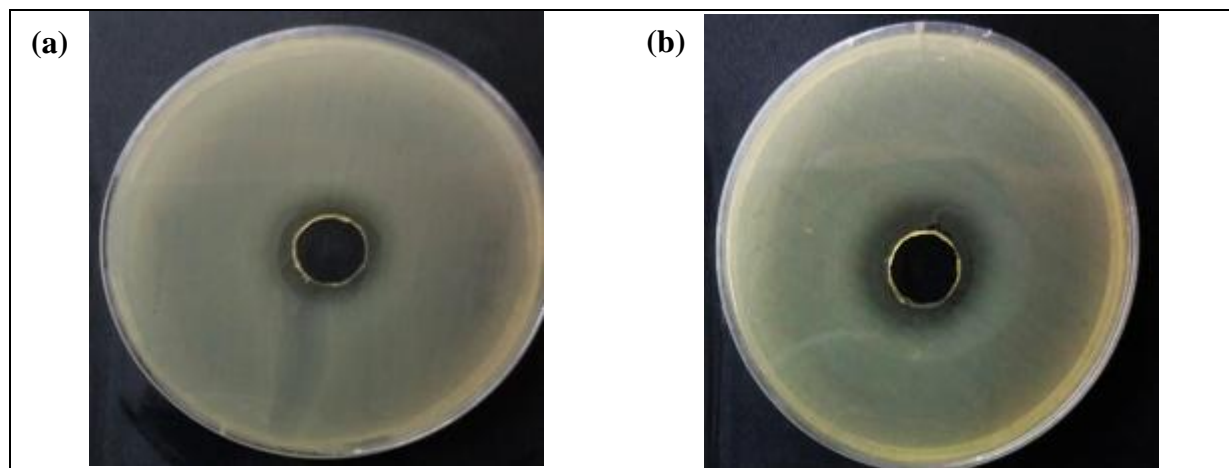


Figure S2. Antibacterial inhibitory zone against *S. aureus* (mm) of Garlic essential oil (a) and Garlic essential oil nanoemulsion (b).

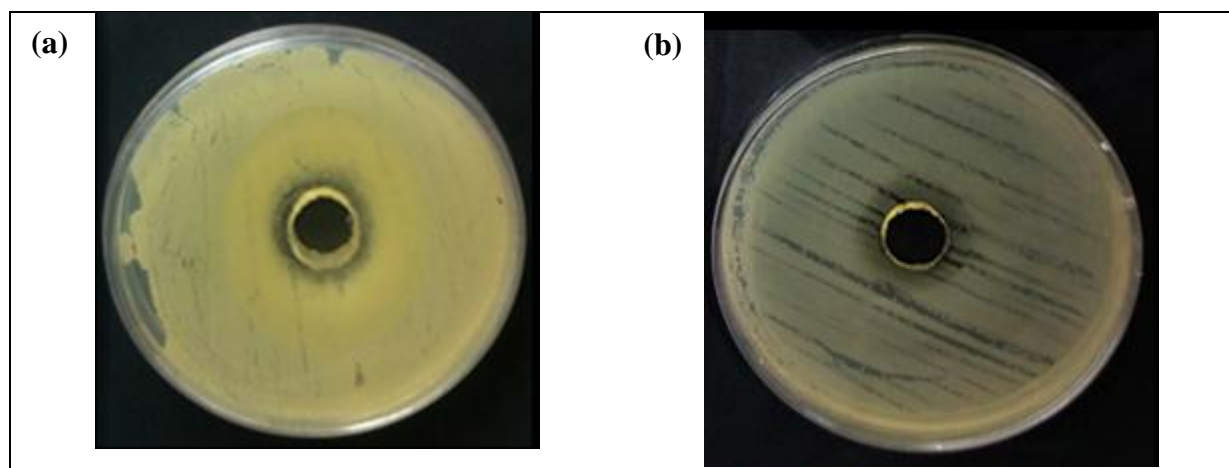


Figure S3. Antibacterial inhibitory zone against *S. aureus* (mm) of Fennel essential oil (a) and Fennel essential oil nanoemulsion (b).

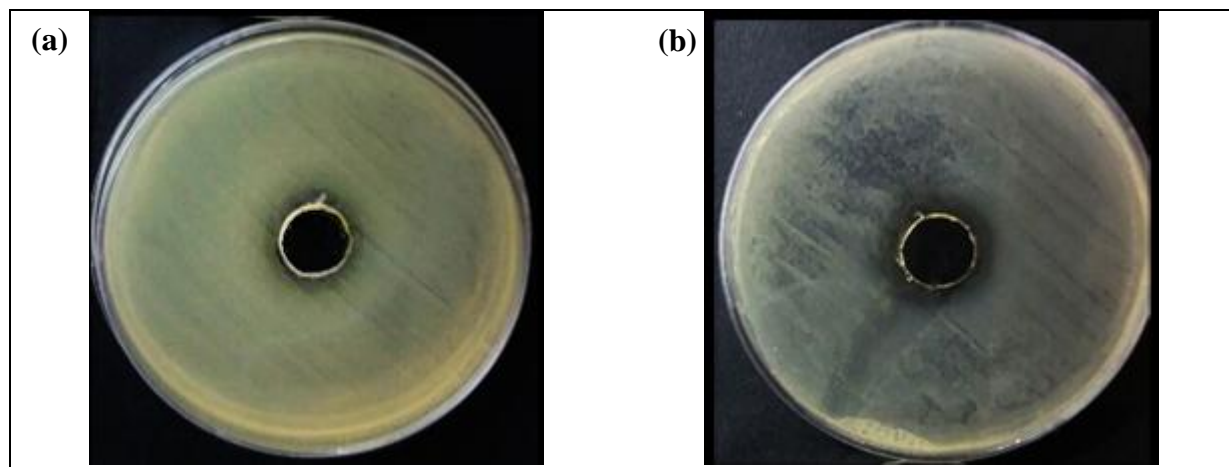


Figure S4. Antibacterial inhibitory zone against *E. coli* (mm) of Licorice essential oil (a) and Licorice essential oil nanoemulsion (b).

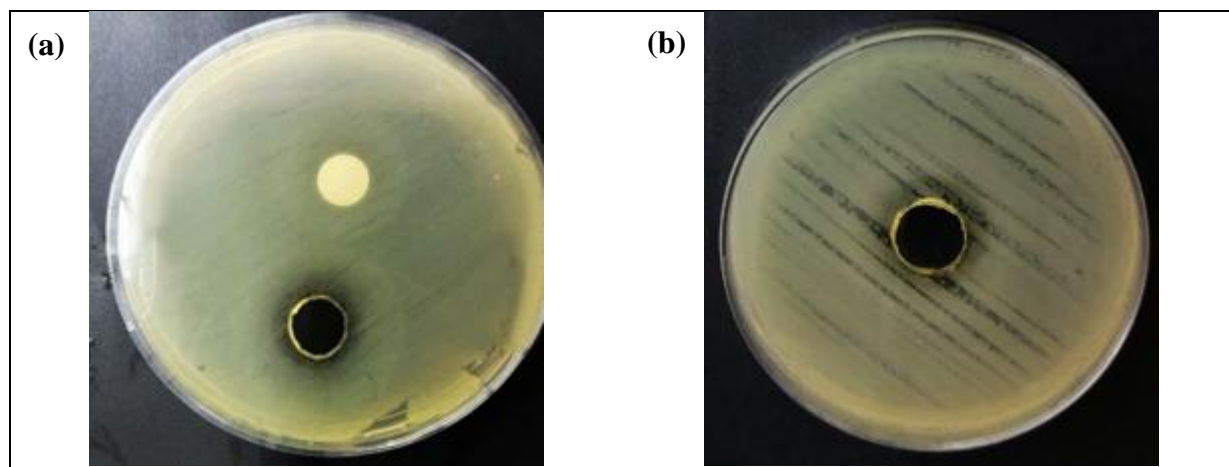


Figure S5. Antibacterial inhibitory zone against *E. coli* (mm) of Garlic essential oil (a) and Garlic essential oil nanoemulsion (b).

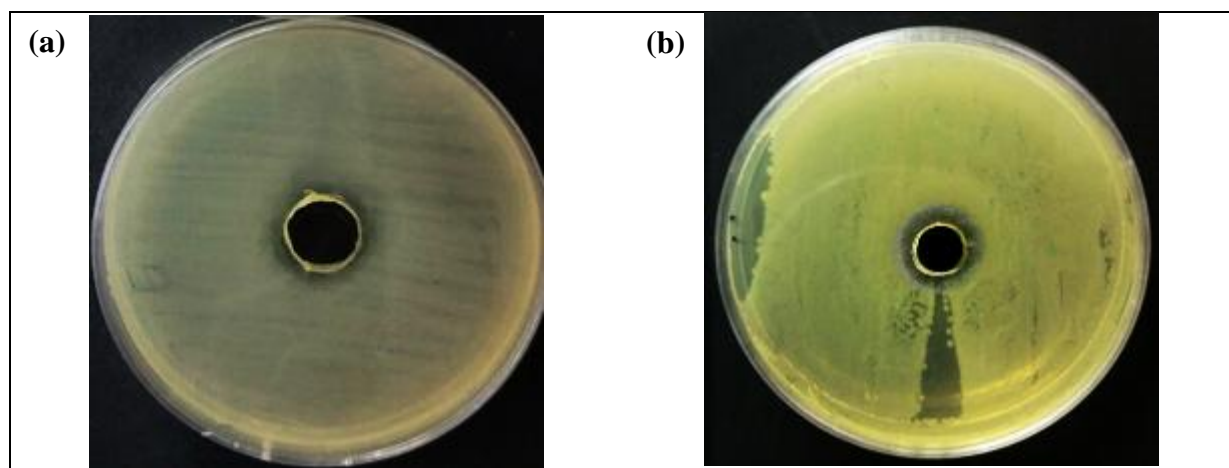


Figure S6. Antibacterial inhibitory zone against *E. coli* (mm) of Fennel essential oil (a) and Fennel essential oil nanoemulsion (b).

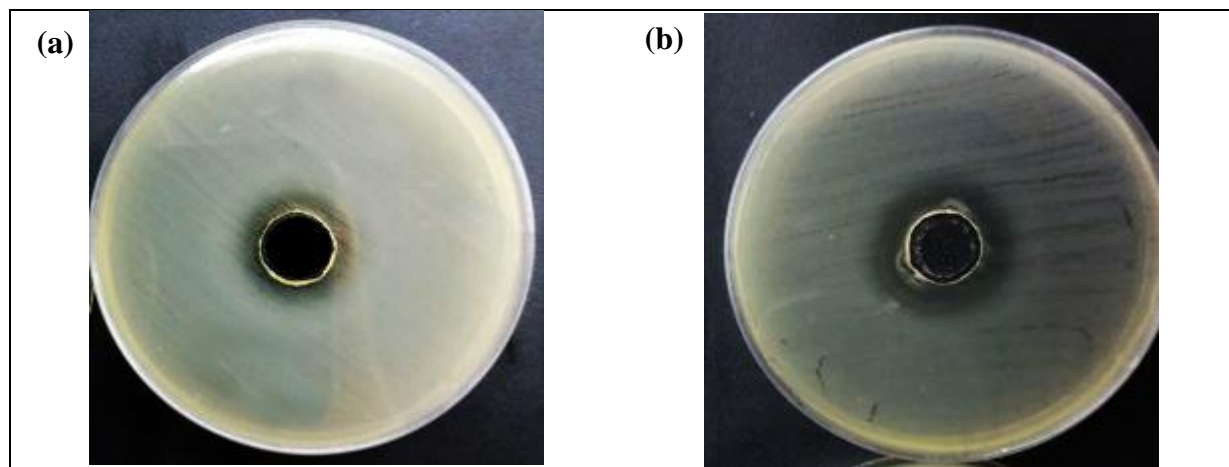


Figure S7. Antibacterial inhibitory zone against *S. aureus* (mm) of Mixture of licorice, garlic and fennel (a) and Mixture essential oil nanoemulsions (b) (oil phase composed of 39% licorice, 40% garlic and 21% fennel essential oil).

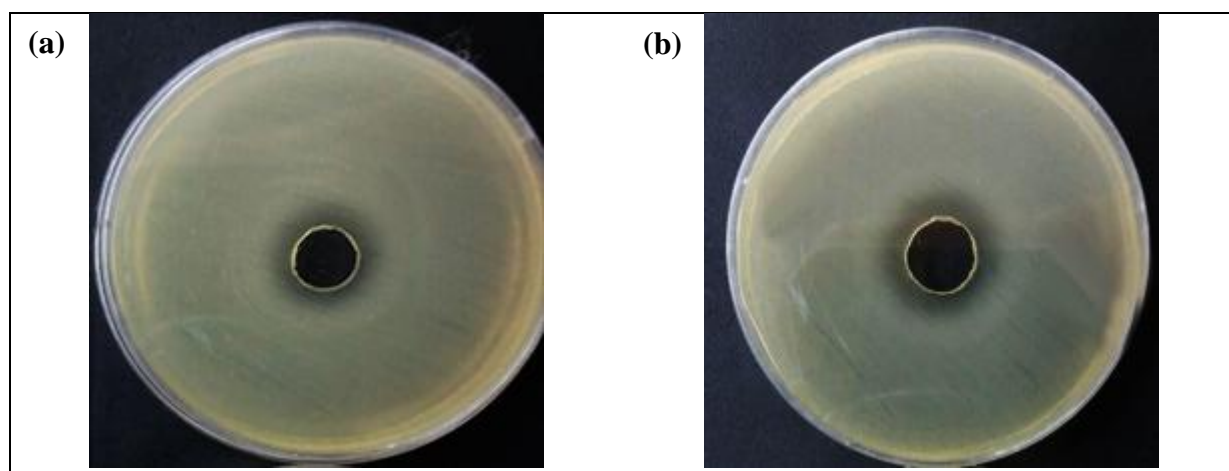


Figure S8. Antibacterial inhibitory zone against *E. coli* (mm) of Mixture of licorice, garlic and fennel (a) and Mixture essential oil nanoemulsions (b) (oil phase composed of 39% licorice, 40% garlic and 21% fennel essential oil).