
A minimal processing approach: unravelling the synergistic effect of combining low & high frequency electric fields to ensure microbial safety in liquid foods

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Radio frequency (RF) is a novel alternative to conventional thermal treatment to ensure microbial safety in liquid foods. The frequency plays an important role in the mechanism of microbial inactivation by RF, with low frequencies (LF) occupying the range below 100 kHz and providing a non-thermal effect whereas high frequencies (HF), within the MHz range, mainly causing thermal inactivation.

Minimal processing approaches exploit the additive or synergistic effects of combining different treatments at mild or moderate conditions to ensure microbial safety. The synergistic effect, which is achieved by targeting multiple sites within the microbial cells, enhances the inactivation level, reduces the required energy input, and minimizes the impact on nutritional and quality attributes. This is of paramount importance as consumer demands in recent years have favored fresh-like and natural products.

In this study, we investigated the synergistic effect of combining LF and HF treatments on *Escherichia coli* (*E.coli*) inactivation in liquid foods. We demonstrated that synergism can be achieved in the liquid food model when LF at a minimum of 10 kV cm⁻¹ and 40 °C was combined with HF at a minimum of 1.9 kV cm⁻¹ and 60 °C. The synergism yielded a minimum 5 log reduction in the *E.coli* population, which fulfilled the requirements set by food authorities. Furthermore, the optimal conditions were applied to actual liquid foods demonstrating synergy. Finally, electron microscopy techniques exhibited that LF alone disrupted the ultrastructure of *E.coli* cell wall whilst HF additionally degraded cytoplasmic components. The HF treatment provided an ultrashort thermal effect as the treatment time was within the ms range. The sequential combination of LF and HF treatments caused greater ultrastructural damage to *E.coli* as designated by detected puncture and rupture of the cell walls as well as leakage of cytoplasmic content.