



# Determination of residual behaviours of deltamethrin and lambda-cyhalothrin in apples under open field conditions and health risk assessment

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## ABSTRACT

This study investigates the dissipation kinetics of deltamethrin and lambda-cyhalothrin residues in apples grown in two distinct regions in Türkiye under open-field conditions. Using the QuEChERS method coupled with LC-MS/MS analysis, the method was validated with recovery rates within acceptable ranges and high sensitivity, achieving LOQ values of 2.77 µg/kg for deltamethrin and 3.40 µg/kg for lambda-cyhalothrin. Both pesticides exhibited first-order kinetic degradation, with half-lives ranging from 1.49 to 1.99 days for deltamethrin and 2.59 to 3.65 days for lambda-cyhalothrin. Residue levels remained below maximum residue limits (MRLs) for recommended application rates shortly after spraying, ensuring compliance with safety standards. However, double-dose applications resulted in higher initial residues, extended half-lives, and increased short-term exposure risks. A health risk assessment revealed hazard quotients (HQa and HQc) well below 1, indicating negligible acute and chronic risks for consumers under recommended practices. These findings underscore the importance of adhering to proper pesticide application guidelines to minimize risks and ensure food safety.

## 1. Introduction

Apple (*Malus domestica* L.), an essential member of the Rosaceae family, is widely cultivated worldwide. Due to its extensive cultivation areas and versatile uses, it is the third most produced fruit globally after bananas and grapes. According to the FAO, in 2022, 6.95 million hectares of land yielded 143.4 million tons of apples. China leads global apple production with 47.5 million tons, followed by Türkiye with 4.8 million tons [21]. Apple production's global prominence highlights the necessity of effective agricultural practices to maintain yield and quality. Apple orchards, like all cultivated plants, are susceptible to numerous diseases and pests that directly impact yield. Major pest species affecting apple trees include codling moth (*Cydia pomonella* L.), lackey moth (*Malacosoma neustria* L.), apple ermine moth (*Yponomeuta malinellus* Zeller), Bituberculatum scale (*Palaeolecanium bituberculatum* Signoret), San Jose scale (*Quadraspidiotus perniciosus* Comstock), leopard moth (*Zeuzera pyrina* L.), apple bark borer (*Synanthedon myopaeformis* Borkhausen), hairy beetle (*Epicometis hirta* Poda), woolly apple aphid

(*Eriosoma lanigerum* Hausmann), leafrollers, aphids, and red spider mites [5]. Various pest management strategies are employed to mitigate the damage caused by these pests and ensure sustainable apple production, including chemical control, biological control, and cultural practices. Pesticides play a crucial role in modern agriculture by enhancing crop productivity, improving quality, extending shelf life, and minimizing post-harvest losses [37].

Deltamethrin and lambda-cyhalothrin are widely used pesticides in apple cultivation due to their effectiveness against harmful organisms [10,26,29,38,50,52]. Studies confirm its frequent use in *Cydia pomonella* management across major apple-producing regions reported that while lambda-cyhalothrin remains effective in codling moth control, its prolonged use has contributed to the evolution of resistance mechanisms, leading to increased pesticide application rates and frequency to maintain efficacy [10,26,29,30,51]. Deltamethrin effectively controls codling moths, but resistance development is a growing concern. Research conducted in Türkiye has reported resistance ratios of codling moth populations to deltamethrin ranging from 3.38 to 22.37-fold, leading to

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