



Pesticide residues in citrus fruits from Türkiye: Assessment of distribution, matrix effects, and health risks in lemon, mandarin, and orange

Hasan Karaağaçlı¹, Tarık Balkan^{*2}, Mehmet Kızılarşlan³, Kenan Kara⁴

Department of Plant Protection, Faculty of Agriculture, Tokat Gaziosmanpaşa University, Tokat 60150, Türkiye

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ABSTRACT

This study investigates the occurrence, distribution, and health risks of pesticide residues in citrus fruits (lemon, mandarin, and orange) collected from various regions in Türkiye. A total of 260 pesticides were analyzed using liquid chromatography-tandem mass spectrometry (LC-MS/MS), and residue levels were evaluated based on EU maximum residue limits (EU-MRLs). Pesticide residues were detected in 109 samples, with 28 exceeding the EU-MRLs. The most frequently detected pesticides were malathion, acetamiprid, and buprofezin. Matrix effects varied significantly among citrus varieties, emphasizing the necessity of matrix-matched calibration for accurate residue quantification. The health risk assessment indicated that chronic exposure to pesticide residues in citrus fruits remained within acceptable limits for adults. However, children were found to be more vulnerable due to their lower body weight and higher consumption relative to body mass. Acute exposure evaluations revealed that certain pesticides (particularly imazalil, chlorpyrifos, and pyrimethanil) exceeded safety thresholds in citrus peels. These findings highlight the need for more rigorous monitoring, improved pre- and post-harvest practices, and risk mitigation strategies, particularly for vulnerable groups such as children. The study emphasizes the importance of considering tissue-specific residue distribution in exposure assessments and policymaking.

1. Introduction

Citrus fruits are a group of plants within the Citrus genus, encompassing numerous economically and agriculturally significant fruit species. Common citrus fruits like oranges, mandarins, and lemons are widely cultivated globally and in Türkiye. In contrast, although less common, others, such as grapefruits, limes, sour oranges, kumquats, and bergamots, also have substantial consumer demand. These plants represent a vital agricultural commodity for the Mediterranean region, including Türkiye (El-Otmani et al., 2011). In 2021, global citrus production was estimated by the Food and Agriculture Organization at 143.5 million tons. China ranked first with 37.7 million tons, followed by Brazil (19.6 million tons) and North America (15 million tons). Türkiye, the eighth-largest citrus producer globally, produced 4.7 million tons in 2022, with production comprising 40 % mandarins, 28 % oranges, 28 % lemons, and 4 % grapefruits (FAO, 2022).

Most of the production is exported to EU countries and the Russian Federation. The Rapid Alert System for Food and Feed (RASFF) reported that citrus fruits exported from Türkiye had detected pesticide residues, with 145, 42, and 23 incidents in lemons, mandarins, and oranges, respectively (RASFF, 2025). Recent international studies have also highlighted similar concerns regarding pesticide residue detections, including unauthorized pesticide usage and residues exceeding regulatory limits, in citrus fruits globally (Golge and Kabak, 2015; Soydan et al., 2021; Bibi et al., 2022; Drábová et al., 2022; Omeroglu et al., 2022; Aslantas et al., 2023; Gormez et al., 2023; Malhat et al., 2025). These findings highlight the importance of aligning monitoring efforts with current regulatory standards to ensure consumer safety and compliance with international standards. Comprehensive residue analysis and risk assessments are essential for meeting global market safety standards, protecting public health, and sustaining Türkiye's competitiveness in citrus exports.

* Corresponding author.

E-mail addresses: Hasankaraagacli68@gmail.com (H. Karaağaçlı), tarik.balkan@gop.edu.tr (T. Balkan), mehmetkizilarşlan60@gmail.com (M. Kızılarşlan), kenan.kara@gop.edu.tr (K. Kara).

¹ 0000-0003-3275-5873

² 0000-0003-4756-4842

³ 0000-0002-6739-6551

⁴ 0000-0003-0439-5639

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