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Research Note

Screening of Pesticide Residues in Cornflakes Available on the UAE Market

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A R T I C L E I N F O

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A B S T R A C T

Cornflakes are a globally popular breakfast cereal, commonly consumed in the United Arab Emirates (UAE). Given the UAE's dependence on imported food products, including cornflakes, ensuring the safety of consumers through vigilant monitoring of pesticide residues is crucial. Following a market screening of major UAE retail markets, this study identified 76 cornflakes stock-keeping units (SKUs) and analyzed them using the quick, easy, cheap, effective, rugged, and safe (QuEChERS) extraction method coupled with liquid chromatography–tandem mass spectrometry (LC–MS/MS). Three pesticide residues, azoxystrobin, chlorpyrifos, and tebuconazole, were detected at trace levels, all below the limit of quantification (LOQ). None of the residues exceeded the maximum residue limits (MRLs) established by UAES MRL 1:2024, which follows a hierarchical approach using Codex Alimentarius (CODEX) and European Union (EU) MRLs. The detection of chlorpyrifos, an organophosphate insecticide, and the fungicides azoxystrobin and tebuconazole, reflects their widespread agricultural use, yet their low levels demonstrate the impact of food processing steps, such as milling, extrusion, and toasting, and effective regulatory oversight. These findings indicate that cornflakes available in the UAE market are safe with respect to pesticide residues, though routine surveillance remains essential.

The global consumption of cereal-based food products is steadily increasing. Among these are cornflakes, which are widely consumed and recognized as important sources of energy and essential nutrients (Hassan et al., 2017; Dimassi et al., 2020; Elrahi et al., 2023). In the UAE, cornflakes are increasingly popular due to urbanization, changing dietary habits, and effective marketing strategies emphasizing health benefits (Ng et al., 2011; Benvenuto, 2018; Parra-Murillo et al., 2021; Ali et al., 2022; Al Sabbah et al., 2023).

The UAE's food system is highly import-dependent because of extreme climatic conditions and limited arable land, making it one of the region's largest net food importers. A wide range of commodities enters via Dubai ports from countries such as India, Egypt, France, Germany, Spain, and Poland (FAO, 2017; PMA, 2020). As these imported commodities are produced under different agricultural practices worldwide, including different levels of pesticide use, concerns arise about the potential presence of residues in food products sold in the UAE (Osaili et al., 2022).

Pesticides are widely used in agriculture to control pests and plant diseases, contributing to increased crop yields and reduced agricultural losses (Khazaal et al., 2022; Osaili et al., 2023; Almenhali et al., 2025). Nearly one-third of agricultural commodities rely on pesticide application, and without them, crop losses would be substantial, with an estimated 78% reduction in fruit yields, 54% in vegetables, and 32% in cereals (Lamichhane, 2017). Globally, pesticide consumption has continued to rise, reaching approximately 3.7 million tons annually in 2022, which enhances production but also amplifies concerns about environmental contamination and resistance (Blair et al., 2015; Steingrímsdóttir et al., 2018; FAO, 2024). Excessive or uncontrolled application can lead to residues in food products, which may cause acute effects such as headaches and nausea, as well as chronic outcomes including cancer and endocrine, reproductive, and neurological disorders (Bakirci et al., 2014; Rezaeigolestani & Hashemi, 2018; Algharibeh & AlFararjeh, 2019; Sadighara et al., 2023).

Monitoring pesticide residues in staple products such as cornflakes is therefore essential to ensure any residues present are safe and acceptable. To mitigate these risks and ensure food safety, international and national authorities have adopted stricter regulations, including lowering maximum residue limits (MRLs) in food products

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(Merhi, Taleb, et al., 2022). In the UAE, MRLs for pesticide residues in agricultural and food products (UAES MRL 1:2024) are regulated and enforced by the Emirates Authority for Standards and Metrology (ESMA), which has now merged into the Ministry of Industry and Advanced Technology (MoIAT) (Abd El-Mageed et al., 2020), following Codex Alimentarius Commission standards (Codex, 2021) and European Commission standards (European Commission, 2021). At the port-of-entry, the Dubai Municipality Food Safety Department monitors imported shipments for compliance. Ensuring food safety is therefore a paramount priority for UAE regulatory authorities.

Given that the UAE has a diverse population representing over 200 nationalities, with highly varied food consumption patterns, our study was designed to comprehensively assess pesticide residues in all cornflakes stock – keeping units (SKUs) available in the UAE market. Moreover, limited data are available on pesticide residues in cereals in the Gulf region, further highlighting the need for such monitoring. Therefore, this study aims to determine and quantify pesticide residues in cornflake samples collected from the UAE, using the quick, easy, cheap, effective, rugged, and safe (QuEChERS) extraction method for sample preparation and liquid chromatography–tandem mass spectrometry (LC–MS/MS) for analysis.

Materials and methods

Sampling. The largest retail markets in the UAE were screened, and a total of 76 different cornflakes SKUs were identified and collected between May and September 2023. All samples were labeled and stored at room temperature until analysis. Sample preparation and analytical procedures were carried out during February and March 2024. Prior to extraction, the cornflakes samples were ground using a blender and thoroughly homogenized.

Extraction of pesticide residues. Pesticide residues were extracted using the QuEChERS EN 15662:2018 method (Mastovska et al., 2009; Khazaal et al., 2022). Briefly, 5 g of ground cornflakes was mixed with 10 mL of distilled water and homogenized for 1 min. Ten mL of acetonitrile (ACN, HPLC grade, Honeywell, Seelze, Germany) was then added, followed by mixing for an additional 1 min. Extraction salts (4 g magnesium sulfate, 1 g sodium chloride, 1 g sodium citrate dihydrate, and 0.5 g sodium citrate sesquihydrate, Sigma-Aldrich, Darmstadt, Germany) were added, and the mixture was shaken vigorously for 3 min and centrifuged at 5000 rpm for 5 min. The supernatant was kept frozen at –20 °C for at least 2 h. An aliquot of 1 mL of the acetonitrile layer was transferred into a 2 mL dispersive solid-phase extraction (d-SPE) tube containing 0.15 g magnesium sulfate, 0.05 g PSA (Sigma-Aldrich, St. Louis, MO, USA), and 0.025 g C18 (Sigma-Aldrich, St. Louis, MO, USA), vortexed for 1 min, and centrifuged again at 5000 rpm for 5 min. The final extract was filtered through a 0.22 μm polyvinylidene fluoride (PVDF) syringe filter and transferred into a 1 mL autosampler glass vial for LC–MS/MS analysis.

LC-MS/MS analysis. LC–MS/MS analysis was performed using a Shimadzu LCMS-8045 triple quadrupole tandem mass spectrometer coupled to a liquid chromatograph (Shimadzu, Kyoto, Japan). Separation of pesticide residues was achieved using a C18 analytical column (Zorbax, 2.1 mm × 100 mm, 3 μm particle size; Agilent Technologies, Santa Clara, CA, USA) maintained at 40 °C. The mobile phases consisted of (A) 5 mM ammonium acetate (HPLC grade, Sigma-Aldrich, Darmstadt, Germany) with 20% methanol (HPLC grade, Sigma-Aldrich, Darmstadt, Germany) in water, and (B) 5 mM ammonium acetate in methanol. The flow rate was 0.2 mL/min, and the injection volume was 10 μL. The gradient elution program was as follows: 40% B for 3.5 min, increased to 55% B for 4.5 min, then increased to 95% B for 22 min, followed by a decrease to 15% B for 10 min. The total run time was 40 min. A total of 104 pesticides were monitored in this study, and their complete list is provided in Table S1 (Supplementary Material).

Results and discussion

A total of 76 cornflakes samples were analyzed for pesticide residues using the QuEChERS extraction method and LC–MS/MS. The results showed that only four samples contained detectable residues (Table 1). Azoxystrobin, chlorpyrifos, and tebuconazole were identified at levels ranging between below the limit of detection (LOD) and below the limit of quantification (LOQ). Notably, none of the residues exceeded the MRLs. Chromatograms of the standards for the detected pesticides are shown in Figure 1, while the corresponding calibration curves are provided in the Supplementary Material (Fig. S1). A representative chromatogram of all pesticide standards is also included in the Supplementary Material (Fig. S2).

In addition, the regulatory framework used for MRL comparison has been clearly justified in the Results section, where we state that according to UAES MRL 1:2024, MRLs are applied following a hierarchical approach: (i) Codex Alimentarius MRLs where available; (ii) European Union MRLs in the absence of Codex limits; and (iii) a default MRL of 0.01 mg/kg when neither Codex nor EU MRLs are established.

Using this framework as a reference, the detected residues were evaluated as follows. Azoxystrobin was detected in two samples: one milk chocolate–flavored cornflake from the UK at levels below the LOD (3.33 ppb), and one cocoa-based cornflake also from the UK at 0.0046 ppm, which was below the LOQ (10 ppb) and well under the MRL of 0.02 ppm. Chlorpyrifos was present in one choco shells sample imported from India at 0.0044 ppm (below LOQ), compared to its MRL of 0.01 ppm. Tebuconazole was detected in one frosted cornflake sample from the UK, below the LOD. These findings indicate that while pesticide residues were occasionally present, their concentration was negligible and did not pose any food safety risk. Although food processing can significantly reduce pesticide residues, it does not guarantee their complete removal. Similar findings were reported in coffee, where various mitigation techniques lowered pesticide levels but did not fully eliminate them, thereby reinforcing the need for routine monitoring in processed products (Merhi, Kordahi, et al., 2022).

Many pesticides have been identified as potential carcinogens by the U.S. Environmental Protection Agency (EPA) (Farshidi et al., 2021). They can be classified based on their toxicity, mode of action, environmental persistence, or chemical structure, and are functionally grouped as herbicides, fungicides, insecticides, and rodenticides (Fenik et al., 2011; Farshidi et al., 2021). Structurally, four major classes are recognized: organophosphate pesticides (OPPs), organonitrogen pesticides (ONPs), organochlorine pesticides (OCPs), and pyrethroids (Fenik et al., 2011; Rezaeigolestani & Hashemi, 2018).

Among the detected residues, chlorpyrifos belongs to OPPs, a widely used class of insecticides. Due to its lipophilic nature, chlorpyrifos can persist in soil, water, and food, and has been reported in fruits, grains, and vegetables (Wołejko et al., 2022). Although its use has been banned or restricted in the EU, Canada, Australia, and several other countries, residues may still be found in imported commodities from regions where its application continues (Database of Notifications of Final Regulatory, 2025). The detection of chlorpyrifos, even at trace levels in cornflakes, highlights the importance of continuous monitoring of imported processed foods to ensure compliance with international MRLs and protect consumers' health.

Similarly, the occurrence of azoxystrobin and tebuconazole, widely used fungicides, reflects their common use in cereal cultivation globally. However, their trace presence in cornflakes in this study demonstrates effective regulatory oversight and the impact of processing in reducing residues, resulting in compliance with international safety standards in the UAE.

Table 1
Detected pesticide residues in cornflakes samples (n = 4) in comparison with MRLs.

Pesticide	Sample 1	Sample 2	Sample 3	Sample 4	MRLs (ppm)
Azoxystrobin	<LOD*	ND	0.0046 ppm (<LOQ)	ND	0.02
Chlorpyrifos (Confirmed by GCMSMS)	ND	0.0044 ppm (<LOQ**)	ND	ND	0.01
Tebuconazole	ND	ND	ND	<LOD	0.02

ND = Not Detected.
* LOD = 3.33 ppb.
** LOQ = 10 ppb.

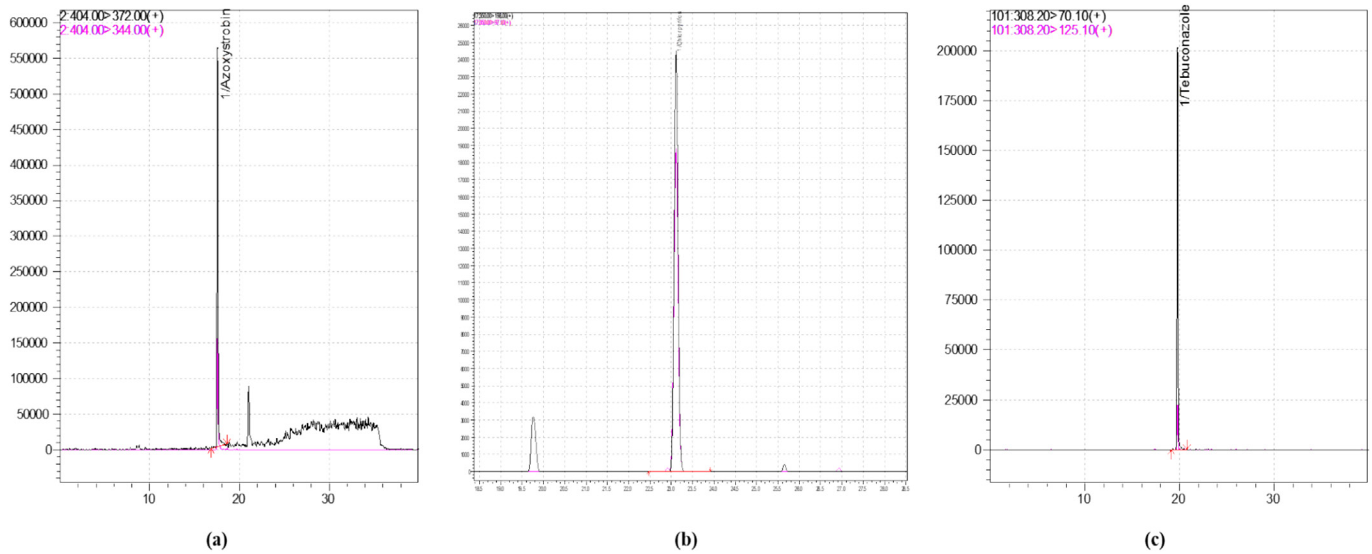

Figure 1. Representative chromatograms of the standards for the pesticides detected: (a) Azoxystrobin, (b) Chlorpyrifos, and (c) Tebuconazole.

A monitoring study conducted on 1,440 cereal grain samples (corn, oats, rice, barley, sorghum, and wheat) imported into the UAE reported that 62.7% of samples were free from residues, 29.1% contained detectable residues, and 8.4% exceeded Codex or EU MRLs, with tricyclazole, thiamethoxam, carbendazim, and buprofezin being the most common violators (Abd El-Mageed et al., 2022). In contrast, the present study on processed cornflakes detected only trace residues, all below established MRLs. This difference may be partly attributed to the effect of processing steps such as milling, extrusion, and toasting, which are known to reduce pesticide levels (Bajwa & Sandhu, 2014), as well as effective regulatory controls that limit noncompliant products from reaching the consumer market.

Overall, the results suggest that cornflakes available on the market in the UAE are safe with respect to pesticide residues. Nevertheless, routine surveillance remains essential to ensure compliance with MRLs, particularly considering the diverse origins of imported food commodities.

This study provides one of the first comprehensive assessments of pesticide residues in processed cereal products, specifically cornflakes, available in the UAE market. The inclusion of all SKUs from major retail chains strengthens the representativeness of the findings. The use of the QuEChERS method coupled with LC–MS/MS ensured high analytical sensitivity, selectivity, and reliability for multiresidue detection. However, certain limitations should be acknowledged. The study was limited to a single product category and sampling period, which may not capture temporal or seasonal variations in residue levels. Future research should expand to other cereal-based products and include a broader range of analytes and sampling periods to better understand residue dynamics in imported foods.

Conclusion

The analysis of 76 cornflakes SKUs imported into the UAE revealed only trace residues of azoxystrobin, chlorpyrifos, and tebuconazole, all below established MRLs. These findings demonstrate that the combined effect of processing in the country of origin, alongside stringent UAE regulatory oversight, effectively ensures low pesticide levels in imported cereal products. While the detected residues were negligible and do not pose a food safety risk, their occasional presence highlights the need for continuous monitoring, particularly for products sourced from diverse agricultural practices worldwide. The study underlines the importance of routine surveillance to maintain compliance with international and national food safety standards. Future studies covering other cereal-based products and extended sampling periods would further strengthen the understanding of pesticide residue patterns in imported foods.

Data availability

Data will be made available on request.

CRediT authorship contribution statement

Nada El Darra: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Salma Khazaal:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Adla Jammoul:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Hussein F. Hassan:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Formal analysis, Data curation. **Nisreen Alwan:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jfp.2025.100681.

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