*Bangladesh Journal of Pharmaceutical 29(2): 235-245, 2026 (July)*

# Residue Levels and Health Risk Assessment of Selected Pesticides in Fruits Marketed in Dhaka, Bangladesh

**Md. Mayin Uddin Hasan[1,§], Shakib Ahmed[1,§], Md. Hanif Biswas[2], Adeeba Anjumand[3] and Md. Zakir Sultan[4]**

[1]Department of Pharmacy, International Islamic University Chittagong, Kumira, Chattogram-4318, Bangladesh
[2]Biological Oceanography Division, Bangladesh Oceanographic Research Institute, Marine Drive, Cox's Bazar- 4730, Bangladesh
[3]Department of Pharmacy, University of Rajshahi, Rajshahi-6205, Rajshahi, Bangladesh
[4]Centre for Advanced Research in Sciences, University of Dhaka, Dhaka-1000, Bangladesh

**(Received: January 04, 2026; Accepted: April 15, 2026; Published (web): July 20, 2026)**

## Abstract

The presence of pesticide contamination in fruits is a substantial concern in the context of food safety and public health. Although pesticides play a crucial role in agricultural techniques for controlling pests and protecting crops, they might potentially endanger consumers' health if they are present in fruit at high levels. Assessing pesticide concentrations, such as carbofuran, fipronil and pretilachlor in different fruit samples, offers a valuable understanding of the intricate nature of pesticide residues and their potential effects on human well-being. A total of 15 distinct varieties of fruit samples were collected from several local fruit markets in Dhaka and the samples were analysed using HPLC for three pesticide residues. The results showed that Carbofuran residues were found in 73.3% of the 15 tested samples, specifically in 11 (Apple, Orange, Grape and Sweet Orange (Malta) samples). Additionally, pretilachlor residues were detected in 16.66% of the samples, with two samples (orange and black grape) exceeding the codex alimentarius maximum residue limits. Most samples contained detectable pesticide residues; however, exceedance of regulatory limits varied by fruit type. The Estimated Average Daily Intakes (EADIs) exceeded the WHO/FAO acceptable daily intake limits for specific fruits, particularly oranges (2.50 mg/kg) and sweet oranges (Malta 2.33 mg/kg). Hazard index (HI) values greater than one were observed for selected fruits, indicating potential health risks, whereas other fruits remained within acceptable safety limits. To effectively address pesticide contamination, it is essential to have strict regulatory oversight and actively promote the adoption of sustainable farming practices. Ensuring food safety and protecting public health relies on collaborative actions throughout the agricultural supply chain. Hence, educating food producers in Bangladesh regarding the proper management and potential pesticide risks is imperative. Understanding the magnitude of pesticide pollution and its compliance with regulatory standards is crucial for ensuring the safety and reliability of the food supply chain.

**Key words:** Pesticide residues, carbofuran, fipronil, pretilachlor, maximum residue limit.

## Introduction

Food security is a critical issue in Bangladesh, with significant progress made in recent years compared to other Asian nations. This progress is driven by policies such as the National Food and Nutrition Security Policy (NFNSP), which aims to ensure access to nutritious food across all life stages. Bangladesh's government has a National Food and Nutrition Security Policy (NFNSP) that attempts to address food security through various laws and policies. This policy aims to enhance food and nutrition security across all phases of life and population categories. These policies, approved in August 2020, constitute a ten-year Plan of Action (POA) and serve as a guideline for ensuring food and nutrition security in the country. Meanwhile, the

**Corresponding authors:** Md. Zakir Sultan; E-mail: zakir.sultan@du.ac.bd; [§]These authors contributed equally.
DOI: https://doi.org/10.3329/bpj.v29i2.91861

government has formed the Bangladesh Food Safety Authority (BFSA) through the Bangladesh Food Safety Act of 2013 (Hosaini, 27 June 2022). The BFSA regulates and implements food safety and quality standards (POLICY and ACTION, 2021-2030).

Food insecurity is characterised by inadequate food and nutrient intake over several months or even years, primarily due to structural factors. It evolves slowly, occurs gradually, and often does not represent an immediate danger to life. Still, it may have significant implications regarding increased susceptibility and long-term adverse effects on health, physical, mental, and cognitive skills. The government of Bangladesh has established the Legal Protection of the Right to Food. This legislative guarantee ensures that every person has access to adequate and nutritious food (Baquedano *et al.*, 2021).

Globally, pesticide contamination is a pressing issue, with the FAO estimating that 3.5 million tonnes of pesticides are used annually, a 20% increase in the last decade, particularly in low-income countries like Bangladesh, where usage has surged 153% to meet food demands (Sarker *et al.*, 2021b). In developing regions, weak regulatory enforcement allows banned substances, such as carbofuran- prohibited in the US since 2009—to persist, resulting in residues in both exports and domestic produce (Lv *et al.*, 2022b). Comparative studies reveal higher contamination levels in South Asia compared to Europe, where strict EU regulations limit residues to below 0.01 mg/kg for many pesticides. In Bangladesh, vegetables often exhibit higher rates of spoilage than fruits; however, fruits like oranges and grapes are particularly vulnerable due to their thin skins and susceptibility to post-harvest treatments (Almamari *et al.*, 2023). Consumer surveys reveal that pesticide residues are the top food safety concern, with over 90% of farmers relying on chemicals and half spraying weekly, leading to 23-43% of households reporting poisoning symptoms (Tambo *et al.*, 2024).

Food adulteration poses significant health hazards to the population of Bangladesh, with studies suggesting that over 4.5 million Bangladeshis are affected by various diseases annually due to the consumption of contaminated food (Yeasmin *et al.*, 2023). Adulteration has been detected in all 43 consumer products examined by the Institute of Public Health Bangladesh, with a rate of 40% in 30 food items and almost 100% in 13 items (Nasreen and Ahmed, 2014). Typical chemical contaminants include colouring agents, insecticides, formalin, carbide, urea, and other derivatives. These chemicals may cause cancer, inflammatory diseases, respiratory disease, and impairment of essential organs such as the liver and kidneys (Thompson and Darwish, 2019).

Pesticides are chemical substances used to defeat or mitigate the effects of harmful organisms. Herbicides, insecticides, fungicides, and nematicides are included (Pathak et al., 2022b). These chemicals prevent, eliminate, repel, or mitigate the presence of pests. Pesticides may cause respiratory, cognitive, dermatological, neurological impairments, pregnancies, and birth abnormalities if consumed for a more extended period (Chowdhury *et al.*, 2018). Food contamination by pesticides is a highly prevalent issue in Bangladesh, causing significant health dangers. Farmers' extensive use of pesticides without implementing adequate standards or safety requirements results in the contamination of pesticide residues on fruit and vegetable plants and harvests (Sarker *et al.*, 2021a). The number of people in Bangladesh affected by illnesses caused by food contamination is alarmingly high, according to numerous reports, including those from the World Health Organisation (WHO) and the Food and Agriculture Organisation (FAO) (Al Banna *et al.*, 2021). Food adulteration, particularly pesticide use, has been identified as a significant contributor to the country's rising incidence of cancer, liver disease, and kidney disease (Rahman *et al.*, 2015).

Carbofuran, chemically known as 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate, is a neurotoxic pesticide frequently employed in insect control across various food sources, posing potential health risks to consumers (Lv *et al.*, 2022a).

Exposure to elevated concentrations of Carbofuran can induce symptoms ranging from nausea, vomiting, and stomach issues to disorientation, impaired vision, and, in severe cases, convulsions, respiratory distress, and fatalities (Kempuraj *et al.*, 2023). Similarly, Fipronil, or 5-amino-1-(2,6-dichloro-α,α,α-trifluoro-p-tolyl)-4-trifluoromethylsulfinylpyrazole-3-carbonitrile, serves as a broad-spectrum pesticide effective against a diverse range of pests, including insects, beetles, and termites. Despite its efficacy, Fipronil's toxicity presents risks to both humans and animals, leading to symptoms like skin irritation, gastrointestinal discomfort, headache, and convulsions upon acute exposure (Liu *et al.*, 2022, Luo, 2023, Mohamed *et al.*, 2004). Pretilachlor, or 2-chloro-2',6'-diethyl-N-(2-propoxyethyl) acetanilide, functions as a chloroacetamide herbicide inhibiting fatty acid synthesis crucial for vegetative growth (Shilpakar *et al.*, 2020). Adverse effects of Pretilachlor on human and animal health include skin irritation, allergic reactions, gastrointestinal disturbances, and potential chronic organ damage (Jiang *et al.*, 2016; Salsabil, *et al.*, 2025; Aktar *et al.*, 2025; Sultan *et al.*, 2025).

The primary objective of analysing fruit samples for pesticide contamination using High-Performance Liquid Chromatography (HPLC) was to detect the presence of Carbofuran, Fipronil, and Pretilachlor pesticides in fruit samples, assess their compliance with safety thresholds, and elucidate the potential health implications associated with pesticide exposure through fruit consumption. By elucidating these dynamics, we can better inform regulatory policies and agricultural practices to mitigate risks and safeguard public health.

## Materials and Methods

*Sample collection:* A total of 15 fruit samples, including apples (n = 5), oranges (n = 5), grapes (n = 2, black and green variety), and sweet oranges (Malta) (n = 3) were directly collected from a temporary floating fruit seller (on a rickshaw hawker) near Ananda Bazar, Gulistan of Dhaka, Bangladesh. The samples were labelled and transported to the laboratory. The samples were kept at -20 °C until analysis.

*Instrumentation:* High-Performance Liquid Chromatography (HPLC, LC solution software) (UFLC, Shimadzu Corporation, Kyoto, Japan) equipped with a UV detector (SPD-10A) and an autosampler was used to analyse the extracts of the sample.

*Reagents and chemicals:* The HPLC-grade solvents were used to prepare the mobile phase. The chemicals and reagents were used to study analytical grade materials purchased from a local vendor.

*Mobile phase:* The mobile phase consisted of a 75:25 (v/v) blend of acetonitrile and 1 mM phosphate buffer (pH 4.5). A phosphate buffer solution with a concentration of 1 mM was made by dissolving 178 mg of disodium hydrogen phosphate in water and diluting it to a final volume of 1000 mL. Orthophosphoric acid was used to alter the pH to 4.5. The mobile phase was passed through a 0.45 µm Millipore membrane filter and treated with an ultrasonic bath sonicator for 15 minutes before utilization. The diluent was used as the mobile phase to prepare the stock standard solution.

*Standard and Sample (Fruits) preparation and analysis:* Working standard solutions (equivalent to 2 to 12 µg/mL) of Carbofuran, Fipronil, and Pretilachlor were prepared by diluting the stock standard solution with the mobile phase.

20 g of each fruit sample finely crushed using by mortar and pestle. Then, a mixture of solvent (50 mL) at the ratio ethyl acetate: hexane: acetone in 30:10:10 to the fruit samples. Then, vortex and sonicate the mixtures. Then, 10g of $MgSO_4$ and 0.05g of silica gel were added to the sonicated mixtures, and the mixtures were filtered with whatman-1 filter paper. The filtrates were taken to the test tubes and centrifuged at 3000 rpm (10 min). Then, the supernatant was concentrated by a rotary evaporator. Approximately 2mL of acetonitrile was added to the fruit samples, sonicated again, and then transferred to vials for analysis by HPLC (Uddin *et al.*, 2024).

*Chromatographic conditions:* These analyses were carried out with the following chromatographic condition:

Column: Phenomenex C18 analytical column (250 mm × 4.6 mm I.D., 5µm particle size)

Flow rate: 1 mL/min.

Column temperature: 25°C

Injection volume: 20 µL

Detection wavelength: 230 nm

Mobile Phase ratio: Acetonitrile: Buffer 75:25

Data Analysis: Pesticide residue levels were measured in mg/kg and compared to the Codex Alimentarius MRL and the Bangladesh Food & Drug Act requirements. Items exceeding Maximum Residue Limits (MRLs) were considered to have violated the regulations, while those meeting or falling below the MRLs were not in violation. Microsoft Excel version 21 (Microsoft Corporation) and STATA version 18.00 (StataCorp, College Station, Texas, USA) were used to calculate the proportion and median of pesticide residue levels in several types of fruits.

*Recovery study:* The quality assurance materials were developed by adding 0.01-0.1 mg/kg of the desired pesticides to fruit samples containing no pesticides. Each analytical batch was subjected to material analysis to confirm the reliability and correctness of the results. The retrieval of pesticides in the quality assurance materials fell within the 80-120% range, and the allowable relative standard deviations (RSDs) for repeated measurements were established to be less than 20%. The used approach had an enlarged uncertainty of U ≤ 25%.

## Results and Discussion

The chromatograms of the reference standards and samples of the Pesticides are shown in figures 1-4. Compliance with maximum residue limits (MRL) in sampled fruits.

Among the 15 samples analysed, 14 (93.3%) sample contained Carbofuran, 9 (60.0%) sample contained Fipronil, and 10 (66.66%) contained Pretilachlor residues in fruit samples. However, 1(6.7%) Carbofuran, 6(40.0%) Fipronil, 4(33.3%) Pretilachlor had none detected residues. Among the samples with residues, 11 samples (73.3%) had Carbofuran residues and 2 samples (16.66 %) with Pretilachlor residues were found to be above codex Alimentarius Maximum Residue Limits (MRLs). The results also showed that Carbofuran contamination was found in orange samples (5/5), while Fipronil was detected in apple samples (5/5), and Pretilachlor was present in apple samples (4/5) (Table 1).

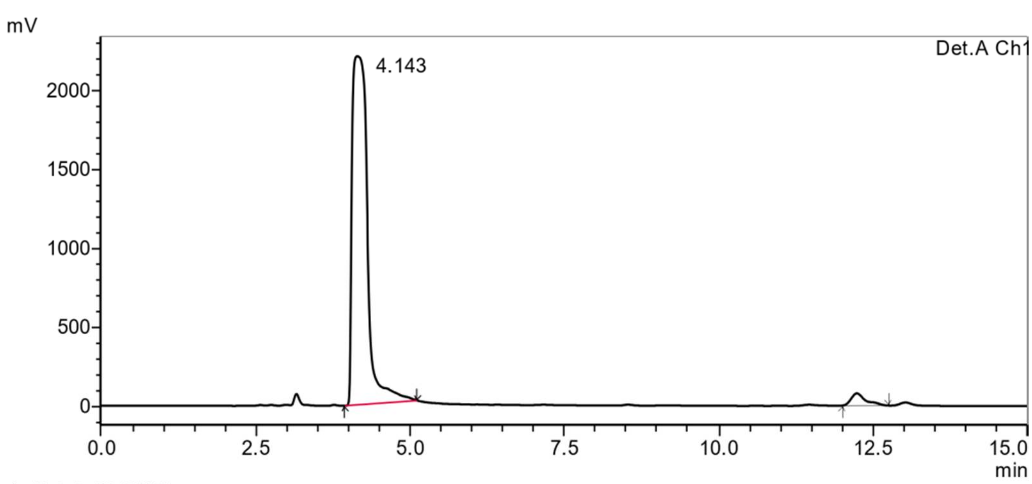


Figure 1. Chromatogram of a carbofuran standard (retention time = 4.14 min).

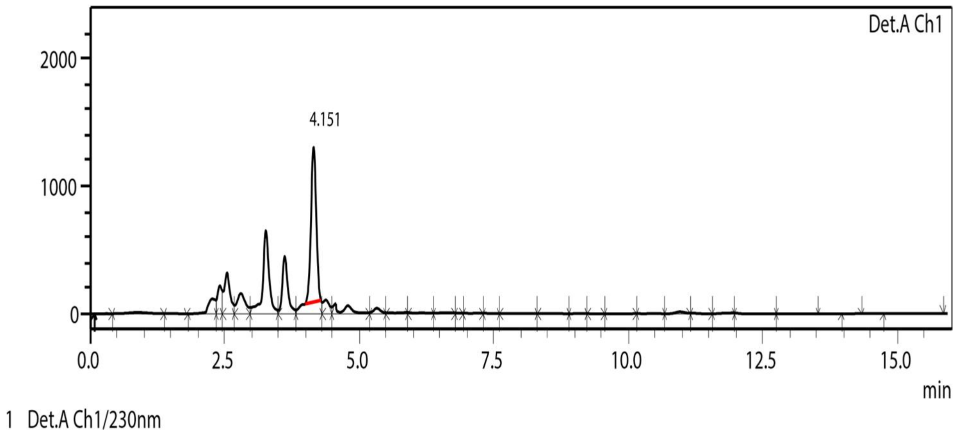


Figure 2. Chromatogram of orange sample showing carbofuran residue (retention time = 4.15 min).

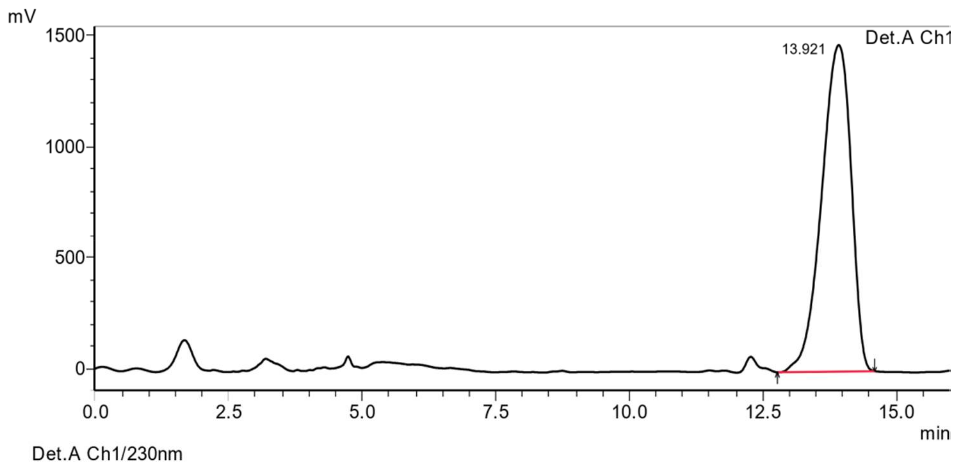


Figure 3. Chromatogram of a Pretilachlor standard (retention time = 13.92 min).

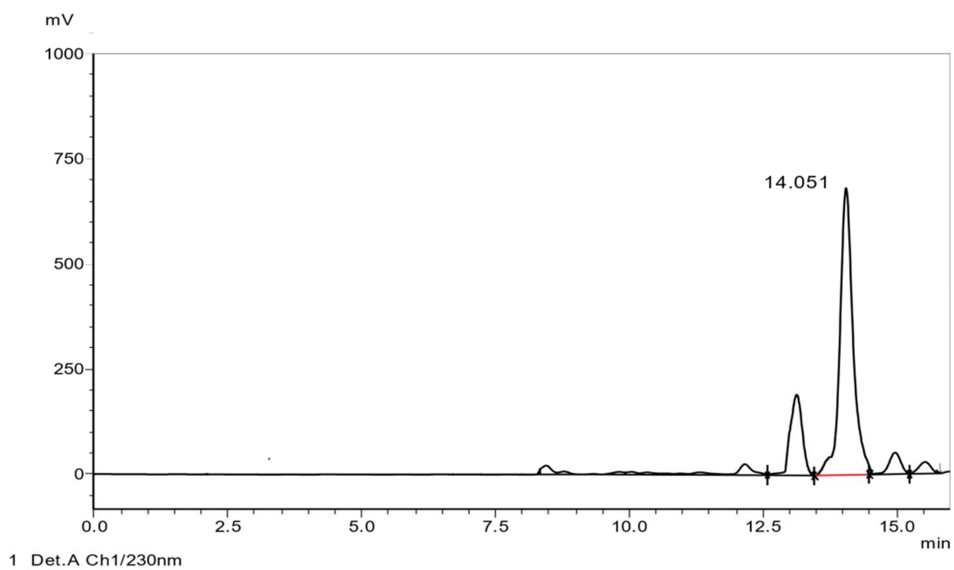


Figure 4. Chromatogram of apple sample showing Pretilachlor residue (retention time = 14.05 min).

**Table 1. Pesticide residue levels in sampled fruits.**

| Name of Pesticide | MRL | Fruits (n=15) | Number of samples without residues | Number of samples with residues | |
|---|---|---|---|---|---|
| | | | | Below MRL | Above MRL |
| Carbofuran | 0.50 mg/kg | Apple | 1 | 2 | 2 |
| | | Orange | - | - | 5 |
| | | Grape | - | - | 1 |
| | | Sweet Orange (Malta) | - | - | 3 |
| | | Black grape | - | 1 | - |
| Fipronil | 0.005 mg/kg | Apple | - | 5 | - |
| | | Orange | 2 | 3 | - |
| | | Grape | - | 1 | - |
| | | Sweet Orange (Malta) | 3 | - | - |
| | | Black grape | 1 | - | - |
| Pretilachlor | 0.04 mg/kg | Apple | 1 | 4 | - |
| | | Orange | 3 | 1 | 1 |
| | | Grape | - | 1 | - |
| | | Sweet Orange (Malta) | - | - | - |
| | | Black grape | - | - | 1 |

MRL = maximum residual limit; and using the MRL determined by EU pesticide database (EU Pesticide, 2005).

The analysis of pesticide residue data across various fruit matrices reveals distinct patterns in contamination levels and adherence to Maximum Residue Limits (MRLs), expressed in milligrams per kilogram (mg/kg) (Ali *et al.*, 2024; Shimo *et al.*, 2023; Muni *et al.*, 2024; Ahmed *et al.*, 2026). Among the 15 samples analyzed, carbofuran residues were detected in 14 samples, of which 11 exceeded their respective maximum residue limits (MRLs). Pretilachlor residues were detected in 8 samples, with 2 samples exceeding the MRLs, while fipronil residues were detected in 9 samples, all of which remained below the established MRLs (Table 1).

This study conducted comparative research to observe the quantities of Carbofuran in different varieties of fruits. Oranges, Sweet Orange (Malta), and Grapes had median levels that were much higher, measuring 2.501 mg/kg, 2.331 mg/kg, and 0.153 mg/kg, respectively. The Estimated Average Daily Intake (EADI) values for these fruits exceeded the WHO/FAO acceptable daily intake (ADI), indicating potential health risks associated with their consumption. Exceeding recommended limits indicates a potential health hazard associated with consuming these fruits. In contrast, Apples and Black Grapes exhibited lower median values, at 0.087 mg/kg and 0.091 mg/kg, respectively. These readings are below the Acceptable Daily Intake (ADI), suggesting no significant health risk. (Table 2)

**Table 2. Presence of carbofuran in several fruits sample.**

| Fruits type | Median value (mg/kg) | WHO/FAO ADI (mg/kg body weight) | EADI (mg/kg body weight) | HI | Health Risk |
|---|---|---|---|---|---|
| Orange | 2.501 | 0.001 | 0.0166733 | 16.67 | Yes |
| Apple | 0.087 | 0.001 | 0.00058 | 0.58 | No |
| Sweet Orange (Malta) | 2.331 | 0.001 | 0.01554 | 15.54 | Yes |
| Grape | 0.153 | 0.001 | 0.00102 | 1.02 | Yes |
| Black-Grape | 0.091 | 0.001 | 0.0006067 | 0.67 | No |

ADI = Acceptable Dietary Intake; EDI = Estimated Dietary Intake; HRI = Human Risk Index. The HRI was calculated by considering an average daily fruit intake of 0.400 kg per person per day for a 60 kg adult.

**Table 3. Presence of fipronil in several fruit samples.**

| Fruits type | Median value (mg/kg) | WHO/FAO ADI (mg/kg body weight) | EDI (mg/kg body weight) | HRI | Health Risk |
|---|---|---|---|---|---|
| Orange | 0.020 | 0.0002 | 0.000133 | 0.666666667 | No |
| Apple | 0.001 | 0.0002 | 0.000007 | 0.032529531 | No |
| Grape | 0.001 | 0.0002 | 0.000004 | 0.01962505 | No |

ADI = Acceptable Dietary Intake; EDI = Estimated Dietary Intake; HRI = Human Risk Index. The HRI was calculated by considering an average daily fruit intake of 0.400 kg per person per day for a 60 kg adult.

The fipronil concentrations detected in oranges, apples, and grapes resulted in Estimated Daily Intake (EDI) values below the WHO/FAO acceptable daily intake (ADI). Corresponding hazard index (HI) values were less than one for all fruits, indicating no significant health risk. (Table 3)

The Pretilachlor concentrations across fruits, with oranges displaying the highest median concentration at 1.501 mg/kg, followed by Sweet Orange (Malta) at 2.331 mg/kg, suggest potential health implications upon consumption. whereas apples had a comparatively low concentration of 0.087 mg/kg. Surprisingly, black grapes showed very little contamination, with a small average concentration of 0.00003 mg/kg, presenting little health hazards. Health risk assessments, based on Estimated Average Daily Intakes (EADIs) compared to Acceptable Daily Intake (ADI) levels, highlighted issues for oranges and Sweet Orange (Malta), whereas grapes, apples, and black grapes exhibited significantly reduced risk profiles (Table 4).

**Table 4. Presence of Pretilachlor in several fruit samples.**

| Fruits type | Median value (mg/kg) | WHO/FAO ADI (mg/kg body weight) | EADI (mg/kg body weight) | HI | Health Risk |
|---|---|---|---|---|---|
| Orange | 1.50100 | 0.008 | 0.0100 | 1.2508 | Yes |
| Apple | 0.08700 | 0.008 | 0.0006 | 0.0725 | No |
| Sweet Orange (Malta) | 2.33100 | 0.008 | 0.0155 | 1.9425 | Yes |
| Grape | 0.15300 | 0.008 | 0.0010 | 0.1275 | No |
| Black-Grape | 0.00003 | 0.008 | 0.0000 | 0.0000 | No |

ADI = Acceptable Dietary Intake; EDI = Estimated Dietary Intake; HRI = Human Risk Index. The HRI was calculated by considering an average daily fruit intake of 0.400 kg per person per day for a 60 kg adult.

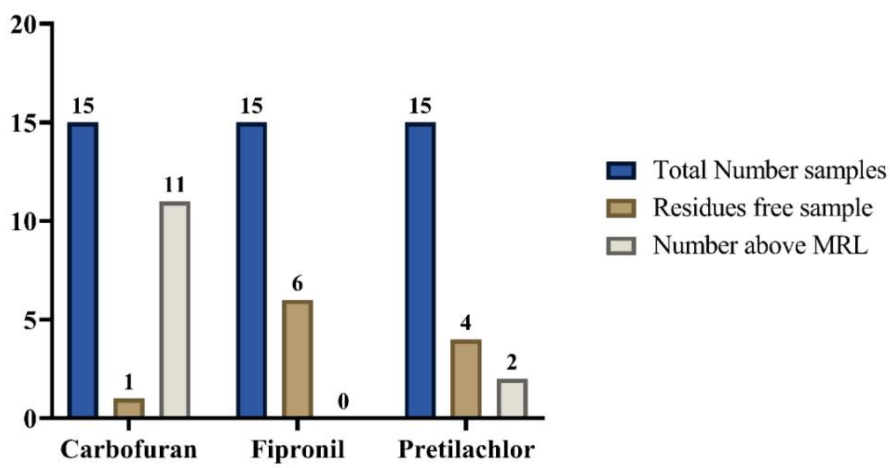


Figure 5. Compliance of pesticide residue levels with maximum residue limits (MRLs) in different fruit samples.

The analysis of pesticide residues in fruit samples reveals distinct trends of adherence to regulations. Carbofuran showed significant contamination, with only one out of 15 tests showing no traces of residues, while 11 samples exceeded the Maximum Residue Limits (MRLs). In contrast, Fipronil demonstrated excellent adherence, since no residues were detected in 6 samples and none above the maximum residue limits (MRLs). Pretilachlor exhibited moderate adherence, with 4 samples free of residues and 2 samples that exceeded maximum residual limits (MRLs) (Figure 5).

The contrasting evaluation of three pesticides—Carbofuran, Fipronil, and Pretilachlor—on different fruit samples reveals varying health risk levels linked to their consumption. Higher amounts of Carbofuran in oranges, Sweet Oranges (Malta), and grapes exceed the acceptable daily intake set by the World Health Organisation/Food and Agriculture Organisation (WHO/FAO), suggesting potential health risks. In contrast, apples and black grapes have lower levels of Carbofuran, indicating a lower risk. On the other hand, the levels of Fipronil found in oranges, apples, and grapes are below the acceptable daily intake (ADI) limit, indicating that the potential health hazards are negligible. Nevertheless, Pretilachlor quantities exceeding the Acceptable Daily Intake (ADI) in oranges and Sweet Oranges (Malta) suggest potential health consequences. In contrast, apples, grapes, and black grapes show much reduced risks. These findings underscore the importance of evaluating fruit pesticide levels to mitigate potential health risks associated with consuming contaminated fruit.

The assessment revealed 76% contamination, with 73.3% carbofuran and 16.6% pretilachlor exceeding Codex standards, and all EADIs above limits (Khan *et al.*, 2020, Ramadan *et al.*, 2020a, Uddin *et al.*, 2024). Hazard index (HI) values greater than one were observed for carbofuran and pretilachlor in oranges and sweet oranges (Malta), indicating potential health risks. In contrast, fipronil residues across all fruit samples exhibited HI values below one, suggesting negligible health risk, consistent with studies showing residues in Dhaka vegetables exceeding MRLs (Adnen *et al.*, 2025, Chowdhury *et al.*, 2014, Bhuiya *et al.*, 2024). These findings align with recent reports of over 58% contamination in fruits nationally, with multi-residues in 217 of 370 samples, often involving broad-spectrum pesticides like those studied here (Łozowicka *et al.*, 2025a).

In Bangladesh, similar patterns are observed in large fruits such as mango and guava, where organophosphorus and pyrethroid residues (e.g., cypermethrin 0.011-0.314 mg/kg in mango, 0.04-0.113 mg/kg in guava) exceed default variability factors, suggesting higher consumer exposure risks than previously estimated (Łozowicka et al., 2025b). Factors include a lack of digital aggregation for safe practices, with only 56% of consumers informed, leading to behaviours like weekly spraying (Begum *et al.*, 2025a). Compared to global data, Bangladesh's rates exceed those in Saudi Arabia (a 20% exceedance) but mirror those of Ghana and Pakistan, where consumer fears drive market shifts (Tambo *et al.*, 2024, Ramadan *et al.*, 2020b). Health implications include acute poisoning (23-43% households affected) and chronic effects like neurotoxicity and cancer, with children at 2-3 times higher risk (Khatun *et al.*, 2023, Beyuo *et al.*, 2024).

In Bangladesh, chlorpyrifos, dimethoate, diazinon, and malathion residues range from 0.006 to 1.8 mg/kg in vegetables, with similar patterns in fruits, such as oranges (Łozowicka *et al.*, 2025b).A systemic review of pesticide contamination in Bangladeshi produce over the last decade reported 29% of samples (1577) contaminated, with 73% exceeding MRLs among contaminated ones (458). HQ>1 for adolescents and adults in items like tomato, eggplant, and beans, highlighting elevated chronic and acute risks from cypermethrin (Khatun *et al.*, 2023).

Dietary risk assessments in similar contexts, such as carbendazim in citrus, show HQ values of 0.066-0.134% and RQ 18.48-82.12%, deeming exposure acceptable but underscoring the need for monitoring due to rapid dissipation half-lives (2-18 days) (Zhang *et al.*, 2022). Non-enzymatic sensors offer promising detection for OPPs in fruits, achieving femtomolar limits for chlorpyrifos and malathion, aiding in mitigating bioaccumulation-related health effects. Elevated HQ emphasises the importance of monitoring and promoting alternatives, such as IPM, which has resulted in a 40% reduction in residues in pilot programs (Nisha *et al.*, 2021, Pathak *et al.,* 2022a). Farmers' use may increase detections, necessitating MRLs, better communication, and washing studies- proper washing removes 30-50% of residues, with combined household agents (e.g., sodium bicarbonate, vinegar, salt, and lemon) achieving a 72-81% reduction in analogous produce (Sarker *et al*., 2021a, Islam *et al.*, 2022). Future research should be expanded to include more regions, encompass organochlorines, and assess bioaccumulation in humans through cohort studies (Lučić and Onjia, 2025, Begum *et al.,* 2025). Comprehensive legislation, incentives for organic farming, and public awareness campaigns are crucial to reduce risks and ensure food security (Fahim *et al.*, 2021, Beyuo *et al*., 2024). Recent evaluations using UHPLC in raw vegetables have confirmed health risks associated with residues, with exceedances found in common produce such as eggplant and tomatoes (Babgapi *et al*., 2025). Advancing food safety requires addressing these through technology and regulation, as legacy OCPs in fruits pose ongoing carcinogenic threats (Ahmed and Kamruzzaman, 2025, Adnen *et al*., 2025).

Farmers and executives are utilising these pesticides, and there is a possibility that their detection levels will increase in the future. Consequently, the authors suggest establishing Maximum Residue Limits (MRLs) for these pesticides in various fruits. Due to economic constraints and limited resources, developing countries may be more prone to permit the use of hazardous pesticides. This funding underscores the absence of communication between competent authorities worldwide. The degrees of exposure to customers may vary when they arrive at their homes and undergo appropriate washing. Further extensive research should be conducted to ascertain the quantities of various pesticide residues on additional vegetables and fruits sourced from various regions in Bangladesh, at several sample intervals. It is essential to regularly monitor the use of popular pesticides on vegetables, as this study revealed the presence of high levels of residual pesticides, which could pose a health risk. Bangladesh should adopt comprehensive legislation to regulate pesticide use and enhance knowledge and technical expertise among the farming community.

## Conclusion

In conclusion, the analysis of pesticide contamination in diverse fruit samples underscores the intricate dynamics inherent in agricultural practices, food safety, and public health. While several fruit samples exhibited pesticide residue levels below regulatory thresholds, specific fruits—particularly oranges and sweet oranges (Malta)—showed residue levels and dietary exposure estimates exceeding recommended safety limits. This variability highlights the importance of on-going surveillance and strict adherence to safety protocols to mitigate potential health risks associated with pesticide exposure through fruit consumption. The results do not provide an overall picture of pesticide contamination. The circumstances may vary depending on an uneducated, unaware, financially struggling street seller who carelessly uses a large quantity of pesticides based on their personal preferences. As we navigate these complexities, collaborative efforts among policymakers, agricultural stakeholders, and public health authorities are crucial to ensuring the sustained safety and integrity of our food supply. We can effectively address emerging concerns and uphold consumer health in an evolving agricultural milieu by prioritising research into sustainable pest management strategies and fostering transparent communication channels.

**Funding Statement**

This research was financially supported by the Centre for Advanced Research in Sciences (CARS), University of Dhaka.

**Conflict of Interest Statement**

The authors declare that no competing interests exist concerning this manuscript.

## References

Adnen, K.S., Sweety, S.J., Tisha, S.S., Hoque, M.M. and Tusher, T.R. 2025. Occurrence and human health implications of legacy organochlorine pesticides and their metabolites in fruits and vegetables of Bangladesh. *Food Safe. Health* **4,** 359-373.

Ahmed, M.W. and Kamruzzaman, M. 2025. Advancing food safety in Bangladesh: Challenges and the promise of smart sensor technology. *Food Safe. Health* **3**, 356-379.

Ahmed, S., Siddique, M.A., Rahman, M., Bari, M.L. and Ferdousi, S. 2019. A study on the prevalence of heavy metals, pesticides, and microbial contaminants and antibiotics resistance pathogens in raw salad vegetables sold in Dhaka, Bangladesh. *Heliyon*. **5**, e01205.

Ahmed, J., Rahman, S.M., Ria, U.H., Aishee, S., Siddiki, A.K.M.N.A., Sultan, M.Z. and Salam, M.A. 2026. Nutritional profiling of sugarcane juice: mineral and water-soluble vitamin composition across selected Bangladeshi varieties. *Bangladesh Pharm. J.* **29**, 1-7.

Aktar, F., Rahaman, M.N., Simol, H.S., Soma, M.A. and Sultan, M.Z. 2025. Quantification and evaluation of vitamins B1 and B2 in marine resources of the Bay of Bengal. *Biomed. Pharmacol. J.* **18**. DOI: https://bit.ly/4dzlOwG

Al Banna, M.H., Disu, T.R., Kundu, S., Ahinkorah, B.O., Brazendale, K., Seidu, A.A., Okyere, J., Rahman, N., Mondal, S., Matubber, B. and Khan, M.S.I. 2021. Factors associated with food safety knowledge and practices among meat handlers in Bangladesh: A cross-sectional study. *Environ. Health Prev. Med.* **26**, 84.

Ali, M.A., Sultan, M.Z., Mia, M.L., Islam, A., Ria, U.H. and Salam, M.A. 2024. Evaluation of thiamine and riboflavin in different varieties of rice grown in Kurigram district, Bangladesh. *Heliyon* **10**, e39868.

Babgapi, A., Mahdavi, V., Bayanati, M., Khanniri, E., Alemi, M., Kia, A.S., Zarei, R. and Mahboubi-Rabbani, M. 2025. Evaluation of pesticide residues in raw vegetables using UHPLC-MS/MS: A risk assessment study. *J. Food Compos. Anal.* **148**, 108611.

Baquedano, F.G., Zereyesus, Y.A., Valdes, C. and Ajewole, K. 2021. International Food Security Assessment 2021-31.

Begum, I.A., Alam, M.J., Shankar, B., Cooper, G., Rich, K., Mastura, T., Parikh, P., Ratna, N.N. and Kadiyala, S. 2025. Pesticide safety behavior among vegetable farmers in Bangladesh: Evaluating the role of market aggregation services. *Heliyon*, **11**, e41013.

Beyuo, J., Sackey, L.N.A., Yeboah, C., Kayoung, P.Y. and Koudadje, D. 2024. The implications of pesticide residue in food crops on human health: a critical review. *Disco. Agric.* **2**, 123.

Bhuiya, A., Yasmin, S., Shaikh, M.A.A., Mustafa, M.G. and Kabir, M.H. 2024. Method development of multi pesticide residue analysis in country beans collected from Dhaka, Bangladesh, and their dietary risk assessment. *Food Chem.* **445**, 138741.

Chowdhury, F. R., Dewan, G., Verma, V. R., Knipe, D. W., Isha, I. T., Faiz, M. A., Gunnell, D. J. & Eddleston, M. 2018. Bans of WHO class I pesticides in Bangladesh—suicide prevention without hampering agricultural output. *Int. J. Epidem.* **47**, 175-184.

Chowdhury, M.A.Z., Jahan, I., Karim, N., Alam, M.K., Rahman, M.A., Moniruzzaman, M., Gan, S.H. and Fakhruddin, A.N.M. 2014. Determination of carbamate and organophosphorus pesticides in vegetable samples and the efficiency of gamma-radiation in their removal. *BioMed. Res. Int.* 145159.

EU Pesticide Database, M.R.L.A.D. and By Ec Regulation 396/2005. 2005. EU Pesticide Database, Maximum Residue Level as determined [Online]. Available: http://ec.europa.eu/food/plant/pesticides/legislation/max residue levels en.htm [Accessed on 2025].

Luo, Y.S. 2023. Bayesian-Based Probabilistic Risk Assessment of Fipronil in Food: A Case Study in Taiwan. *Toxics*, **11,** 677. https://doi.org/10.3390/toxics11080677.

Lv, X., Chang, Q., Li, H., Liang, S., Zhe, Z., Shen, S. and Pang, G. 2022a. Risk assessment of carbofuran residues in fruits and vegetables at the Chinese market: A 7-year survey. *Ecotoxicol. Environ. Saf.* **239**, 113667.

Mohamed, F., Senarathna, L., Percy, A., Abeyewardene, M., Eaglesham, G., Cheng, R., Azher, S., Hittarage, A., Dissanayake, W., Sheriff, M.H., Davies, W., Buckley, N.A. and Eddleston, M. 2004. Acute human self-poisoning with the N-phenylpyrazole insecticide fipronil--a GABAA-gated chloride channel blocker. *J. Toxicol. Clin. Toxicol*. **42**, 955-63.

Muni, M., Mim, M.M.A., Aktar, F., Afrin, S.S., Alam, S., Sikder, A.A., Chowdhury, J.K., Chowdhury, A.A., Kabir, S.K., Sultan, M.Z. and Amran, M.S. 2024. Exploration of antidiabetic activity of the whole plant extract of Eclipta prostrata by in silico, in vitro, and in vivo methods. *Avicenna J. Med. Biochem.* **12**, 64-76. doi:10.34172/ajmb.2531.

Nasreen, S. and Ahmed, T. 2014. Food adulteration and consumer awareness in Dhaka City, 1995-2011. J. Health Popul. Nutr. **32**, 452-64.

Nisha, U.S., Khan, M.S.I., Prodhan, M.D.H., Meftaul, I.M., Begum, N., Parven, A., Shahriar, S., Juraimi, A.S. and Hakim, M.A. 2021. Quantification of pesticide residues in fresh vegetables available in local markets for human consumption and the associated health risks. *Agronomy* **11**, 1804.

Pathak, V. M., Verma, V. K., Rawat, B.S., Kaur, B., Babu, N., Sharma, A., Dewali, S., Yadav, M., Kumari, R. and Singh, S. 2022a. Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: A comprehensive review. *Front. Microb.* **13**, 962619.

Policy, B.N.F.A.N.S. and Action, P.O. 2021-2030. Bangladesh National Food And Nutrition Security Policy, Dhaka, Bangladesh National Food And Nutrition Security Policy. https://faolex.fao.org/docs/pdf/BGD214404.pdf (Access on January 2026).

Rahman, M.A., Sultan, M.Z., Rahman, M.S. and Rashid, M.A. 2015. Food Adulteration: a serious public health concern in Bangladesh. *Bangladesh Pharm. J.* **18**, 1-7.

Ramadan, M.F.A., Abdel-Hamid, M.M.A., Altorgoman, M.M.F., Algaramah, H.A., Alawi, M.A., Shati, A.A., Shweeta, H.A. and Awwad, N.S. 2020a. Evaluation of pesticide residues in vegetables from the Asir Region, *Saudi Arabia. Molecules* **25**, 205.

Rather, I.A., Koh, W.Y., Paek, W.K. and Lim, J. 2017. The Sources of Chemical Contaminants in Food and Their Health Implications. *Front. Pharmacol.* **8**, 830.

Sarker, A., Islam, T., Rahman, S., Nandi, R. and Kim, J.E. 2021. Uncertainty of pesticides in foodstuffs, associated environmental and health risks to humans—a critical case of Bangladesh with respect to global food policy. *Environ. Sci. Pollut. Res.* **28**, 54448-54465.

Salsabil, S., Salam, M.A., Sultan, M.Z. and Siddiki, A.K.M.N.A. 2025. Phytochemical and antidiabetic study of methanolic extract of Portulaca oleracea L. *Dhaka Univ. J. Pharm. Sci.* **24**, 211-218. DOI: https://doi.org/10.3329/dujps. v24i2.86371

Shilpakar, O., Karki, B. and Rajbhandari, B. 2020. Pretilachlor poisoning: A rare case of a herbicide masquerading as organophosphate toxicity. *Clin. Case Rep.* **8**, 3507-3509.

Shimo, N.A., Salam, M.A., Parvin, M., Sultan, M.Z. 2023. Assessment of selected metals (chromium, lead and cadmium) in the hair of tannery workers at Hemayetpur, Bangladesh. *J. Trace Elem. Min.* **4**, 100056. https://doi.org/10.1016 /j.jtemin.2023.100056

Sultan, M.Z., Matin, M.A., Miazi, R. and Rashid, M.A. 2025. Studies of some antiatherosclerotic medicinal plants of Bangladesh. *Bangladesh J. Bot.* **54**, 167-170.

Tambo, J.A., Kansiime, M.K., Alaganthiran, J.R., Danish, M., Duah, S.A., Faisal, S., Khonje, M.G., Mbugua, F. and Rajendran, G. 2024. Consumer pesticide concerns and the choice of fruit and vegetable markets in five low-and middle-income countries. *Glob. Food Sec.* **42**, 100801.

Thompson, L.A. and Darwish, W. S. 2019. Environmental Chemical Contaminants in Food: Review of a Global Problem. *J. Toxicol.* **2019**, 2345283.

Uddin, M.M., Ahmed, S. and Sultan, M.Z. 2024. Assessment of residue levels and health risk of carbofuran, chlorpyriphos, abamectin, imidacloprid, and pretilachlor in locally available fruits in Dhaka, *Bangladesh. J. Food Tech.* **11**, 109-117. DOI: 10.18488/jftr.v11i4.4013

Yeasmin, D., Baker, M., Kamal, A.H.M., Islam, M.S., Rahman, M., Winch, P.J. and Unicomb, L. 2023. Exploring customers' perceptions of food adulteration at bazaars and supermarkets in Dhaka, Bangladesh; a qualitative exploration. BMC Pub. *Health* **23**, 206.

Zhang, Y., Zhou, Y., Duan, T., Kaium, A. and Li, X. 2022. Dissipation and dietary risk assessment of carbendazim and epoxiconazole in citrus fruits in China. *J. Sci. Food Agric.* **102**, 1415-1421.