



Evaluation of Aflatoxins and Heavy Metals Contamination in Milled Melon Seeds from Markets in Lagos State: Food Safety Implications

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ABSTRACT

Milled melon seeds (*Citrullus colocynthis*) are often consumed as part of soup ingredients in Nigeria; however, they are susceptible to aflatoxin and heavy metal contamination. In this study, milled melon samples from three Lagos State markets (Badagry, Epe, and Mile 12) and a laboratory-prepared control were evaluated for aflatoxins and heavy metals. Thereafter, the contaminants were compared to international safety standards. The results showed that the total aflatoxin concentrations ranged from 0.09 to 0.36 µg/kg, with mean concentrations of aflatoxin B1 (0.06 µg/kg), aflatoxin B2 (below detection), aflatoxin G1 (0.03 µg/kg), and aflatoxin G2 (0.12 µg/kg). The aflatoxin levels were well below the recommended maximum level of 4 µg/kg by the National Agency for Food and Drug Administration and Control, and 20 µg/kg set by the United States Food and Drug Administration (FDA). On the other hand, the heavy metals varied significantly ($p < 0.05$) and were higher than global limits. The values obtained for lead (Pb) ranged from 0.46 mg/kg (control) to 1.91 mg/kg (Epe samples). Generally, the values obtained for Pb frequently exceeded EU and Codex guidelines (0.10–0.30 mg/kg); the Epe sample had 0.80 mg/kg chromium (Cr) and was above the WHO limit of 0.20 mg/kg. The most abundant element was copper (Cu), which was higher in the Epe sample at 4.54 mg/kg, while being within FDA and FAO/WHO standards. The arsenic (As) constituent was below detection; cadmium (Cd) was found at trace quantities (≤ 0.10 mg/kg). Aflatoxin pollution was generally minimal, but exposure to heavy metals, especially Pb and Cr, poses serious dangers to human health. The results highlight the necessity for a more stringent enforcement of food safety laws, better post-harvest handling, and regular monitoring to protect consumers.

Keywords: Aflatoxin, heavy metals, milled melon seeds, Lagos State markets, food safety.

Introduction

Melons (*Citrullus colocynthis*) are major food crops in sub-Saharan Africa and other tropical regions. They belong to the Cucurbitaceae family, which includes a wide variety of fruits, and their seeds are used in many dishes (Mabaleha et al., 2007). The main areas of cultivation are the Middle East and West Africa, particularly Nigeria, Ghana, Togo, and Benin, where the crop is interplanted with maize, cassava, and yam (Uruakpa and Aluko, 2004). Melon seeds are a good source of oil, protein, minerals, vitamins, and energy. Per 100 g of edible seeds, there are 4.6 g of carbohydrates, 0.6 g of protein, 0.6 g of crude fibre, 33 mg of vitamin C, 17 mg of calcium, 16 mg of phosphorus, and 230 mg of potassium (Olaniyi, 2008). They are also an excellent source of minerals and essential amino acids, as well as polyunsaturated fatty acids and

phospholipids, and they contain significant amounts of tocopherols and phenolic compounds that are beneficial to humans (Schippers, 2000; Arthur et al., 2020). The melon seeds are prepared for consumption by parching and pounding to free the seed coat from the kernel, after which they may be eaten raw or cooked. Usually, they are milled into a powder and added to soups (Arthur et al., 2020). They may also be ground into a paste, moulded into balls, and added to daily meals as a meat substitute (Schippers, 2000). Melon seeds deteriorate quickly in storage due to fungal infection, which may result in decreased nutritive value, colour changes, increased peroxide value, and mycotoxin production (Bankole et al., 2004). If proper sorting of seeds is not carried out before milling, this may pose a

health hazard to consumers. In addition, microbial attack, production, handling, and distribution practices may cause chemical changes that ultimately affect the quality and safety of the product (Arthur et al., 2020). The accumulation of trace metals also compromises food safety because these metals interfere with the proper function of the nervous system, kidneys, and other vital organs. The presence of many of these elements has been reported in numerous foods; for instance, arsenic, lead, nickel, copper, chromium, and cadmium have been detected in fruit and vegetable products, cereals, root tubers, and meat (Lanre-iyanda and Adekunle, 2012; Ofori et al., 2016).

During harvesting, drying, shipping, storage, milling, and retailing, melon seeds, a popular oilseed used as a soup thickener in Nigerian diets, are frequently sold in open markets where they are exposed to environmental pollutants like aflatoxin and heavy metals. Concerns regarding their safety for human consumption are raised by this exposure, which raises the possibility of contamination by both chemical and biological agents (Adeyemo and Jacxsens, 2018). Because milled melon seeds have a high oil content and are frequently sun-dried and stored in unmanaged environments, they are quite vulnerable to fungal contamination (Adeyemo and Jacxsens, 2018). Dust, wetness, and unsanitary handling techniques can all raise the danger of aflatoxin and heavy metal contamination during marketing, leading to food safety issues. Due to the ongoing contamination of food commodities with harmful elements like heavy metals and aflatoxins, food safety has emerged as a significant global public health concern. Because of their environmental longevity, capacity to bioaccumulate in biological systems, and potential long-term health effects on humans, these pollutants are of special concern (Bereda, 2025). Food contamination is often associated with poor farming practices, environmental pollution, inadequate processing techniques, and subpar storage conditions in many developing nations, including Nigeria (Christiana-Cudjoe et al., 2022).

Aspergillus flavus and *Aspergillus parasiticus*, which flourish in warm, humid conditions frequently encountered in tropical storage environments, are the primary producers of aflatoxins, which are hazardous secondary metabolites (Adeyemo and Jacxsens, 2018). These very persistent poisons have been shown to have immunosuppressive, mutagenic, hepatotoxic, and carcinogenic properties. Particularly in susceptible groups, long-term exposure to aflatoxins has been connected to immunological suppression, liver cancer, and stunted growth (Esan et al., 2020). According to earlier studies, melon seeds gathered from several

Nigerian markets surpassed the European Commission's 4 µg/kg total aflatoxin limit for oilseeds meant for direct human consumption (Ezekiel et al., 2016; Esan et al., 2020). The aflatoxin levels of commercially milled melon seeds in Lagos State have not been the subject of any published studies. Similarly, contaminated soil, irrigation water, pesticides used, industrial emissions, and inappropriate waste disposal often allow heavy metals, including lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), arsenic (As), mercury (Hg), and zinc (Zn), to enter food chains (Ahmad et al., 2026). Following their introduction into agricultural systems, these metals are easily absorbed by plants and may build up in edible portions, endangering consumers' health (Mititelu et al., 2025). Numerous health issues have been linked to dietary exposure to heavy metals (Shetty et al., 2025). Cadmium build-up can cause kidney and liver damage, whereas lead exposure is associated with neurological conditions and developmental abnormalities (Kumar, 2025). Additionally, carcinogenic consequences and other chronic disorders have been linked to chromium and arsenic (Jomova et al., 2025). Even at modest exposure levels, heavy metals have a tendency to build up in human tissues over time due to their non-biodegradability, which may induce long-term toxicity and metabolic problems (Mititelu et al., 2025). There is little information about Nigerian commercial milled melon seed's heavy metal contamination, specifically in Lagos State.

During harvesting, drying, shipping, storage, and retailing, milled melon seeds (*Citrullus colocynthis*), a popular oilseed used as a soup thickener in Nigerian diets, are frequently sold in open markets; where they are exposed to environmental pollutants like aflatoxin and heavy metals. Concerns regarding its safety for human consumption are raised by this exposure, which raises the possibility of contamination by both chemical and biological agents (Adeyemo and Jacxsens, 2018; Anukwuorji et al., 2020). Because milled melon seeds have high oil content and are frequently sun-dried and stored in unmanaged environments, they are quite vulnerable to fungal contamination (Adeyemo and Jacxsens, 2018). Dust, wetness, and unsanitary handling techniques contribute to the danger of infection during marketing. Because milled melon seeds are widely consumed by people from all socioeconomic backgrounds, ensuring their safety is essential for maintaining food quality and protecting public health. Rapid urbanisation, industrial activity, careless waste disposal, and the extensive use of agrochemicals all contribute to Nigeria's food contamination problem (Onakpa et al., 2018). Numerous studies have documented high concentrations of heavy metals in food crops and

vegetables sold in Nigerian marketplaces, frequently surpassing regulatory agencies' allowable limits (Ogundele et al., 2019; Awoyale et al., 2024; Awoyale et al., 2025). Despite these results, the combined evaluation of heavy metals and aflatoxins in milled melon seeds sold in Lagos State's main marketplace has received little attention. Therefore, the purpose of this study is to evaluate the amounts of aflatoxins and heavy metals in milled melon seeds that are sold in Lagos State's main markets.

Materials and Methods

Sources of Samples

Milled melon seeds (*Citrullus lanatus*) samples were aseptically purchased from three major markets in Lagos State, Nigeria. The selected markets included Badagry Market, Epe Market, and Mile 12 International Market along Ikorodu Road in Ketu, Lagos State, Nigeria. About 200 g of unshelled melon seeds were purchased from Basic Agro Tech Nigeria Limited, Lagos State, and used as the control. The samples were transported in Ziplock bags to the laboratory for analysis.

Sampling and sample preparation

Markets were selected using a purposive sampling technique based on trade volume and popularity. From each market, three vendors were randomly chosen, and two cups (200 g) of *Luru* were purchased from each, giving six cups (600 g) per market and eighteen cups (1,800 g) in total. To minimise cross-contamination and moisture loss, samples were bought in the same manner as regular customers and placed in sterile, labelled polyethylene zip-lock bags. Only milled melon seeds produced within one day and stored in cool, dry conditions were sampled. For each market, the three vendor samples were thoroughly mixed, and a single laboratory sample was drawn using appropriate quadrant sampling methods under strict quality control. This ensured that analytical results on contaminants could be reliably generalised to the broader food system, so each market was represented by one laboratory sample for the determination of heavy metal and aflatoxin content. For the control sample, the unshelled melon seeds (200 g) purchased from Basic Agro Tech Nigeria Limited, Lagos State, were dehulled, cleaned with distilled water, allowed to air-dry, and then ground into a fine powder using an attrition mill (Kajihaua et al., 2025). The limitations of this study are a small number of market samples, a single control source, and no risk-assessment calculation done.

Determination of aflatoxin content

Aflatoxin content in milled melon seed samples was determined following AOAC (2005), whereby

20 g of homogenized sample (in duplicate) was blended with 100 mL of 70% methanol for 3 min, shaken at 4×100 rpm for 30 min, filtered through Whatman No.1 paper, and partitioned with dichloromethane and distilled water, with the organic phase dried overnight, reconstituted in dichloromethane, purified using an immunoaffinity column (IAK), and analyzed by high-performance liquid chromatography (HPLC-Agilent, 1100 series, U.S.A.) with a fluorescence detector, calibrated against aflatoxin standards (B1, B2, G1, G2), with limits of detection equivalent to 0.004 µg/kg for B1 and G1, and 0.07 µg/kg for B2 and G2.

Determination of heavy metals

Heavy metals were analyzed following the method described by Awoyale et al. (2025), in which 0.20 g of milled melon seed sample was digested in a Milestone microwave digestion system with 6 mL concentrated HNO₃ and 2 mL H₂SO₄, subjected to a three-step heating program (80–150 °C ramp for 5 min, 225 °C hold for 15 min, and 70 °C cooling for 10 min), diluted to a final volume of 25 mL with ultrapure water, and subsequently quantified using a Perkin-Elmer ELAN DRC-e ICP-MS system (Scott Spray Chamber, Norwalk, USA) calibrated with a 10 µg/L multi-element standard solution, under operating conditions of RF power 1000 W, nebulizer gas flow 0.81 L/min Ar, auxiliary gas flow 1.20 L/min Ar, plasma gas flow 19 L/min Ar, 20 sweeps, one reading, and three replicates, with detection limit approximately to 0.06 mg/kg for Pb, 0.08 mg/kg for Cr, 0.10 mg/kg for Cu, 0.03 mg/kg for Cd, and 0.06 mg/kg for As, and with reagent blanks included to check for interferences.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 20 (SPSS Inc., Chicago, IL, USA) was used to separate the means using the Duncan multiple range test at a 95% confidence level ($p < 0.05$). The mean values of all analyses were subjected to a one-way analysis of variance (ANOVA) to determine significant differences.

Results and Discussion

Aflatoxin content of milled melon seeds

The aflatoxin content of the milled melon seeds obtained from different markets and the control showed generally low levels across all samples. The mean aflatoxin content of the milled melon seeds was aflatoxin B1 0.06 µg/kg, aflatoxin B2 below the limit of detection, aflatoxin G1 0.03 µg/kg, and aflatoxin G2 0.12 µg/kg. Although there was no significant difference ($p > 0.05$) in the aflatoxin contents of all samples and the control, the order of occurrence of the aflatoxins is G2>B1>G1>B2 (Table 1).

Table 1. Aflatoxin content of milled melon seeds from different markets

Milled melon	Aflatoxin B1 (µg/kg)	Aflatoxin B2 (µg/kg)	Aflatoxin G1 (µg/kg)	Aflatoxin G2 (µg/kg)	Total (µg/kg)
Badagry market	0.02 ± 0.02 ^a	BDL	0.03± 0.02 ^a	0.19± 0.22 ^a	0.23± 0.21 ^a
Epe market	BDL	BDL	0.01± 0.02 ^a	0.07± 0.09 ^a	0.09 ± 0.10 ^a
Mile-12 market	0.19± 0.21 ^a	BDL	0.06± 0.07 ^a	0.12± 0.175 ^a	0.36± 0.42 ^a
Control	0.03± 0.00 ^a	BDL	0.03 ± 0.00 ^a	0.11 ± 0.13 ^a	0.16± 0.13 ^a
Mean	0.06		0.03	0.12	0.22
p level	NS		NS	NS	NS

Below Detection Limit (BDL) = 0.004 µg/kg for B1 and G1, and 0.07 µg/kg for B2 and G2.
Means with different superscripts within the same column are significantly different (p<0.05).

The total aflatoxin content ranged from 0.09 µg/kg in the Epe market sample to 0.36 µg/kg in the Mile 12 market sample, with no significant difference ($p > 0.05$) among samples. The elevated value in the Mile 12 market sample may be attributed to poor sanitary conditions, longer storage duration, and higher humidity levels in densely populated market environments (Awoyale *et al.*, 2024). Despite these differences, all values were far below international permissible limits for aflatoxins in food commodities (FDA, 2021), indicating that the milled melon seed samples are generally safe for consumption in terms of aflatoxin contamination. By interacting with deoxyribonucleic acid (DNA), aflatoxin inhibits the transcription of genetic material. This can have long-term negative effects on humans and other animals, making food contamination from aflatoxin a major concern (Awoyale *et al.*, 2025). Furthermore, teratogenic effects, acute liver injury, liver cirrhosis, and cancer growth have all been connected to the acute and chronic toxicity of aflatoxin (Margenat *et al.*, 2019).

The concentration of aflatoxin B1 in the samples ranged from below the limit of detection in the Epe market sample to 0.19 µg/kg in the Mile-12 market sample. Although there was no significant difference ($p > 0.05$) among the samples, the Mile-12 market sample recorded the highest value, suggesting comparatively more favourable storage conditions for fungal growth. A similar value for the aflatoxin content of melon seeds (0.09 µg/kg), cassava chips (0.02 µg/kg), and *Ogbono* (0.15 µg/kg) from southeastern Nigeria was reported by Anukwuorji et al. (2021). Awoyale et al. (2024) had earlier reported that AFB1 levels in powdered pepper from different markets in Ilorin varied between 1.39 µg/kg and 7.64 µg/kg, which was higher than that of this study. Similarly, higher values of aflatoxin B1 were reported for powdered

okro (1.52 µg/kg to 2.13 µg/kg). In addition, high values of aflatoxin B1 (2.51-63.20 µg/kg) were reported for ground red pepper that was collected from regions in Ethiopia's Amhara Region (Adugna et al., 2022), as well as in dried okro samples taken from several Ibadan marketplaces (26.69 to 33.49 µg/kg) (Okigbo & Anene, 2017). Okigbo & Anene (2017) added that the aflatoxin content of dried products in Ibadan metropolis ranged from 0.85 to 1.43 µg/kg. The variations in the aflatoxin content may be attributed to plant varieties, sources of products and market conditions. Aflatoxin B1 is the most toxic and carcinogenic form of aflatoxin and is commonly associated with poorly stored oilseeds such as melon seeds (Awoyale *et al.*, 2025). Because it stops animals from producing proteins and nucleic acids, aflatoxin B1 has been described as the most dangerous of all the aflatoxins (Abass *et al.*, 2017). The values of the aflatoxin B1 are below the National Agency for Food and Drug Administration and Control (NAFDAC) stipulated maximum limit of 4 µg/kg total aflatoxins for ready-to-eat foods (NAFDAC, 2024), and below the United States Food and Drug Administration (US FDA) threshold of 20 µg/kg (FDA, 2021). The high aflatoxin B1 level in the Mile 12 market sample may be linked to exposure to moisture, poor packaging, and fluctuating environmental conditions typical of open market storage (Awoyale *et al.*, 2024). The absence of detectable aflatoxin B1 in the Epe market sample may suggest better handling and storage practices (Şen and Kabak, 2025).

A mycotoxin known as AFG1, which causes hepatocellular carcinoma or chronic liver cancer, is present in some fungal species, especially those in the *Aspergillus* genus (Zamir-Nasta *et al.*, 2021). Aflatoxin G1 values for the samples ranged from 0.01 µg/kg in the Epe market sample to 0.06 µg/kg in the Mile 12 market sample, with no significant

difference ($p > 0.05$) observed among samples. The aflatoxin G1 value obtained for the Mile 12 sample further suggested greater exposure to conditions favourable for fungal growth (Zamir-Nasta et al., 2021). A similar range of values for aflatoxin G1 content was reported by Anukwuorji et al. (2021) for melon seed (0.01 µg/kg) and Ogbono (0.07 µg/kg) in southeastern Nigeria. Aflatoxin content in commercial powdered okro from different markets in Ilorin was reported to range from 1.52 µg/kg to 2.13 µg/kg, which was higher than that reported in the present study (Awoyale et al., 2025). Powdered pepper was also reported to have higher aflatoxin G1 contents (1.52 to 7.54 µg/kg) compared to that of this study (Awoyale et al., 2024). Okigbo & Anene (2017) reported higher values of aflatoxin G1 in dried okro (1.36 to 22.58 µg/kg) and dried tomatoes (0.40 to 1.51 µg/kg) in different markets in the Ibadan metropolis. The variations in the aflatoxin G1 content of this study and those of other studies may be attributed to inadequate agronomic practices, suboptimal harvesting techniques, poor handling and processing methods, improper storage conditions, and insufficient market hygiene (Okigbo et al., 2015). Aflatoxin G1 is commonly produced alongside Aflatoxin B1 by toxigenic *Aspergillus* species and is often detected in oil-rich seeds (Awoyale et al., 2025). The generally low levels recorded suggest that the milled melon seed samples underwent some degree of drying and handling before marketing, which may have limited fungal proliferation and allowed the concentration of aflatoxin G1 in the samples to be lower than the FDA's declared limit of contamination (FDA, 2021). Processing and drying practices have been shown to influence the microbial safety and stability of seed-based food products (Awoyale et al., 2024).

Aspergillus flavus and *Aspergillus parasiticus* are two mould species that produce aflatoxin G2. This toxin is well-known for its potent carcinogenic and toxic effects on humans and animals, even though it is thought to be less harmful than aflatoxin B1 (Popescu et al., 2022). It may infect a variety of food crops, particularly in warm, humid locations where mould growth is more prevalent (Awoyale et al., 2024). It poses major health risks when ingested or inhaled because it can damage the liver and impair immunity (Popescu et al., 2022). Aflatoxin G2 concentrations ranged from 0.07 µg/kg in the Epe market sample to 0.19 µg/kg in the Badagry market sample, with no significant difference ($p > 0.05$) among samples. The higher value observed in the Badagry market sample may reflect greater susceptibility to fungal contamination during storage or transportation (Awoyale et al., 2024). Adugna et al. (2022)

reported aflatoxin levels in red pepper from Ethiopia ranging between 0.53 µg/kg and 2.04 µg/kg, while Rosas-Contreras et al. (2016) documented concentrations in Mexican pepper samples ranging from 0.05 to 3.35 µg/kg. The findings of Adugna et al. (2022) were higher than those of the present study, but the results of this study fall within the range of values reported by Rosas-Contreras et al. (2016). Okigbo and Anene (2017) observed that aflatoxin G2 was highest in samples from Orita-merin market (1.38 µg/kg) and lowest in samples from Shasha market (0.93 µg/kg), all in Ibadan, which were higher than those of this study. Commercial powdered pepper was reported to have higher aflatoxin G2 (1.33 to 2.55 µg/kg) compared to that of this study (Awoyale et al., 2024). Awoyale et al. (2025) also reported higher values of aflatoxin G2 for commercial powdered okro (1.96 to 3.60 µg/kg) in the Ilorin markets. However, lower values of aflatoxin G2 were reported for dried cassava chips (0.0067 µg/kg), melon seeds (0.0004 µg/kg) and Ogbono (0.000 µg/kg) (Anukwuorji et al., 2021). The differences in the aflatoxin G2 contents may be linked to inadequate agronomic practices, suboptimal harvesting techniques, poor handling and processing methods, improper storage conditions, and insufficient market hygiene (Okigbo et al., 2015). The most common occurrence of aflatoxin G2 in all the samples compared to other aflatoxins indicates the presence of toxigenic fungi, which need to be properly monitored to avoid accumulation in the human body that may lead to different levels of disease (Abass et al., 2017). Anukwuorji et al. (2021) reported similar aflatoxin G2 contents in dried cassava chips (0.04 µg/kg), melon seeds (0.23 µg/kg) and Ogbono (0.26 µg/kg) from southeastern Nigeria. The aflatoxin G2 concentration of the samples in this investigation was lower than the aflatoxin contamination threshold published by the Food and Drug Administration (FDA, 2021).

Heavy metal content of milled melon seeds

The presence and concentration of heavy metals (Pb, Cr, Cu, Cd, and As) in milled melon samples from different markets (Badagry, Epe, Mile 12) and the control reveal noticeable variations as presented in Table 2. The mean heavy metal content of the samples is lead (Pb) 1.29 mg/kg, chromium (Cr) 0.55 mg/kg, copper (Cu) 3.83 mg/kg, cadmium (Cd) 0.61 mg/kg and Arsenic (As) below the detection limit. Significant differences exist in all the heavy metal compositions except in Cd and As, which are not significantly different ($p > 0.05$). These variations reflect differences in environmental exposure, handling practices, and storage conditions across the sampled locations

(Awoyale *et al.*, 2024). Heavy metals come from both natural sources, such as the "earth's crust," and human activities, such as mining, manufacturing, and agriculture. The usage of phosphate fertilisers, metallo-pesticides, and irrigation with contaminated water has increased their presence in the ecosystem (Liang *et al.*, 2019). Heavy metals have accumulated in soil and water over several decades due to their non-biodegradable nature and high rate of soil-to-plant transfer. They eventually make their way into the food chain (Dhalaria *et al.*, 2020).

The concentrations of Pb varied significantly ($p < 0.05$) across samples, ranging from 0.46 mg/kg in the control to 1.91 mg/kg in the Epe market sample. The order of occurrence of Pb in the samples is Epe market sample > Badagry market sample > Mile-12 market sample > control sample, indicating that samples from the Epe market had the highest Pb contamination compared to the control sample. This may be attributed to higher levels of environmental pollution, vehicular emissions, and improper waste disposal around market environments (Awoyale *et al.*, 2024). Elevated blood pressure, neurological abnormalities, pain in the muscles and joints, and reproductive issues have all been associated with high levels of lead exposure (EPA, 2007). Lead (Pb) has been connected to abnormal movement and reflexes, peripheral neuropathy, peripheral neurological effects, inhibition of heme biosynthesis, moderate anaemia, and ulcers, according to Sridevi-Sangeetha and Umamaheswari (2020). Commercial powdered Okra in Kwara State was reported to have Pb content ranging from below the detection limit to 0.06 mg/kg, which was lower than in the present study. Higher values of Pb were reported for commercial powdered pepper from Ilorin markets (1.84 - 3.45 mg/kg). Similar observations were reported by Bawa (2023), who noted elevated Pb levels in food crops exposed to contaminated urban environments. Ogundele *et al.* (2019) also reported increased Pb accumulation in food items sold in Lagos markets, linking it to anthropogenic activities and poor environmental sanitation. The higher Pb levels in market samples compared to the control may suggest contamination occurring during post-harvest handling, transportation, and market exposure (Awoyale *et al.*, 2024). Anukwuorji *et al.* (2020) reported that dried melon seed samples obtained from markets in Southeastern Nigeria contained lead concentrations ranging from 8 to 39 mg/kg, a broader range than that observed in the present study. Similarly, Omokaro *et al.* (2023) documented lead uptake in okro across different locations, with values of 0.15 mg/kg at market dumpsites, 0.10

mg/kg at farmland dumpsites, 0.12 mg/kg at residential land dumpsites, and 0.06 mg/kg at the Faculty of Agriculture dumpsites. These findings suggest that the lead contamination detected in milled melon seeds from Epe market may be attributable to environmental pollution associated with market conditions. There is a safety concern in the Pb content of the milled melon in this study because all the samples had Pb concentrations higher than the 0.1 mg/kg threshold for Pb in foods established by the FDA (2021), and that of the FAO/WHO general standard for contaminants and toxins in food (0.30 mg/kg) (FAO/WHO, 2015).

The atmosphere is full of chromium (Cr). Tanneries, textiles, chrome plating, steel manufacturing, refractories, and other industries use it. Exposure to chromium compounds can result in ulcers that take months to cure (Onyedikachi *et al.*, 2019). Cr levels showed significant variation ($p < 0.05$), with the Epe market sample (0.80 mg/kg) recording the highest concentrations, while the control (0.18 mg/kg) recorded the lowest. However, there is no significant difference ($p > 0.05$) in the Cr content of the Epe market samples and those of the Badagry market. It was reported by Homa *et al.* (2016) that the intake of Cr above the WHO permissible limit (0.2 mg/kg) can result in renal and dermal injuries. The elevated Cr levels in market samples and the control may be associated with industrial emissions, contaminated soil, and polluted water sources used during processing or handling of the melon seeds (Onyedikachi *et al.*, 2019). However, the Cr content of the present study is within the range of values (0.01 to 26.32 mg/kg) reported by Onyedikachi *et al.* (2019) for vegetables, tubers, fruits, and nuts from industrial Areas in Southeastern States of Nigeria.

Copper (Cu) was the most abundant heavy metal detected across the experimental samples, with the Epe market sample recording the highest value (4.54 mg/kg) and the control the lowest (3.12 mg/kg). The significant differences ($p < 0.05$) suggest varying degrees of environmental exposure and possible contamination from processing equipment, storage containers, or environmental deposition in the Epe market sample (Awoyale *et al.*, 2024). However, the Cu content of the Mile-12 market sample is statistically the same as that of the control sample ($p > 0.05$). The Cu content of this study falls within the range of values (2.64 to 6.42 mg/kg) reported for commercial powdered pepper in Ilorin (Awoyale *et al.*, 2024). Awoyale *et al.* (2025) reported Cu content of commercial powdered okro in Ilorin to range from 0.11 to 0.32 mg/kg, which was lower compared to that of this study. It is noteworthy that

even the control sample, which was made in a sterile setting, had a Cu content of up to 3.12 mg/kg. This indicates that soil contamination during plant cultivation, rather than incorrect processing methods, may be the primary cause of the high Cu content in the milled melon samples. The element (Cu) is a naturally occurring heavy metal that is essential to human health in trace amounts. On the other hand, high amounts of Cu can be dangerous. Cu can contaminate food from environmental sources such as contaminated soil or industrial contaminants (Awoyale *et al.*, 2024). High exposure to Cu can cause several ailments, and the clinical significance of Cu poisoning has been studied (Taylor *et al.*, 2020). Also, the findings of this study were higher than those reported by Iwegbue (2011), who documented copper concentrations ranging from 0.01 to 2.12 mg/kg in various Nigerian vegetables and spices. Omokaro et al. (2023) demonstrated that copper concentrations in okro fruits vary across environments, with the highest uptake recorded in residential land (36 mg/kg) and the lowest in farmland (23 mg/kg). These findings suggest that the copper contamination observed in milled melon seeds from the Epe market may originate from fruits cultivated on residential lands that have been repurposed as dumping sites for vehicular components such as tyres and alloy rims (Farombi et al., 2020). It is noteworthy that even the control sample, which was made in a sterile setting, had a Cu content of up to 3.12 mg/kg. This indicates that soil contamination during plant cultivation, rather than incorrect processing methods, may be the primary cause of the high Cu content in the milled melon samples (Awoyale et al., 2024). The Food and Drug Administration has established a

maximum allowable amount of Cu of 10 mg/kg for all food additives, including spices (FDA, 2021), and the FAO/WHO (2015) stipulated 73.3 mg/kg for copper in food. As a result, there Cu toxicity may not be present in the milled melon samples because their total Cu concentration is below the permitted maximum limit.

The body's exposure to dangerous concentrations of heavy metals, such as Cd, in food has been connected to developmental abnormalities, especially in young children (Awoyale *et al.*, 2025). Cadmium (Cd) was not detected in the control and the Epe market samples and was present only in trace amounts in Badagry and Mile-12 market samples, with values reaching up to 0.10 mg/kg. A similar value was reported for the Cd content (0.01 mg/kg) of commercial powdered okro in Ilorin (Awoyale *et al.*, 2025), while Cd was not detected in commercial powdered pepper in Ilorin (Awoyale *et al.*, 2024). The Cd content of the milled melon in this study is lower compared with the stipulated regulatory standard (0.2 mg/kg) of FAO/WHO (2015). The Cd concentrations observed in this study were lower than those reported for several Nigerian vegetables and spices (0.2–4.5 mg/kg) (Iwegbue, 2011). Abou-Arab et al. (1996) highlighted that dietary exposure to hazardous levels of Cd has been associated with developmental defects, particularly in young children. Furthermore, the FAO/WHO (2015) established a permissible limit of 0.2 mg/kg for cadmium in food, which exceeds the values obtained in this investigation. Therefore, the milled melon seeds analysed across all markets are unlikely to constitute a potential source of Cd poisoning.

Table 2. Heavy metal content of milled melon seeds from different markets

Sample	Pb (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	As (mg/kg)
Control	0.46 ± 0.01 ^d	0.18 ± 0.01 ^c	3.12 ± 0.01 ^c	BDL	BDL
Badagry market	1.34 ± 0.20 ^b	0.63 ± 0.08 ^a	3.80 ± 0.29 ^b	0.10 ± 0.09 ^a	BDL
Epe market	1.91 ± 0.11 ^a	0.80 ± 0.05 ^a	4.54 ± 0.22 ^a	BDL	BDL
Mile-12 market	1.07 ± 0.08 ^c	0.42 ± 0.18 ^b	3.51 ± 0.20 ^{bc}	0.10 ± 0.01 ^a	BDL
Mean	1.29	0.55	3.83	0.61	
p level	***	***	***	NS	NS

Below Detection Limit (BDL) = 0.06 mg/kg for Pb, 0.08 mg/kg for Cr, 0.10 mg/kg for Cu, 0.03 mg/kg for Cd, and 0.06 mg/kg for As.
Means with different superscripts within the same column are significantly different (p<0.05).

Conclusion

In terms of aflatoxin and heavy metal contamination, this study offers vital baseline information on the safety of milled melon seeds marketed in well-known Lagos State marketplaces. The results showed that there was no risk of mycotoxin exposure from eating milled melon seeds because aflatoxin levels were consistently low in all markets and control samples, staying well below internationally acceptable standards. However, market samples had considerably higher quantities of heavy metals, especially lead (Pb) and chromium (Cr), with values beyond both EU and Codex criteria. The Epe market samples showed the highest level of contamination, highlighting the impact of handling errors, market storage conditions, and ambient pollution on food safety. Given their cumulative and carcinogenic potential, the discovery of cadmium (Cd) and arsenic (As), even when they are within legal limits, is nonetheless toxicologically significant. In contrast to intrinsic seed composition, post-harvest processing, transportation, and market exposure are the main sources of contamination, as demonstrated by the lower levels of contamination in the laboratory-prepared control sample. These findings draw attention to a critical public health issue: long-term health hazards such as neurological diseases, renal impairment, and carcinogenesis may occur from chronic exposure to heavy metals through commonly ingested staples like pulverised melon seeds. Therefore, the considerable metal burden in market-sold milled melon seed requires immediate attention even though aflatoxin contamination does not presently constitute a serious concern. To reduce the danger of contamination, regular monitoring, tighter enforcement of food safety laws, and better post-harvest handling techniques are crucial. To protect public health, it will be essential to promote hygienic storage, strengthen environmental cleanliness around markets, and increase customer awareness. In the end, protecting consumers, maintaining trust in traditional food systems, and improving food security in Nigeria all depend on the safety of milled melon seeds.

Conflict of Interest

The authors declare that there is no conflict of interest.

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