Libyan Journal of Ecological & Environmental Sciences and Technology
(LJEEST)

LJEEST
ISSN: 2710-5237
www.srcest.org.ly/jou

DOI: https://doi.org/10.63359/tvfwgz39

Assessment of Ascorbic Acid and Heavy Metal Contamination in Mango *Mangifera indica* Varieties from Southern Libya: Implications for Food Safety and Nutritional Quality

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ARTICLE INFO

Vol. 7 No. 3 Dec., 2025
Pages (69- 74)

Article history:
Revised form 07 November 2025
Accepted 20 December 2025

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Keywords:
Heavy metals, Ascorbic acid, Mango, Food safety, Southern Libya
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A B S T R A C T

This study provides a comprehensive evaluation of ascorbic acid (vitamin C) content and selected heavy metals (Fe, Cu, Zn, and Pb) in mango (Mangifera indica L.) varieties cultivated in southern Libya. Samples were collected from seven agricultural regions and analyzed using Atomic Absorption Spectroscopy (AAS) and iodometric titration. The mean concentrations (±SD) of Fe, Cu, Zn, and Pb in mango pulp and peel were found to be within the permissible limits established by the World Health Organization, confirming their safety for human consumption. Vitamin C levels ranged from 11.44 ± 0.5 to 55.44 ± 0.9 mg/g, indicating high antioxidant potential. This study provides the first comprehensive baseline data on heavy metal contamination and vitamin C content in mangoes cultivated in southern Libya, an area that has received limited scientific attention. The findings contribute to environmental monitoring, food safety assessment, and support sustainable agricultural practices in arid regions.

تقييم محتوى حمض الأسكوربيك والتلوث بالمعادن الثقيلة في أصناف المانجو من جنوب ليبيا: الآثار المترتبة على سلامة الغذاء وجودته الغذائية

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تقدّم هذه الدراسة تقييماً شاملاً لمحتوى حمض الأسكوربيك (فيتامين C) وبعض المعادن الثقيلة المختارة، وهي الحديد (Fe) والنحاس (Cu) والزنك (Zn) والرصاص(Pb) ، في ثمار المانجو (Mangifera indica L.) المزروعة في جنوب ليبيا. جُمعت العينات من سبع مناطق زراعية مختلفة، وتم تحليلها باستخدام تقنية الامتصاص الذري (AAS) ومعايرة اليود لتحديد تراكيز فيتامين C .أظهرت النتائج أن متوسط تراكيز المعادن الثقيلة (± الانحراف المعياري) في لب وقشور المانجو يقع ضمن الحدود المسموح بها وفقاً لمعايير منظمة الصحة العالمية، مما يؤكد سلامتها للاستهلاك البشري. كما تراوح محتوى فيتامين C بين 11.44 ± 0.5 و55.44 ± 0.9 ملجم/جرام، وهو ما يعكس القيمة الغذائية العالية والقدرة المضادة للأكسدة لهذه الثمار.. وتُعد هذه الدراسة الأولى من نوعها التي توفّر بيانات مرجعية شاملة حول التلوث بالمعادن الثقيلة ومحتوى فيتامين C في ثمار المانجو المزروعة في جنوب ليبيا، مما يسهم في دعم جهود الرصد البيئي، وتقييم سلامة الغذاء، وتعزيز الممارسات الزراعية المستدامة في المناطق الجافة.

INTRODUCTION

Food contamination with heavy metals poses a major public health concern worldwide due to the bioaccumulation of toxic elements in the human body, which can lead to chronic diseases and organ dysfunction (1). Agricultural products, particularly fruits and vegetables, are key dietary indicators of environmental quality, as they can absorb metals from soil, irrigation water, and atmospheric deposition (2). Mango (Mangifera indica L.) is a widely consumed tropical fruit recognized for its nutritional, economic, and antioxidant value, primarily owing to its high ascorbic acid (vitamin C) content (3). In Libya, mango cultivation is concentrated in the southern regions, yet limited research has been conducted on potential contamination by heavy metals.

The assessment of heavy metal accumulation and vitamin C concentration provides critical insight into food safety and nutritional quality (4). Elevated levels of toxic metals such as lead (Pb) can adversely affect human health, while micronutrients such as iron (Fe), copper (Cu), and zinc (Zn) are essential in trace amounts for metabolic processes but become harmful at excessive concentrations (5). Therefore, evaluating these metals alongside vitamin C content offers a comprehensive understanding of fruit safety and quality.

Previous investigations in various countries have reported varying concentrations of heavy metals in mango fruits. For instance, in Iran, the levels of Pb and Cd in mangoes ranged between 0.008–0.05 ppm and 0.002–0.014 ppm, respectively, depending on cultivation conditions and environmental exposure (6). Similar findings were observed in India and Indonesia, where agricultural practices such as the use of chemical fertilizers, pesticides, and irrigation with contaminated water significantly contributed to metal accumulation in edible crops (7, 8). According to a recent study, typical concentrations of Fe, Zn, and Cu in mature mango pulp are 0.45, 0.24, and 0.17 mg/100 g, respectively, reflecting their physiological importance as micronutrients when present within safe limits (9). Despite the abundance of global studies, there is a notable scarcity of research focusing on heavy metal contamination in mango fruits cultivated in Libya, particularly in the southern regions where mango farming is expanding. Southern Libya is characterized by unique agro-environmental conditions, including arid soils, limited freshwater resources, and reliance on groundwater irrigation factors that may influence metal uptake and accumulation in crops (10). Therefore, establishing baseline data on heavy metal concentrations and vitamin C levels in Libyan mangoes is crucial for assessing potential health risks and ensuring compliance with international food safety standards.

This study aims to: (1) quantify Fe, Cu, Zn, and Pb concentrations in mango samples collected from different regions of southern Libya; (2) determine their ascorbic acid content; and (3) compare the results with WHO permissible limits for heavy metals in fruits, the findings will provide valuable baseline information for environmental monitoring, support the development of sustainable agricultural practices, and promote consumer protection through the assurance of fruit safety and nutritional quality. Furthermore, the results may contribute to the establishment of local guidelines for heavy metal surveillance in agricultural products and enhance public awareness regarding environmental and food safety in Libya.

In light of the aforementioned gaps in the existing literature, the present study aims to despite the increasing global concern regarding heavy metal contamination in food crops, research focusing on mango (Mangifera indica L.) cultivated in Libya remains limited, particularly in the southern regions of the country. Previous studies have reported variable concentrations of heavy metals in mango fruits depending on environmental conditions, agricultural practices, and irrigation sources; however, most of these investigations have been conducted in regions outside Libya and often rely on descriptive reporting rather than analytical comparison. As a result, there is a lack of comprehensive data that critically evaluates the extent of metal accumulation in Libyan mangoes within an environmental and nutritional context.

Although several studies have examined the presence of heavy metals and vitamin C in tropical fruits, inconsistencies in analytical approaches, reporting units (e.g., mg/kg versus mg/100 g), and sampling strategies have limited the comparability of findings across different regions. Moreover, few studies have simultaneously assessed both nutritional quality and potential toxicological risks, particularly in arid and semi-arid environments where soil composition and irrigation practices may significantly influence metal uptake by plants.

In this context, the present study aims to address these gaps by providing a systematic evaluation of selected heavy metals (Fe, Cu, Zn, and Pb) and ascorbic acid content in mango fruits cultivated in southern Libya. By employing standardized analytical methods and presenting results in a unified framework, this study offers a reliable assessment of food safety and nutritional quality. Importantly, this work represents one of the first comprehensive investigations to generate baseline data on heavy metal contamination in mangoes from this region, thereby contributing to environmental monitoring efforts, supporting food safety assessments, and informing sustainable agricultural management in arid environments.

MATERIALS AND METHODS

Materials

Mango fruit samples were collected during the peak harvesting season between June and August 2023 from seven agricultural regions in southern Libya: Zuwaila, Wadi Atba, Hamira, Traghan, Traghan Al-Hamra, Tiwiwi, and Traghan Al-Safra. Analytical-grade chemicals were used in the analysis, including nitric acid (HNO_3, 70%), hydrogen peroxide (H_2O_2, 35%), potassium iodide (KI), iodine (I_2), and starch supplied by Aldrich and BDH. Distilled water was used throughout all experiments. All chemicals used in this study were of analytical reagent grade. Nitric acid (HNO_3, 70%, analytical grade), hydrogen peroxide (H_2O_2, 35%, analytical grade), iodine (I_2, ≥99.8% purity), potassium iodide (KI, ≥99.5%), and starch indicator were obtained from Sigma-Aldrich and BDH Chemicals. Deionized water was used throughout all experimental procedures.

Sample Preparation

Mango fruits were thoroughly washed with distilled water, cut into small slices, and separated into pulp and peel portions. The peels were air-dried, while the pulps were oven-dried at 100 °C for 6 hours. After drying, each sample was ground into a fine powder using a mortar and stored in clean plastic containers.

Digestion Procedure

Two grams of each powdered sample were weighed and placed in a beaker, followed by the addition of 20 mL concentrated nitric acid (HNO_3). The mixture was heated until near dryness, then 10 mL hydrogen peroxide (H_2O_2) was added and reheated until fully evaporated. Subsequently, 20 mL of 0.1 N dilute nitric acid was added, and the solution was gently warmed. The digested sample was filtered into a 50 mL volumetric flask and diluted to the mark with distilled water.

Determination of Heavy Metals

The concentrations of heavy metals (Fe, Cu, Zn, and Pb) were determined using an Atomic Absorption Spectrophotometer (AAS, Model: [Insert Model Number], Manufacturer: [Insert Company Name]). The instrument was calibrated using certified standard solutions prior to analysis to ensure accuracy and reproducibility of the measurements, The measured concentrations were compared with the permissible limits established by the World Health Organization (WHO).(11) permissible limits for heavy metals in fruits.

Determination of Ascorbic Acid

Ascorbic acid was determined by iodometric titration. Ten milliliters of fresh mango juice were titrated against 0.1 N iodine solution in the presence of 1% starch indicator until a blue endpoint appeared. The vitamin C concentration was calculated using the stoichiometric relation between iodine and ascorbic acid.

RESULTS AND DISCUSSION

Determination of Ascorbic Acid in Fresh Mango Juice

The results obtained for the determination of vitamin C (ascorbic acid) in fresh mango juice samples are presented in Table (3). The data show that the vitamin C content varied between 11.44 mg/g and 55.44 mg/g, with sample C exhibiting the highest concentration (55.44 mg/g). This value is slightly lower than the range reported in previous studies (56.5–77.1 mg/g). The differences may be attributed to factors such as mango variety, ripeness, and storage conditions.(12), The observed variations may be influenced by genetic differences, soil composition, fruit maturity, and postharvest storage conditions (4). These results align with previous findings (5), confirming that mangoes serve as a rich dietary source of antioxidants.

Table(1): Determination of Ascorbic Acid in Fresh Mango Juice

Sample Code	Fe $\times10^{-5}$	Cu $\times10^{-5}$	Zn $\times10^{-5}$	Pb $\times10^{-5}$
A1	40.00	25.02	1.336	40.89
A2	-	5.494	17.99	55.03
B1	18.35	29.51	3.757	68.56
B2	-	8.467	9.91	59.77
C1	-	19.23	-	58.10
C2	-	39.49	3.666	46.40
D1	3.526	17.26	3.766	14.30
D2	-	6.758	76.91	43.50
E1	31.88	13.60	4.132	30.17
E2	-	5.90	3.534	21.33
F1	43.59	26.93	9.874	24.74
F2	2.30	9.735	14.90	13.55

In Figure(1). Concentrations of [Fe / Cu / Zn / Pb] in mango (Mangifera indica L.) samples collected from different locations in southern Libya. Values are expressed as mean ± standard deviation (n = 3) and reported in mg/kg fresh weight. Sample codes (A–G) represent distinct sampling sites as follows: A – Zuwaila, B – Wadi Atba, C – Hamira, D – Traghan, E – Traghan Al-Hamra, F – Tiwiwi, and G – Traghan Al-Safra.

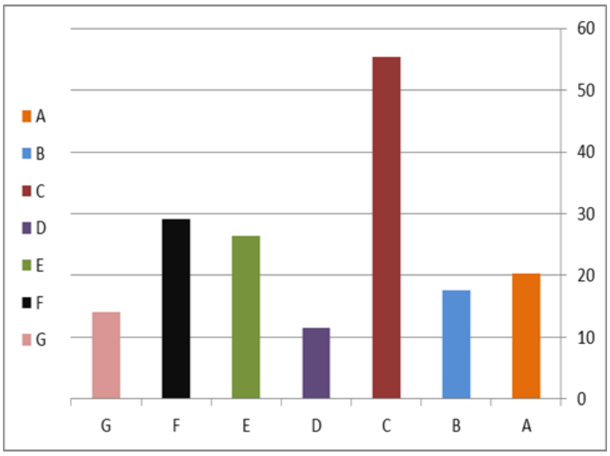

Figure (1): Ascorbic Acid Content in Fresh Mango Juice (mg/g). Sample C recorded the highest concentration, followed by F and E.

Determination of Heavy Metal Concentrations in Fresh Mango Samples

The concentrations of selected heavy metals iron (Fe), copper (Cu), zinc (Zn), and lead (Pb) were determined using Atomic Absorption Spectroscopy (AAS). The obtained data were compared with the permissible limits set by the World Health Organization (WHO) (11), All analyzed samples showed metal concentrations below WHO limits, indicating no significant contamination. The highest Fe concentration (43.59 × 10^{-5} mg/g) was observed in sample F1, while Pb levels ranged between 13.55 × 10^{-5} and 68.56 × 10^{-5} mg/g. The low metal accumulation suggests clean environmental conditions and minimal industrial pollution in the studied regions. Similar findings were reported (1), who observed low contamination levels in fruits from rural agricultural areas.

The essential metals Fe, Cu, and Zn play significant physiological roles in plants and human metabolism but must remain within safe limits to prevent toxicity, Pb, being non-essential and toxic, was present at levels well below the maximum allowable concentration, indicating the safety of mangoes grown in these regions.
The presence of trace heavy metals in agricultural produce can reflect soil quality and irrigation water composition (2). The results of this study demonstrate that southern Libyan soils remain relatively uncontaminated, which supports sustainable fruit

cultivation. High vitamin C levels further enhance the nutritional profile of mangoes, contributing to antioxidant defense mechanisms and overall dietary health.

Table(2): Determination of Heavy Metal Concentrations in Fresh Mango Samples.

Sample Code	Average Titration Volume (mL)	Concentration (N)	Amount (g/g)	Amount (mg/g)
A	0.23	0.0023	0.02024	20.24
B	0.20	0.0020	0.01760	17.60
C	0.63	0.0063	0.05544	55.44
D	0.13	0.0013	0.01144	11.44
E	0.30	0.0030	0.02640	26.40
F	0.33	0.0033	0.02904	29.04
G	0.16	0.0016	0.01408	14.08

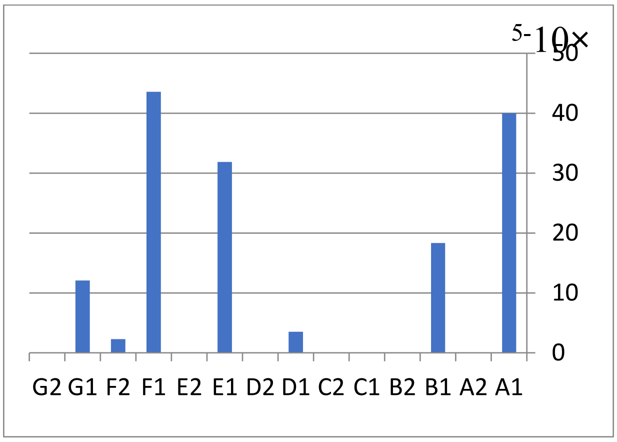

Figure (2): Determination of Heavy (Fe) Concentrations in Fresh Mango Samples

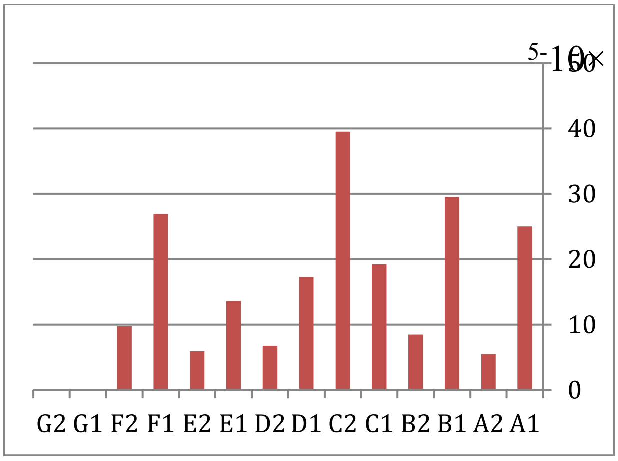

Figure (3): Determination of Heavy (Cu) Concentrations in Fresh Mango Samples.

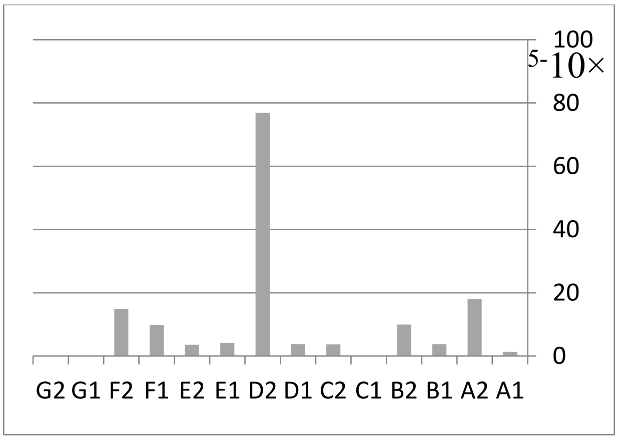

Figure (4): Determination of Heavy (Zn) Concentrations in Fresh Mango Samples.

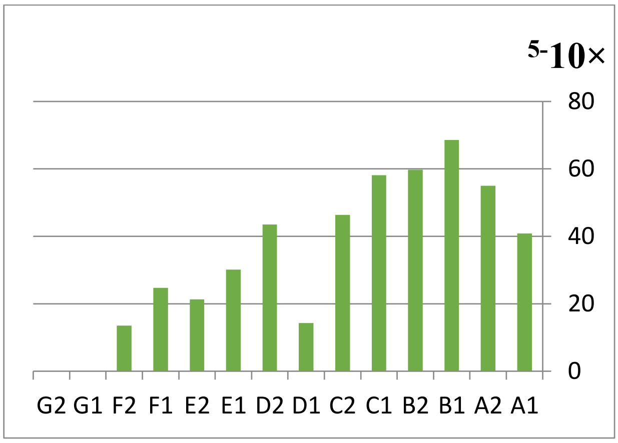

Figure (5): Determination of Heavy (Pb) Concentrations in Fresh Mango Samples.

Figures (5) illustrate the concentration variations of Fe, Cu, Zn, and Pb among mango samples. All measured values were below WHO permissible limits, confirming the safety of the analyzed fruits. The low concentrations may result from clean soils and irrigation water in the sampled areas. Proper washing and peeling before analysis likely reduced surface contaminants.
Vitamin C content ranged between 11.44 mg/g and 55.44 mg/g, with the highest level observed in the Hamira sample. This high ascorbic acid concentration reflects the strong antioxidant and nutritional quality of the fruit.
Overall, the results confirm that mango fruits cultivated in southern Libya are safe for human consumption, showing no hazardous accumulation of heavy metals and a high nutritional value.

CONCLUSION

This study demonstrates that mango fruits cultivated in southern Libya are safe for human consumption and nutritionally beneficial. Heavy metal levels were well below WHO permissible limits, while vitamin C concentrations were high, confirming the antioxidant richness of the fruit. Future research should explore seasonal variations, soil–plant transfer mechanisms, and use advanced analytical techniques such as ICP-MS for further validation.

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