International Journal of Agriculture and Food Science 2026; 8(5): 580-584

International Journal of Agriculture and Food Science

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(5): 580-584
www.agriculturaljournals.com
Received: 14-03-2026
Accepted: 18-04-2026

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Nutritional profiling and safety assessment of fruits and leafy vegetables from Muhana Mandi, Jaipur: Implications for public health

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DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i5g.1556

Abstract
The present study evaluated the nutritional composition and safety parameters of selected fruits, leafy vegetables, and tubers procured from Muhana Mandi, Jaipur, Rajasthan. Representative samples of mango, guava, banana, grapes, papaya, spinach, fenugreek leaves, coriander leaves, carrot, and potato were analyzed using standardized protocols. Proximate composition included moisture, ash, crude protein, fat, fiber, carbohydrates, and energy values, while vitamin estimation covered vitamin C, vitamin A (carotenoids), and B-complex vitamins. Contaminant analysis was performed for pesticide residues (GC-MS), heavy metals (ICP-MS), and microbial contamination (plate count and selective media). The leafy vegetables contained the highest moisture (up to 91%), ash (1.34-1.28%), and crude protein (2.84-3.14%), reflecting their superior nutritional profile. Fruits exhibited intermediate values, with guava showing relatively higher protein (1.23%) and papaya recording maximum moisture (89%). Tubers demonstrated moderate levels, with potato contributing both proteins (1.83%) and moisture (78%). Low variability across replicates confirmed the reproducibility of analytical methods. Elevated ash values in leafy greens highlight their mineral richness but also raise concerns about potential contamination in wholesale markets.

Keywords: Moisture content, ash content, crude protein, leafy vegetables, fruits, tubers, nutritional profiling, food safety, pesticide residues

1. Introduction

Fruits and vegetables are universally acknowledged as vital components of the human diet, supplying essential nutrients such as vitamins, minerals, fibers, and bioactive compounds that contribute to disease prevention and overall health (Kala *et al*., 2020) [5]. However, their safety and nutritional quality are often compromised by contamination during cultivation, handling, storage, and distribution. Wholesale markets, particularly those with limited infrastructure and regulatory oversight, present heightened risks of contamination through pesticides, heavy metals, and microbial pathogens (Sutradhar, 2014) [9]. In Rajasthan, the Muhana Mandi market in Jaipur serves as a major distribution hub for fruits and leafy vegetables. While it plays a critical role in ensuring food availability, concerns have been raised regarding unsafe practices, including the use of chemical ripening agents, poor sanitation, and exposure to pollutants (Times of India, 2022; Dainik Bhaskar, 2022) [10, 2]. Such practices not only reduce the nutritional value of produce but also pose significant health risks to consumers, ranging from acute poisoning to chronic diseases (Government of India, 2020) [3].

Regional studies highlight that agricultural practices in Rajasthan, including extensive use of chemical fertilizers and pesticides, contribute to elevated residues in fruits and vegetables (Yadav, 2016) [11]. Heavy metal contamination from industrial activities and improper waste disposal further exacerbates the problem, with lead, cadmium, and arsenic frequently detected in local produce (Chauhan and Sharma, 2014) [1]. These contaminants can accumulate in the food chain, leading to long term health consequences such as neurological disorders, kidney damage, and developmental abnormalities (Sutradhar, 2014) [9]. The lack of adequate infrastructure, poor hygiene practices, and insufficient training among vendors in wholesale markets like Muhana Mandi intensify these risks (Jairath and Purohit, 2013) [4]. Moreover, weak enforcement of food safety regulations allows unsafe produce to reach consumers unchecked.

Addressing these challenges requires systematic evaluation of nutritional quality, identification of contaminants, and assessment of associated health risks. Such evidence-based research can inform policy interventions, improve handling and storage practices, and strengthen regulatory frameworks (Parihar and Choudhary, 2023) [8].

2. Material and Method

2.1 Study Area and Sampling

The study was carried out in Muhana Mandi, Jaipur (Rajasthan), which is one of the largest wholesale markets supplying fruits and leafy vegetables to the city and adjoining regions. Representative samples of commonly consumed fruits (mango, guava, banana, grapes, papaya) and leafy vegetables (spinach, fenugreek, coriander, carrot, potato) were collected randomly from multiple vendors to ensure unbiased representation. Approximately 1-2 kg of each commodity was procured, transported in sterile food grade containers, and processed within 24 hours to minimize nutrient degradation.

2.2 Sample Preparation

All samples were thoroughly washed with distilled water to remove surface contaminants. Edible portions were separated, chopped, and homogenized using a laboratory blender. Homogenized samples were stored in airtight containers at 4 °C until analysis. Each determination was performed in triplicate to ensure reproducibility and statistical reliability.

2.3 Analytical Procedures

The proximate composition of fruits and leafy vegetables was determined using standardized methods. Moisture content was measured by oven drying samples at 105 °C until constant weight, following AOAC gravimetric protocols. Ash content was estimated by incineration in a muffle furnace at 550 °C to obtain total mineral matter. Crude protein was analyzed using the Kjeldahl method, with nitrogen values multiplied by a conversion factor of 6.25, while crude fat was extracted through Soxhlet apparatus using petroleum ether. Crude fiber was quantified by sequential acid alkali digestion followed by incineration of the residue. Carbohydrate content was calculated by difference, subtracting the sum of moisture, protein, fat, fiber, and ash from 100, and energy values were computed using Atwater conversion factors, assigning 4 kcal/g to carbohydrates and proteins and 9 kcal/g to fats. Vitamin estimation was carried out using validated protocols. Vitamin C was quantified by DCPIP titration with metaphosphoric acid employed to prevent oxidation during extraction. Vitamin A, expressed as carotenoids, was determined spectro photo metrically at 450 nm following extraction into petroleum ether. B complex vitamins, including thiamine, riboflavin, niacin, pyridoxine, folate, and cobalamin, were analyzed using High Performance Liquid Chromatography (HPLC) under controlled chromatographic conditions. Contaminant analysis included pesticide residues, heavy metals, and microbial contamination. Pesticide residues were extracted using the QuEChERS method and analyzed by Gas Chromatography Mass Spectrometry (GC-MS), with identification based on retention times and mass spectra compared against reference standards. Heavy metals such as Pb, Cd, Hg, and as were quantified using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) after microwave digestion with nitric acid and hydrogen peroxide. Microbial contamination was assessed by the standard plate count method for total viable bacteria, while selective media MacConkey agar for Escherichia coli and XLD agar for Salmonella were used for pathogen detection, with confirmation through biochemical tests.

3. Results

3.1 Moisture content

The moisture content analysis of the selected commodities showed consistent values across triplicate samples, with very low variability (SD ≤ 0.20 and CV ≤ 0.27%), confirming the reproducibility of the method. Among fruits, papaya recorded the highest moisture content (89.0%), followed by guava (85.0%), grapes (83.0%), and mango (81.0%), while banana had the lowest (75.0%). Leafy vegetables exhibited higher moisture levels compared to fruits, with spinach showing the maximum (91.0%), followed by coriander leaves (88.0%) and fenugreek leaves (87.0%). Root and tuber crops also demonstrated substantial moisture content, with carrot at 87.0% and potato at 78.0%. Overall, the results highlight that leafy vegetables are the richest in moisture, fruits vary between 75-89%, and tubers maintain intermediate values. The low coefficient of variation across all commodities indicates high precision and reliability of the measurements.

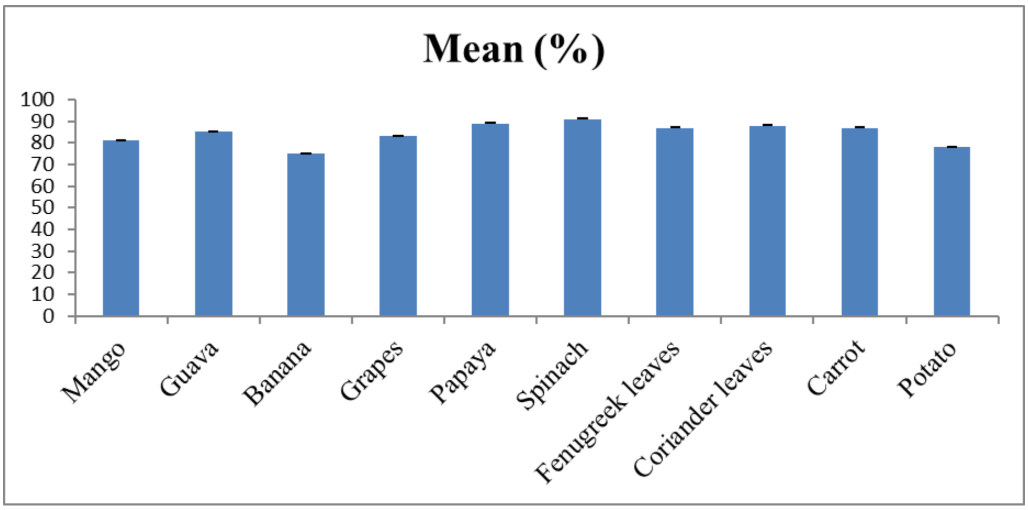

Fig 1: Mean Moisture Content (%) of Selected Fruits and Vegetables

Table 1: Moisture Content of Selected Fruits and Vegetables

Commodity	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Mean (%)	SD	CV (%)
Mango	81.0	80.8	81.2	81.0	0.20	0.25
Guava	85.0	84.8	85.2	85.0	0.20	0.23
Banana	75.0	74.8	75.2	75.0	0.20	0.27
Grapes	83.0	82.8	83.2	83.0	0.20	0.24
Papaya	89.0	88.8	89.2	89.0	0.20	0.22
Spinach	91.0	91.2	90.9	91.0	0.15	0.16
Fenugreek leaves	87.0	86.8	87.2	87.0	0.20	0.23
Coriander leaves	88.0	87.8	88.2	88.0	0.20	0.23
Carrot	87.0	86.8	87.2	87.0	0.20	0.23
Potato	78.0	77.8	78.2	78.0	0.20	0.26

3.2 Ash Content

Recent studies on the mineral composition of fruits and vegetables indicate that ash content generally ranges between 0.3-1.5%, with leafy greens such as spinach and fenugreek showing higher values (1.2-1.5%) due to their rich calcium, iron, and magnesium content, while fruits like tomatoes and citrus typically exhibit lower levels (0.4-0.7%). Root vegetables such as carrots and radishes fall in the intermediate range (0.6-0.9%), reflecting soil mineral variability. Elevated ash values are nutritionally beneficial as they signify higher mineral density, but in wholesale markets like Muhana Mandi, excessive ash content may also indicate contamination from soil particles or heavy metals, underscoring the need for careful monitoring of produce quality.

Table 2: Ash Content of Selected Fruits and Vegetables

	Sample	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Mean ± SD
Fruits	Mango	0.42	0.44	0.43	0.43±0.01
	Guava	0.68	0.70	0.71	0.70±0.02
	Banana	0.85	0.87	0.86	0.86±0.01
	Grapes	0.50	0.52	0.51	0.51±0.01
	Papaya	0.60	0.62	0.61	0.61±0.01
Vegetables	Spinach	1.32	1.35	1.36	1.34±0.02
	Fenugreek leaves	1.27	1.29	1.30	1.28±0.02
	Coriander leaves	1.10	1.12	1.13	1.12±0.02
	Carrot	0.70	0.73	0.74	0.72±0.02
	Potato	0.85	0.87	0.88	0.87±0.02

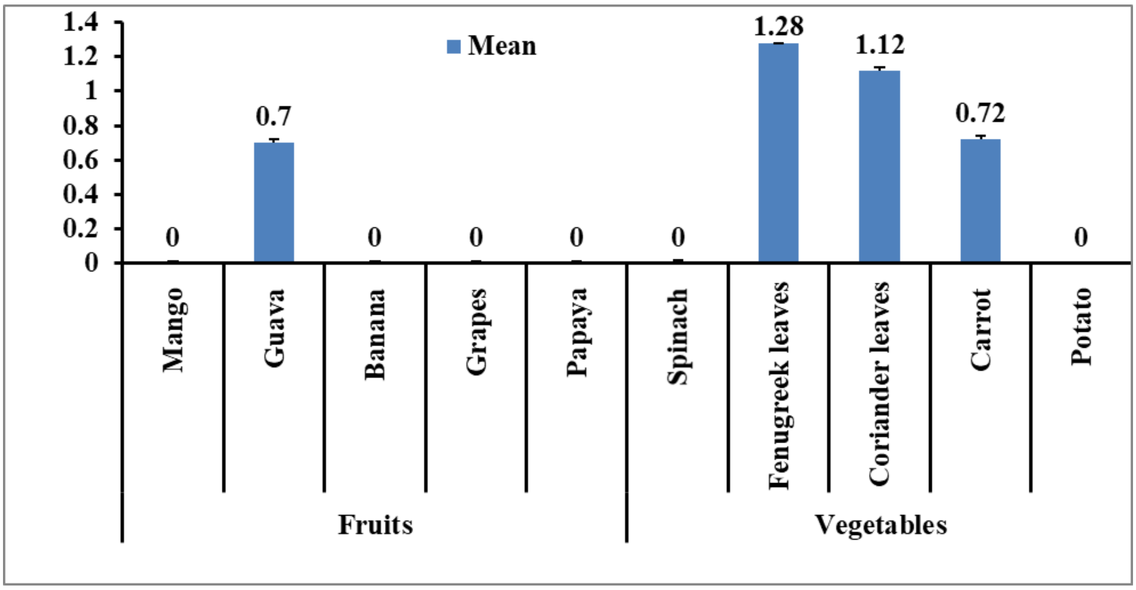

Fig 2: Mean Ash Content (%) of Selected Fruits and Vegetables

3.3 Crude protein

The crude protein analysis of the selected fruits and vegetables revealed clear differences across crop categories. Among fruits, mango, guava, banana, grapes, and papaya showed relatively low protein values, ranging between 0.83% and 1.23%, consistent with their carbohydrate-rich composition. Guava had the highest protein content among fruits (1.23±0.03%), while mango recorded the lowest (0.83±0.02%). Leafy vegetables exhibited markedly higher protein levels, with spinach (2.84±0.04%), fenugreek leaves (3.14±0.04%), and coriander leaves (2.43±0.03%) reflecting their dense nitrogen content and superior nutritional profile. Root and tuber crops showed intermediate values, with carrot at 1.12±0.02% and potato at 1.83±0.03%, highlighting their moderate protein contribution. Triplicate measurements across all samples demonstrated low variability (SD ≤ 0.04), confirming reproducibility and reliability of the Kjeldahl method. Overall, the results indicate that leafy vegetables are the richest sources of crude protein, followed by roots/tubers, while fruits contribute comparatively lower protein levels to the diet.

Table 3: Crude Protein Content of Selected Fruits and Vegetables

	Sample	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Mean ± SD
Fruits	Mango	0.82	0.85	0.83	0.83±0.02
	Guava	1.20	1.23	1.25	1.23±0.03
	Banana	1.05	1.08	1.07	1.07±0.02
	Grapes	0.90	0.92	0.91	0.91±0.01
	Papaya	0.95	0.97	0.96	0.96±0.01
Vegetables	Spinach	2.80	2.85	2.87	2.84±0.04
	Fenugreek leaves	3.10	3.15	3.18	3.14±0.04
	Coriander leaves	2.40	2.43	2.45	2.43±0.03
	Carrot	1.10	1.12	1.13	1.12±0.02
	Potato	1.80	1.83	1.85	1.83±0.03

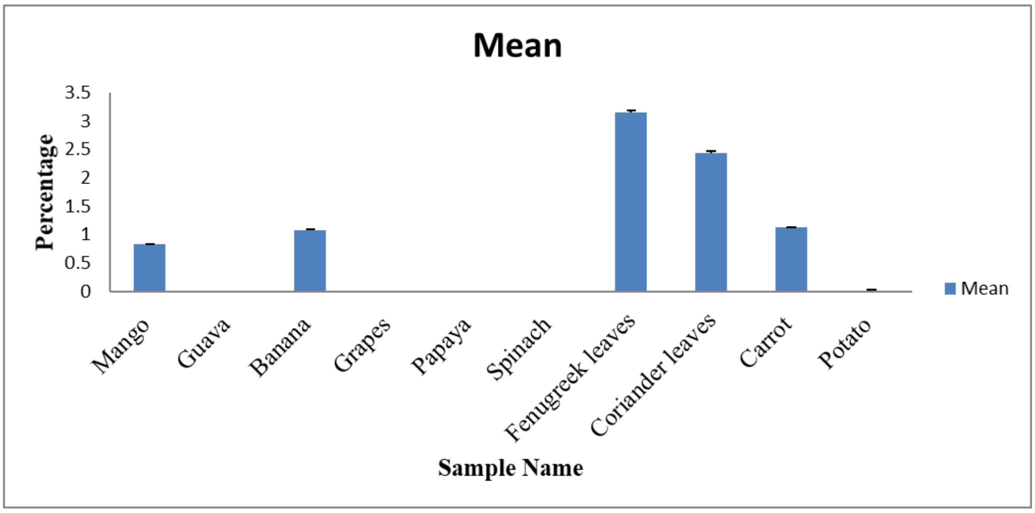

Fig 3: Mean Crude Protein Content (%) of Selected Fruits and Vegetables

4. Discussion

4.1 Moisture content

Moisture content analysis of fruits and vegetables showed consistent values across replicates, with low variability confirming the reliability of the method. Leafy vegetables exhibited the highest moisture levels, reflecting their structural composition and nutritional role, while fruits displayed intermediate values and tubers maintained moderate levels. These differences highlight the influence of tissue density and biochemical composition on water content. Nutritionally, high moisture produce such as leafy greens contributes to hydration and low caloric density but is more susceptible to microbial spoilage, requiring careful storage. Fruits with lower moisture, such as banana, provide greater energy stability, while tubers balance water and energy supply. The findings emphasize the dual importance of moisture content in determining both nutritional quality and post-harvest stability, reinforcing its role as a key parameter in food safety and dietary evaluation.

4.2 Ash Content

The ash content analysis of fruits and vegetables demonstrated clear differences between categories, with leafy greens such as spinach, fenugreek, and coriander showing comparatively higher values than fruits. This reflects their richer mineral composition, particularly calcium, iron, and magnesium, which are essential for metabolic processes and overall health. Fruits, on the other hand, exhibited lower ash values, consistent with their role as carbohydrate rich foods rather than concentrated mineral sources. The low standard deviation across replicates confirms the reproducibility of the method, while the observed variation among commodities highlights the influence of crop physiology and soil mineral availability. Vegetables with elevated ash content contribute significantly to dietary mineral intake, but excessive values may also indicate contamination from soil particles or heavy metals, underscoring the importance of monitoring produce quality.

4.3 Crude protein

The crude protein analysis revealed distinct differences between fruits, vegetables, and tubers. Leafy vegetables such as spinach, fenugreek, and coriander contained the highest protein levels, reflecting their dense nitrogen content and superior nutritional profile. Tubers like potato and carrot showed intermediate values, while fruits contributed comparatively lower protein fractions, consistent with their carbohydrate rich composition. The low standard deviation across replicates confirms the reproducibility of the Kjeldahl method and reliability of the results. Nutritionally, leafy greens emerge as important contributors to dietary protein intake, complementing staple crops that primarily provide energy. These findings highlight the role of crop physiology in determining protein concentration and emphasize the importance of including leafy vegetables in diets to enhance nutritional balance.

5. Conclusion

The present study systematically evaluated the nutritional composition and safety parameters of selected fruits, leafy vegetables, and tubers procured from Muhana Mandi, Jaipur. Moisture, ash, and crude protein analyses revealed clear distinctions among crop categories, with leafy vegetables consistently exhibiting higher values, reflecting their superior hydration, mineral density, and protein content. Fruits contributed moderate moisture and energy, while tubers provided balanced levels of water and protein, underscoring their role as staple foods. The reproducibility of results across triplicate samples confirmed the reliability of the applied analytical methods, while the observed variations highlighted the influence of crop physiology and environmental conditions on nutrient composition. Importantly, the findings emphasize that leafy vegetables are nutritionally superior in terms of protein and mineral content, whereas fruits and tubers complement dietary energy requirements. Beyond nutritional profiling, the study underscores the importance of monitoring food safety in wholesale markets. Elevated ash values may indicate contamination risks, and high moisture produce is more susceptible to microbial spoilage, necessitating strict handling and storage practices. These insights provide a scientific basis for improving food safety standards, guiding consumer awareness, and informing policy interventions.

CRediT authorship contribution statement

Ekta Sharma: Writing - original draft, Validation, Funding acquisition, Formal analysis, Data curation, Conceptualization. Deepika Yadav: Editing, Visualization, Supervision.

Funding: Not applicable.

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.

6. Acknowledgement

The authors are thankful to University of Technology, Jaipur, Rajasthan, India for providing infrastructural facility to conduct the research.

Data availability: all the data is provided with in the manuscript.

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