



Mineral Composition of Tropical Fruits: Banana (*Musa* spp.), Mango (*Mangifera indica*), Pineapple (*Ananas comosus*) and Watermelon (*Citrullus lanatus*)

Clare Kwamboka Riöse*, Grace Lagat, Pius Kipkemboi

Department of Chemistry and Biochemistry, School of Science, University of Eldoret, Eldoret, Kenya

Email: *clareriose@gmail.com

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Abstract

Tropical fruits contribute substantially to human mineral intake, yet most nutritional studies focus narrowly on the edible flesh and overlook the mineral contribution of peels and seeds, fractions routinely discarded as waste. This study determined the mineral composition of the flesh, peel and, where applicable, seed fractions of four tropical fruits commonly consumed in Kenya: banana (*Musa* spp.), mango (*Mangifera indica*), pineapple (*Ananas comosus*) and watermelon (*Citrullus lanatus*). Twenty mature fruits of each species were sourced from retail markets in Eldoret, Uasin Gishu County, separated into their respective fractions, oven-dried, ground and analysed for potassium, zinc, calcium, magnesium and iron using Atomic Absorption Spectrophotometry following dry-ashing, in accordance with AOAC protocols. Potassium emerged as the dominant mineral across all samples, reaching its highest concentration in banana peel (66.84 mg/100g), while iron occurred at generally low concentrations throughout. Banana recorded the highest mean potassium (52.08 mg/100g) and zinc (9.80 mg/100g) content among the four fruits, whereas mango recorded the highest mean magnesium (9.85 mg/100g) and iron (4.73 mg/100g) content. Watermelon showed the lowest concentrations across most minerals examined. Across all four fruits, peel fractions consistently accumulated higher concentrations of potassium, zinc, calcium and magnesium than flesh, while seed fractions carried the highest iron content. One-way ANOVA revealed no statistically significant differences in mineral composition among the four fruit species ($p = 0.1698$) or among the three fruit fractions ($p = 0.4623$) at the 95% confidence level. These findings indicate that peel and seed fractions retain mineral concentrations comparable to, and in several cases exceeding, those of the edible flesh, positioning them as viable candidates for val-

orisation into flour, animal feed or nutraceutical products rather than continued disposal as agricultural waste.

Subject Areas

Nutrition and Health

Keywords

Tropical Fruits, Mineral Composition, Fruit Fractions, Peel Valorisation, AOAC, Atomic Absorption Spectrophotometry (AAS), ANOVA

1. Introduction

Tropical fruits contribute substantially to human mineral intake worldwide, and banana, mango, pineapple and watermelon rank among the most widely consumed species in this category. Each fruit accumulates a distinct mineral profile that depends on species, cultivar, growing conditions and the specific plant fraction examined, since minerals distribute unevenly between the flesh, peel, rind and seed of a single fruit [1]. Calcium, potassium, iron, phosphorus, magnesium and zinc constitute the most nutritionally significant minerals supplied by fruit, and these elements play essential roles in human metabolic pathways, from electrolyte balance and bone formation to enzyme cofactor activity [1].

Nutritive composition of fruits differs not only between species but also across the different anatomical parts of the same fruit. For example, the flesh, peel and seeds of the same fruits have been shown to vary in terms of nutritional content. However, most of the available research focuses on the edible flesh and tends to leave out the nutritional contribution made by peels and seeds. These parts, mostly discarded as waste, can hold significant amounts of dietary fibre, natural sugars, minerals and other nutrients. Detailed analysis of nutrient content across every fruit fraction would give researchers a more complete grasp of a fruit's true nutritional value [2]. Therefore, this study aimed to determine the mineral composition of not only the edible flesh but also the peel and seed fractions of four tropical fruits namely, Banana (*Musa* spp.), Mango (*Mangifera indica*), Pineapple (*Ananas comosus*) and Watermelon (*Citrullus lanatus*).

2. Methodology

2.1. Research Design

The study employed a laboratory-based experimental research design to evaluate the mineral composition of selected tropical fruits fractions. Four commonly consumed tropical fruits in Kenya, namely banana (*Musa* spp.), mango (*Mangifera indica*), pineapple (*Ananas comosus*), and watermelon (*Citrullus lanatus*), were selected for the study. To keep biological variability down and improve sample uniformity, fruits of the same type were chosen for similar maturity, size and colour,

with no visible physical defects or signs of spoilage. Each fruit type traced back to a single source so that growth conditions stayed comparable across the set.

2.2. Study Area

This study was conducted in Eldoret town, Uasin Gishu County in Kenya. Eldoret is one of the major urban centers in the North Rift region and serves as an important commercial hub for agricultural produce, including fresh fruits sourced from different parts of the country. The town was selected because its fruit markets receive produce from various fruit-growing regions in Kenya, making it a suitable location for obtaining representative fruit samples subjected to different post-harvest handling and marketing practices.

2.3. Sample Collection and Preparation

Twenty (20) mature fruits of each species were sourced from farmers and from fruit vendors operating in Eldoret's retail markets, Uasin Gishu County. This sourcing pattern applied uniformly to all four fruit species; no single farm or vendor supplied the entire sample of any fruit type, and growing conditions across the pooled sample of each species were accordingly heterogeneous. Once collected, the fruits were taken straight to the laboratory in clean, well-ventilated containers, which kept mechanical damage and contamination to a minimum. On arrival, the samples were washed thoroughly with distilled water to strip away dust, dirt and other surface contaminants. They were then let to air-dry at room temperature before sorting then kept at 4°C until analysis. All the fruit samples were separated into peel, flesh, and seeds (where applicable) for detailed analysis. The separated fractions were then placed into an oven at 40°C - 50°C and stayed there until they reached a constant weight, a step that kept moisture variation low and improved sample stability. Once dried, the samples were ground into a fine, uniform powder using a blender. Then transferred into sterile, airtight, moisture-proof containers, labelled, and stored at 4°C until further processing.

2.4. Determination of Mineral Composition

The mineral content of the fruit fractions was assessed following AOAC INTERNATIONAL Official Method 975.03, Metals in Plants and Pet Foods [3], employing Atomic Absorption Spectrophotometry (AAS).

Each fruit fraction was ground into a fine powder then passed through a fine mesh sieve (20 cm by 20 cm) to yield a homogeneous sample. Five gram of powdered sample was precisely weighted in clean porcelain crucibles, dried-ashed in a muffle furnace at 550°C for 4 - 5 hours until all organic matter burnt completely to have a white or light gray ash. Ash was cooled in a desiccator then subsequently dissolved in dilute HCl solution (2.5% v/v). The resulting solution was filtered using Whatman filter paper to remove any insoluble particles. The filtrate was transferred into a volumetric flask and made up to 50 mL with deionized water.

The prepared solutions were analyzed using an Atomic Absorption Spectrophotometer (AAS) for the determination of potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn). Calibration was performed using standard solutions of each element, and the concentrations were recorded in mg/L. The mineral concentrations were subsequently expressed as mg/100 g dry weight of the sample using Equation (1) below:

$$\text{Mineral concentration (mg/100g)} = \frac{C \times V \times D \times F \times 100}{W \times 1000} \quad (1)$$

where:

- C = Concentration of the mineral obtained from the AAS (mg/L).
- V = Final volume of the digested solution (mL).
- DF = Dilution factor.
- W = Weight of the sample (g).

2.5. Data Analysis

Data was recorded in triplicates, keyed into Microsoft excel spread sheets before being transferred to Statgraphics Centurion software (version XVI) for Statistical analysis. Results were expressed as mean $\pm$ standard deviation. ANOVA was used to test for statistical significances in the mineral levels at 95% confidence level ($p \leq 0.05$) among the fruits as well as in the different fruit fractions. A p-value of ≤ 0.05 were considered statistically significant.

3. Results

The mineral composition of the various fractions in the four selected tropical fruits is presented in **Table 1** below.

Table 1. Mineral composition of fruit fractions (mg/100g).

Fruit	Fraction	K	Zn	Ca	Mg	Fe
Banana	Flesh	37.33	9.5155	1.76	7.9865	0.141
	Peel	66.835	10.0925	2.18	8.2045	0.7105
Pineapple	Flesh	12.47	4.5155	1.844	6.1475	2.0035
	Peel	29.545	3.1695	8.432	6.764	2.8835
Mangoes	Flesh	37.23	2.5925	2.39	10.009	5.574
	Peel	15.565	4.5155	6.8055	10.442	4.4355
	Seeds	14.315	3.7465	1.004	9.0885	4.177
Watermelon	Flesh	2.43	3.446	2.821	4.45	0.538
	Peel	8.21	6.277	6.191	6.077	1.615
	Seeds	2.2	4.554	3.135	4.654	2.261

Potassium was the dominant mineral, reaching almost 67 mg/100 g dry weight in banana peel, while iron concentrations were generally low (**Table 1**). Magne-

sium concentrations were moderate throughout. Zinc concentrations remained relatively constant among fractions. Peels generally accumulated more calcium than flesh (**Table 1**), and this calcium pattern held for every fruit examined; the potassium, zinc and iron patterns, discussed further below, did not hold for every fruit (**Table 1**).

Considering all five minerals collectively, Mango exhibited the highest mean magnesium (9.85 mg/100g) and iron (4.73 mg/100g) concentrations while maintaining moderate potassium and calcium contents therefore ranking best in mineral concentrations (**Table 2**). On the other hand, Watermelon had generally lower concentrations of most minerals except calcium where the lowest concentration was recorded in banana fruit averaging 1.97 mg/100g. Banana ranked second due to exceptionally high potassium (mean = 52.08 mg/100g) and zinc concentrations (mean = 9.8 mg/100g), although its calcium and iron contents were comparatively low, while Pineapple ranked third because of its high calcium concentration (mean = 5.14 mg/100g) and moderate iron content as shown in **Table 2** below.

Table 2. Mean mineral composition in the four fruits (mg/100g).

Fruit	K	Zn	Ca	Mg	Fe
Banana	52.08 ± 14.75	9.80 ± 0.29	1.97 ± 0.21	8.10 ± 0.11	0.43 ± 0.28
Mangoes	22.37 ± 10.52	3.62 ± 0.79	3.40 ± 2.47	9.85 ± 0.56	4.73 ± 0.61
Pineapple	21.01 ± 8.54	3.84 ± 0.67	5.14 ± 3.29	6.46 ± 0.31	2.44 ± 0.44
Watermelon	4.28 ± 2.78	4.76 ± 1.16	4.05 ± 1.52	5.06 ± 0.72	1.47 ± 0.71

Values are means ± standard deviation.

Peels exhibited the greatest accumulation of potassium (mean = 30.04 mg/100 g dry weight), zinc (mean = 6.01 mg/100g), calcium (mean = 5.90 mg/100g) and magnesium (mean = 7.62 mg/100g) at the fraction-mean level shown in **Table 3**, and flesh generally contained lower mineral concentrations than peel at this aggregated level. Three fruit-mineral combinations in **Table 1** depart from this general pattern and are reported here explicitly rather than absorbed into the aggregate mean: mango flesh potassium (37.23 mg/100g) exceeded mango peel potassium (15.565 mg/100g); mango flesh iron (5.574 mg/100g) exceeded both mango peel iron (4.4355 mg/100g) and mango seed iron (4.177 mg/100g); and pineapple flesh zinc (4.5155 mg/100g) exceeded pineapple peel zinc (3.1695 mg/100g). Seed fractions carried the fraction-mean highest iron concentration (mean = 3.22 mg/100g, **Table 3**); at the level of individual fruits. However, this held for only one of the two fruits bearing a seed fraction, with watermelon seed iron (2.261 mg/100 g dry weight) exceeded watermelon flesh and peel iron, whereas mango flesh iron exceeded mango seed iron. Pineapple does not carry a reported seed fraction, and banana likewise does not carry a reported seed fraction, so this seed-level comparison applied only to mango and watermelon.

Table 3. Mean mineral composition in fruit fractions (mg/100g).

Fruit fraction	K	Zn	Ca	Mg	Fe
Flesh	22.37 ± 15.33	5.02 ± 2.68	2.20 ± 0.43	7.15 ± 2.07	2.06 ± 2.14
Peel	30.04 ± 22.58	6.01 ± 2.60	5.90 ± 2.30	7.62 ± 1.67	2.41 ± 1.40
Seed	8.26 ± 6.06	4.15 ± 0.40	2.07 ± 1.07	6.87 ± 2.22	3.22 ± 0.96

Values are means ± standard deviation.

ANOVA was used to test for statistical significance at $p \leq 0.05$. It was determined that there is no significant differences in the mineral composition among the fruits ($p = 0.1698$) as well as the different fruit fractions (0.4623) as shown in **Table 4** below.

Table 4. ANOVA table on mineral composition.

Source of Variation	SS	Df	MS	F	p-value	Inference
Fruit	674.936	3	224.979	1.75	0.1698	Not Statistically Significant
Residuals	5910.74	46	128.494			
Total	6585.68	49				
Fruit fraction	212.698	2	106.349	0.78	0.4623	Not Statistically Significant
Residuals	6372.98	47	135.595			
Total	6585.68	49				

4. Discussion

The dominance of potassium across all four fruits, with the highest concentration recorded in banana peel, agrees with reports on banana and plantain by-products, in which potassium consistently forms the most abundant mineral in both flesh and peel fractions [4]. Potassium accumulates in greatest amounts in peel because the peel portion contains more vascular and phloem tissue. This is because potassium translocates in fruits via phloem tissue during development. The mean amount recorded in this study for banana was less than concentration reported in fresh banana peel by Tsado *et al.*, [4], this is due to cultivar selection, mineral nutrition of the soil and stage of maturity at harvest of sample.

Mango has the highest mean for Mg and Fe. It has also been observed in numerous studies that mango pulp can be an important supply for major minerals and some trace minerals namely magnesium, iron and zinc [5]. Since they play a major role in metabolism such as chlorophyll synthesis and respiration, iron and magnesium is high because of greater period of maturation of mango compared to watermelon, which also had lowest mean concentration in almost every mineral apart from Ca. The concentrations for Calcium, Potassium, Zinc and Magnesium were found in corresponding peel to be higher compared to the flesh in each of the four tropical fruits.

Table 3 therefore concurs with the findings concerning the separation of ele-

ments in *Musa* tissue which shows high concentration of mineral element in the peel (and in the peel extract) rather than in the pulp [6]. Peel tissue are known to accumulate nutrients at the exterior of fruit tissues since it's closer to the epidermis and the cuticle. Therefore, they receive minerals from the vascular tissues as they are transferred from the rest of the plant to the various fruit tissues before a portion reaches the flesh during ripening processes [7].

Seeds, in contrast, recorded the highest iron concentration among the fractions, which corresponds with findings on mango seed which showed the significant concentration of essential elements in mango seed kernel with high fat and protein concentration [8]. The lack of a statistically significant difference in mineral composition between fruits and in fraction in present study showed general consistency in the overall elemental makeup.

The minerals concentrated in these four fruits carry direct relevance for addressing global micronutrient deficiencies, particularly given that calcium, iron, zinc, copper and magnesium deficiencies remain prevalent worldwide [9]. Potassium, the dominant mineral across all four fruits examined, supports blood pressure regulation, nerve function and muscle contraction, and adult potassium requirements range from approximately 2600 to 3400 mg per day [10]. Calcium, Iron and zinc, though present in comparatively modest amounts in the fruit flesh, reach considerably higher concentrations in the seed and peel fractions. This observation positions the underutilized fruit parts as potential targets for future food fortification or nutraceutical development strategies aimed at addressing micronutrient malnutrition, particularly in regions where these fruits are cultivated at large scale [11] [12].

5. Conclusions and Recommendations

This study concludes that the four fruits, along with their flesh, peel and seed fractions, differ appreciably in their mineral content. These differences, however, did not reach statistical significance ($p > 0.05$) at either the fruit or fraction level. Potassium dominated the mineral profile across all samples, particularly in banana peels. Peels also consistently outperformed flesh in mineral composition in all the fruits.

This study recommends that peel and seed fractions of banana, mango, pineapple, and watermelon be considered for further evaluation toward valorisation into flour, animal feed, or nutraceutical extracts, on the basis of the measured potassium, zinc, calcium, magnesium and iron concentrations reported here, which are comparable to, or in several instances higher than, the corresponding flesh concentrations for these five minerals. Food safety, contaminant levels such as pesticide residues or heavy metals beyond the five minerals measured, the effect of processing steps on mineral retention, and the bioavailability of these minerals to a human consumer were not evaluated in this study and requires dedicated assessment before a practical valorisation is acted upon. Discarding peel and seed fractions as waste without such assessment nonetheless represents an avoidable loss of measured nutritive value.

Data Availability

All data generated or analyzed during this study are included in this published article.

Author Contributions

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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