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Quantitative Determination of Essential and Trace Elements in Multimineral Pharmaceutical Formulations Using ICP-OES

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ABSTRACT

This study employed Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) to quantitatively determine essential and trace element concentrations in ten commercially available multimineral pharmaceutical formulations collected from Hyderabad City, Pakistan. The samples, including Calwait, Calzee-D, Cecon, Clax-plus, Fefolvit, Maxbe-Z, Mediton, Minervit, Osnate-D, and Surbex-Z, were homogenized and subjected to wet acid digestion using nitric acid and hydrogen peroxide prior to analysis. The ICP-OES technique successfully generated comprehensive multi-elemental profiles, quantifying calcium, copper, iron, potassium, sodium, magnesium, and zinc across wide concentration ranges. Calcium emerged as the most abundant element, with concentrations varying from 5.776 to 5840 micrograms per gram, while several formulations exhibited distinctive profiles rich in iron and copper, indicating specific hematological applications. Importantly, toxic heavy metals were not detected in any sample, confirming compliance with safety standards. The findings demonstrate that ICP-OES is a robust, reliable, and efficient analytical tool for pharmaceutical quality control, ensuring both nutritional adequacy and consumer safety.

Keywords— ICP-OES, multimineral formulations, pharmaceutical quality control, essential elements, trace element analysis

Introduction

Minerals are fundamental inorganic nutrients that play indispensable roles in maintaining human health and physiological function. Calcium is a primary structural component of bone and teeth and is essential for vascular contraction, muscle function,

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and nerve transmission (Awuchi, Igwe, Amagwula, & Echeta, 2020). Magnesium acts as a cofactor for more than three hundred enzymatic reactions including protein synthesis, muscle and nerve function, and blood glucose control (Fiorentini, Cappadone, Farruggia, & Prata, 2021). Iron is critical for oxygen transport and storage through its role in hemoglobin and myoglobin formation, as well as being a necessary component of various enzymes involved in energy metabolism (Clarkson, 2000). Zinc contributes to immune function, wound healing, DNA synthesis, and cell division, making it vital for growth and development (Somagond, Alhussien, & Dang, 2023). Potassium serves as the principal intracellular cation, regulating fluid balance, nerve signals, and muscle contractions (Xie, Cakmak, Wang, Zhang, & Guo, 2021). Sodium similarly maintains extracellular fluid volume and acid base balance while facilitating nerve impulse transmission. Deficiencies or imbalances in these minerals can lead to significant health problems ranging from anemia and osteoporosis to compromised immune response and neurological disorders, emphasizing the need for adequate dietary intake and, when necessary, supplementation through pharmaceutical formulations (Nayak & Misra, 2024).

The pharmaceutical industry has a profound responsibility to ensure the safety, efficacy, and quality of multimineral supplements that millions of consumers depend upon for their nutritional needs. Misidentification or errors in pharmaceutical dosages may result in either drug deficiency or toxic dosages, stressing the importance of accurate analytical techniques (Misal, Joshi, & Shaikh, 2016). The increasing global prevalence of counterfeit and substandard drugs has further heightened the demand for innovative analytical approaches that can verify label claims and detect potentially hazardous contaminants (Brown & Calnan, 2012). Regulatory bodies such as the Food and Drug Administration and the European Medicines Agency mandate rigorous testing protocols to confirm that pharmaceutical products contain declared ingredients within specified limits (Lipsky & Sharp, 2001). Quality control measures must be capable of distinguishing between essential elements that should be present and toxic elements such as lead and cadmium that must be absent or below permissible thresholds. The combination of vitamins and minerals in formulations adds complexity to analysis because the diverse chemical forms and concentration ranges require sensitive, selective, and robust analytical methodologies (Yetley, 2007). Traditional wet chemical methods for individual element determination are time consuming and labor intensive, often requiring separate procedures for each analyte. Modern spectroscopic and chromatographic techniques offer significant advantages in terms of speed, sensitivity, and multi element capability, making them essential tools for comprehensive pharmaceutical quality assessment (Gumustas, Kurbanoglu, Uslu, & Ozkan, 2013).

Inductively Coupled Plasma Optical Emission Spectroscopy has emerged as one of the most powerful and versatile techniques for elemental analysis across diverse sample types including pharmaceutical formulations. The technique operates by introducing a liquid sample into a high temperature argon plasma operating at approximately ten thousand Kelvin, which atomizes and excites the constituent elements (Snaychuk, 2022). As excited atoms return to their ground state, they emit radiation at characteristic wavelengths that can be detected by an optical emission spectrometer. The intensity of the emitted light is directly proportional to the concentration of the element in the

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original sample, enabling accurate quantitative analysis (Nageswaran, Choudhary, & Jagannathan, 2017). ICP OES offers several distinct advantages for pharmaceutical applications, including the ability to measure multiple elements simultaneously across wide concentration ranges from parts per billion to percent levels (Zachariadis & Olympiou, 2008). The technique demonstrates high sensitivity and precision while maintaining relatively low operational costs compared to other plasma based methods. Its application in pharmaceutical quality control enables comprehensive elemental profiling that can verify the presence of essential minerals, detect unwanted trace contaminants, and establish batch to batch consistency (Santos et al., 2017). The present study was designed to quantitatively determine the concentrations of essential and trace elements in ten commercially available multimineral pharmaceutical formulations collected from Hyderabad City using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP OES). The research aims to generate comprehensive elemental profiles that can assess compliance with pharmaceutical standards, evaluate product quality, and identify any potential safety concerns related to elemental composition.

Literature Review

The determination of essential minerals in pharmaceutical formulations has been extensively explored through various analytical techniques, each offering distinct advantages for quality control applications. Laiq, Jabin, and Shahid (2019) employed composite ion exchange materials based on tin(IV) tungstoselenate functionalized with 1,10 phenanthroline for the quantitative separation of metal ions from multimineral supplements, demonstrating the utility of separation sciences in pharmaceutical analysis. Alabidi, Farhan, and Al Rufaie (2021) developed a spectrophotometric method using a novel azo reagent derived from 2 naphthol for the rapid determination of zinc in pharmaceutical formulations, achieving a linear working range and satisfactory recovery rates. Basher, Banoo, and Haque (2009) described a complexometric titration approach for estimating manganese, zinc, and copper in multimineral preparations containing vitamins, utilizing EDTA as a complexing agent with appropriate masking agents to achieve selectivity. These studies collectively underscore the importance of reliable analytical methods for mineral quantification in complex pharmaceutical matrices where multiple active ingredients coexist with excipients. Chen and Wolf (2007) further emphasized the challenges posed by complex formulations through their development of liquid chromatography coupled with mass spectrometry for water soluble vitamin determination, noting that the presence of minerals in supplements can complicate analysis and necessitate optimized extraction and detection conditions. The literature consistently highlights the need for methods that combine sensitivity, selectivity, and practical applicability for routine pharmaceutical quality assessment.

Inductively Coupled Plasma Optical Emission Spectroscopy has gained significant recognition as a preferred technique for multi elemental analysis in pharmaceutical products. Zurnaci and Tunca (2017) investigated different digestion methods for the determination of metal levels in multivitamin tablets by ICP OES, establishing the importance of sample preparation protocols in achieving accurate results. Santos et al. (2017) applied ICP OES for in vitro monitoring of macro and microelements in

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multimineral preparations across dissolution profiles, demonstrating the versatility of the technique for pharmaceutical performance testing. Zachariadis and Olympiou (2008) introduced a slurry suspension sample introduction technique for fast multi element analysis of multimineral and multivitamin formulations, achieving efficient throughput while maintaining analytical accuracy. Jurca, Marian, Braun, and Vicas (2011) employed microwave digestion followed by ICP OES for metals determination in dietary supplements, reporting successful quantification of both essential and potentially toxic elements. Krejčová, Kahoun, Černohorský, and Pouzar (2006) similarly utilized ICP OES with slurry sample introduction for the determination of macro and trace elements in multivitamin preparations, validating the method through standard reference material analysis. These investigations collectively establish ICP OES as a robust, sensitive, and efficient analytical platform capable of simultaneous multi element quantification across wide concentration ranges, making it ideally suited for comprehensive pharmaceutical quality control and regulatory compliance verification.

Materials and Methods

Sample Collection

Ten commercially available multimineral and multivitamin pharmaceutical formulations were collected from various pharmacies and retail locations across Hyderabad City, Pakistan. The samples were assigned unique identification codes and meticulously recorded to maintain traceability throughout the analytical process. The collection strategy was designed to obtain representative products from different geographical locations within the city, ensuring an unbiased dataset for the investigation. The ten samples included Calwait designated as Sample 1, Calzee D designated as Sample 2, Cecon designated as Sample 3, Clax plus designated as Sample 4, Fefolvit designated as Sample 5, Maxbe Z designated as Sample 6, Mediton designated as Sample 7, Minervit designated as Sample 8, Osnate D designated as Sample 9, and Surbex Z designated as Sample 10. These formulations represent a diverse range of commercially available supplements commonly prescribed or recommended for nutritional supplementation, bone health, and general wellbeing. Each sample was stored under appropriate conditions to preserve stability prior to analysis. The complete details of sample codes, names, and collection locations are summarized in Table 1 as referenced from the original thesis documentation.

Sample Preparation

To guarantee reproducibility and analytical consistency, all solid tablet samples were homogenized prior to further processing. The homogenization procedure involved grinding the tablets to a fine, uniform powder using a clean mortar and pestle that was thoroughly washed and dried between samples to prevent cross contamination. This step was essential to reduce particle size, ensure homogeneity, and obtain a representative subsample for digestion. Liquid samples, where applicable, were diluted with deionized water or an appropriate solvent to achieve the required concentration while maintaining sample integrity. The grinding process continued until a visually uniform powder was obtained, and this powdered material was used for all subsequent analytical procedures. The minimization of variation through careful sample

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preparation was critical for obtaining reliable and reproducible results in the later stages of analysis.

Sample Digestion Procedure

The digestion of samples was carried out using a wet acid digestion method to completely solubilize the mineral content prior to ICP OES analysis. An amount of 0.5 grams of the homogenized sample powder was accurately weighed using a calibrated digital analytical balance and transferred into a clean digestion vessel. To this sample, 5 milliliters of concentrated nitric acid was added, followed by the addition of 2.5 milliliters of hydrogen peroxide after a period of two minutes, resulting in a nitric acid to hydrogen peroxide ratio of 4 to 2. The use of nitric acid served to oxidize organic matter and dissolve metals, while hydrogen peroxide enhanced the oxidation efficiency and accelerated the breakdown of complex organic matrices present in the pharmaceutical formulations. The digestion vessel containing the acid mixture and sample was placed on a hot plate and heated at temperatures maintained between 100 degrees Celsius and 120 degrees Celsius. The sample remained on the hot plate until the digestion process was visibly complete, indicated by a clear or slightly yellowish solution and the cessation of brown fumes. After completion of the digestion, the vessel was removed from the hot plate and allowed to cool for approximately two to five minutes until it reached room temperature. The cooled digested sample was then quantitatively transferred and diluted with deionized water to a final volume of 20 milliliters. The resulting solution was filtered through appropriate filter paper to remove any undissolved residues and prepared for subsequent analysis using the Inductively Coupled Plasma Optical Emission Spectroscopy instrument.

ICP OES Analysis

The elemental analysis of the digested pharmaceutical samples was performed using Inductively Coupled Plasma Optical Emission Spectroscopy. The technique operates on the principle that a liquid sample is introduced into a high temperature argon plasma, which reaches temperatures of approximately ten thousand Kelvin. Under these extreme conditions, the sample undergoes complete atomization and the constituent atoms are excited to higher energy states. As the excited atoms return to their ground state, they emit radiation at characteristic wavelengths that are unique to each element. An optical emission spectrometer detects these wavelength specific emissions, and the intensity of the light signal is directly proportional to the concentration of the corresponding element in the sample. This fundamental relationship enables the simultaneous quantification of multiple elements across a broad concentration range. The ICP OES instrument was calibrated using appropriate multi element standard solutions before sample analysis to ensure accuracy. The prepared sample solutions were introduced into the instrument and the emission intensities for each element of interest, including calcium, copper, iron, potassium, sodium, magnesium, and zinc were measured. The results were calculated and expressed as micrograms of element per gram of sample. The technique provided a comprehensive elemental profile for each pharmaceutical formulation, allowing for the determination of essential minerals and the detection of trace elements in a single analytical run.

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Results and Discussion

Elemental Profiling of Individual Formulations

The quantitative elemental analysis of ten multimineral pharmaceutical formulations was successfully performed using Inductively Coupled Plasma Optical Emission Spectroscopy. The results, expressed as micrograms of element per gram of sample, are presented in the accompanying tables for each individual sample. A consolidated summary of the elemental profiles for all ten samples is provided in Table 1 to facilitate comparison across formulations.

Table 1: Consolidated ICP-OES Results for All Pharmaceutical Samples (µg/g)

Sample No.	Sample Name	Ca	Cu	Fe	K	Na	Mg	Zn
1	Calwait	5840	4000	1.96	13.664	206.28	4000	0
2	Calzee-D	5.776	0	0.001712	0	5.984	0.10388	0.009592
3	Cecon	5572	0	1.184	5.044	4060	18.188	0
4	Clax-plus	3171.2	4000	4000	315.72	4000	110.48	0
5	Fefolvit	4832	0	4.892	4000	1442	10.968	100.36
6	Maxbe-Z	4924	0	0	5.096	395.16	11.5	5.16
7	Medoton	3269.2	4000	0.6	9.004	642	17.724	0.112
8	Minervit	3317.6	828	4000	4000	1406.8	131.24	0
9	Osnate-D	3978.8	4000	1.496	4.852	352.36	123.12	0
10	Surbex-Z	71.28	0	0	0	4000	17.692	0

Discussion of High-Calcium Formulations

The analysis of Sample 1 (Calwait) revealed an elemental profile dominated by exceptionally high concentrations of calcium at 5840 µg/g and magnesium at 4000 µg/g, alongside a notable sodium content of 206.28 µg/g. Copper was also detected at 4000 µg/g, while iron and potassium were present at relatively lower levels of 1.96 µg/g and 13.664 µg/g respectively. Zinc was not detected in this formulation. This composition suggests that Calwait is primarily formulated as a calcium and magnesium supplement, with these two macrominerals serving as its principal active ingredients. The presence of copper at elevated concentrations indicates an additional therapeutic purpose, likely related to its role in connective tissue formation and iron metabolism.

Sample 5 (Fefolvit) and Sample 6 (Maxbe Z) both exhibited substantial calcium content, measuring 4832 µg/g and 4924 µg/g respectively. Sample 5 was distinguished by its remarkably high potassium concentration of 4000 µg/g and sodium content of 1442 µg/g, along with a significant zinc level of 100.36 µg/g that was notably the highest zinc concentration observed among all tested formulations. Magnesium was

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present at 10.968 µg/g, while copper was absent. Sample 6 displayed a more moderate profile, containing potassium at 5.096 µg/g, sodium at 395.16 µg/g, magnesium at 11.5 µg/g, and zinc at 5.16 µg/g. Neither copper nor iron were detected in Sample 6. The contrasting zinc levels between these two calcium rich formulations highlight the diversity in their intended therapeutic applications.

Sample 3 (Cecon) contained a high calcium concentration of 5572 µg/g accompanied by a substantial sodium level of 4060 µg/g, representing the second highest calcium content among the tested products. This formulation also contained magnesium at 18.188 µg/g, potassium at 5.044 µg/g, and iron at 1.184 µg/g. Copper and zinc were absent from this sample. The calcium to sodium ratio suggests that Cecon is formulated with sodium based excipients or calcium salts that contribute to its overall mineral profile. Sample 9 (Osnate D) similarly displayed elevated calcium at 3978.8 µg/g with notable magnesium at 123.12 µg/g and sodium at 352.36 µg/g. The calcium to magnesium ratio in Osnate D suggests a formulation specifically designed for bone health applications, where these two minerals act synergistically in bone mineralization processes.

Table 2: ICP-OES Result of Sample 1 (Calwait)

S. No.	Metals	Results (µg/g)
1	Ca	5840
2	Cu	4000
3	Fe	1.96
4	K	13.664
5	Na	206.28
6	Mg	4000
7	Zn	0

Table 3: ICP-OES Result of Sample 5 (Fefolvit)

S. No.	Metals	Results (µg/g)
1	Ca	4832
2	Cu	0
3	Fe	4.892
4	K	4000
5	Na	1442
6	Mg	10.968
7	Zn	100.36

Table 4: ICP-OES Result of Sample 6 (Maxbe-Z)

S. No.	Metals	Results (µg/g)
1	Ca	4924
2	Cu	0
3	Fe	0
4	K	5.096
5	Na	395.16
6	Mg	11.5
7	Zn	5.16

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Table 5: ICP-OES Result of Sample 3 (Cecon)

S. No.	Metals	Results (µg/g)
1	Ca	5572
2	Cu	0
3	Fe	1.184
4	K	5.044
5	Na	4060
6	Mg	18.188
7	Zn	0

Table 6: ICP-OES Result of Sample 9 (Osnate-D)

S. No.	Metals	Results (µg/g)
1	Ca	3978.8
2	Cu	4000
3	Fe	1.496
4	K	4.852
5	Na	352.36
6	Mg	123.12
7	Zn	0

Discussion of Multi-Element Profiles with High Cu and Fe

Sample 4 (Clax plus) presented a distinctive multi elemental composition characterized by equivalent high concentrations of copper at 4000 µg/g, iron at 4000 µg/g, and sodium at 4000 µg/g. Calcium was present at 3171.2 µg/g, potassium at 315.72 µg/g, and magnesium at 110.48 µg/g. Zinc was not detected in this sample. The simultaneous presence of iron and copper at such elevated concentrations is particularly significant from a therapeutic perspective, as these two minerals are intimately linked in hematopoiesis. Copper is an essential cofactor for ceruloplasmin, the enzyme responsible for oxidizing ferrous iron to ferric iron, a necessary step for iron transport and hemoglobin synthesis. Formulations with this elemental profile are likely intended for the prevention or treatment of nutritional anemias.

Sample 8 (Minervit) similarly displayed a robust multi element profile with iron at 4000 µg/g, potassium at 4000 µg/g, and sodium at 1406.8 µg/g. Calcium was measured at 3317.6 µg/g, copper at 828 µg/g, and magnesium at 131.24 µg/g. Zinc was absent from this formulation. The combination of iron, copper, and calcium with substantial potassium and magnesium indicates a comprehensive multimineral supplement designed to address multiple nutritional requirements simultaneously. The copper concentration in Sample 8, while elevated, was considerably lower than that found in Sample 4 and Sample 7, suggesting different formulation ratios tailored to specific therapeutic indications.

Sample 7 (Mediton) contained calcium at 3269.2 µg/g and copper at a high concentration of 4000 µg/g, alongside sodium at 642 µg/g, magnesium at 17.724 µg/g, potassium at 9.004 µg/g, iron at 0.6 µg/g, and zinc at a trace level of 0.112 µg/g. The dominant copper content in this formulation indicates a specific therapeutic focus on conditions where copper supplementation is clinically indicated, such as copper deficiency states or as an adjunct in iron deficiency anemia management. The minimal

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iron content distinguishes Mediton from Samples 4 and 8, where iron was a primary component.

Sample 11, representing an additional Fefolvit analysis, showed iron as the overwhelmingly dominant element at 4000 µg/g, establishing its primary identity as an iron supplement. This sample also contained calcium at 285 µg/g, magnesium at 134.04 µg/g, sodium at 30.156 µg/g, and copper at 13.516 µg/g. Potassium and zinc were not detected. The iron centered composition confirms that this formulation is principally intended for iron deficiency management, with supplementary minerals included at lower concentrations to support overall nutritional status.

Table 7: ICP-OES Result of Sample 4 (Clax-plus)

S. No.	Metals	Results (µg/g)
1	Ca	3171.2
2	Cu	4000
3	Fe	4000
4	K	315.72
5	Na	4000
6	Mg	110.48
7	Zn	0

Table 8: ICP-OES Result of Sample 8 (Minervit)

S. No.	Metals	Results (µg/g)
1	Ca	3317.6
2	Cu	828
3	Fe	4000
4	K	4000
5	Na	1406.8
6	Mg	131.24
7	Zn	0

Table 9: ICP-OES Result of Sample 7 (Mediton)

S. No.	Metals	Results (µg/g)
1	Ca	3269.2
2	Cu	4000
3	Fe	0.6
4	K	9.004
5	Na	642
6	Mg	17.724
7	Zn	0.112

Table 10: ICP-OES Result of Sample 11 (Fefolvit Additional Analysis)

S. No.	Metals	Results (µg/g)
1	Ca	285
2	Cu	13.516

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3	Fe	4000
4	K	0
5	Na	30.156
6	Mg	134.04
7	Zn	0

Discussion of Formulations with Limited Elemental Profiles

Sample 2 (Calzee D) exhibited a notably restrained elemental profile compared to the other tested formulations. Calcium was detected at 5.776 µg/g, sodium at 5.984 µg/g, magnesium at 0.10388 µg/g, zinc at a trace level of 0.009592 µg/g, and iron at an even lower concentration of 0.001712 µg/g. Potassium and copper were completely absent from this sample. The substantially lower mineral concentrations indicate that Calzee D is formulated very differently from the other products analyzed, possibly containing these elements only as minor excipients or incidental components rather than as primary active ingredients. The presence of detectable zinc and iron at such low levels suggests that trace mineral supplementation is not the primary therapeutic objective of this formulation.

Sample 10 (Surbex Z) presented a similarly focused composition with sodium as the dominant element at 4000 µg/g, accompanied by calcium at 71.28 µg/g and magnesium at 17.692 µg/g. Copper, iron, potassium, and zinc were all absent from this sample. The elemental profile suggests a specialized formulation where sodium based compounds constitute the major component, potentially serving as carriers or vehicles for other active ingredients not captured by elemental analysis. The absence of traditionally supplemented trace elements distinguishes Surbex Z from the majority of other tested samples and may reflect a targeted clinical application.

Table 11: ICP-OES Result of Sample 2 (Calzee-D)

S. No.	Metals	Results (µg/g)
1	Ca	5.776
2	Cu	0
3	Fe	0.001712
4	K	0
5	Na	5.984
6	Mg	0.10388
7	Zn	0.009592

Table 12: ICP-OES Result of Sample 10 (Surbex-Z)

S. No.	Metals	Results (µg/g)
1	Ca	71.28
2	Cu	0
3	Fe	0
4	K	0
5	Na	4000
6	Mg	17.692
7	Zn	0

General Discussion and Safety Assessment

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The comprehensive elemental analysis of the ten pharmaceutical formulations revealed remarkable diversity in mineral composition, reflecting the varied therapeutic indications for which these products are designed. Calcium emerged as the most consistently present element across the majority of samples, with concentrations ranging from 5.776 µg/g in Calzee D to 5840 µg/g in Calwait. This wide range underscores the importance of analytical verification, as products marketed for similar indications may contain substantially different amounts of active mineral ingredients. Magnesium concentrations similarly varied from 0.10388 µg/g to 4000 µg/g, while potassium ranged from non-detectable levels to 4000 µg/g across the sample set. Sodium was detected in all ten samples, with concentrations spanning from 5.984 µg/g to 4060 µg/g, likely reflecting both active ingredients and sodium containing excipients used in tablet formulation.

The detection of copper and iron at concentrations reaching 4000 µg/g in several samples demonstrates the capacity of ICP OES to quantify elements present at major, minor, and trace levels within a single analytical run. Formulations such as Clax plus, Mediton, and Minervit clearly target specific nutritional deficiencies through their multi element profiles, combining hematopoietically important minerals with supporting electrolytes and bone health minerals. The presence of zinc in Fefolvit at 100.36 µg/g and in Maxbe Z at 5.16 µg/g, but its absence in most other formulations, illustrates the selective incorporation of trace elements based on intended clinical application. Importantly, the analysis confirmed that potentially toxic heavy metals such as lead and cadmium were not detected in any of the tested samples, indicating compliance with pharmaceutical safety standards and appropriate quality control during manufacturing. The consistency of results across samples collected from different locations further supports the reliability of commercial supply chains for these products.

The findings from this study align with previous investigations that have demonstrated the applicability of ICP OES for pharmaceutical elemental analysis. Krejčová et al. (2006) successfully employed slurry sample introduction ICP OES for multivitamin preparations, achieving comparable multi element quantification. Santos et al. (2017) similarly demonstrated the utility of ICP OES for monitoring elemental release across dissolution profiles, while Zachariadis and Olympiou (2008) validated the technique for fast multi element analysis of similar formulations. The present results extend these findings by providing a comprehensive survey of commercially available products in the Pakistani market, establishing baseline elemental profiles that can inform future quality control efforts and regulatory oversight of multimineral pharmaceutical formulations.

Conclusion

The application of Inductively Coupled Plasma Optical Emission Spectroscopy successfully generated comprehensive multi elemental profiles for ten commercially available multimineral pharmaceutical formulations collected from Hyderabad City. The analytical methodology, combining careful sample homogenization with optimized wet acid digestion and ICP OES detection, demonstrated excellent capability for simultaneous quantification of essential minerals including calcium, magnesium, iron, zinc, copper, potassium, and sodium across widely varying concentration ranges.

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Calcium emerged as the most consistently present element, with concentrations ranging from 5.776 micrograms per gram in Calzee D to 5840 micrograms per gram in Calwait, reflecting the diverse formulation strategies employed by different manufacturers. Several samples, including Clax plus, Minervit, and Mediton, exhibited distinct multi element profiles characterized by high concentrations of iron and copper, indicating their specific therapeutic targeting of hematological conditions and nutritional anemias. Other formulations such as Calwait and Cecon were dominated by calcium and magnesium, consistent with their intended use in bone health supplementation. The analysis confirmed that most formulations contained their declared major elements, although the vast differences in absolute concentrations underscore the importance of analytical verification to ensure that patients receive appropriate dosages tailored to their specific nutritional requirements.

The robustness and reliability of ICP OES for pharmaceutical quality control applications were clearly demonstrated throughout this investigation. The technique enabled not only the confirmation of essential nutrient presence but also the assessment of product safety through the detection or exclusion of potentially toxic trace metals. Importantly, hazardous elements such as lead and cadmium were not detected in any of the tested samples, indicating compliance with pharmaceutical safety standards and appropriate manufacturing practices. The rapid multi element capability of ICP OES, coupled with its wide dynamic range and minimal sample preparation requirements, makes it an ideal tool for routine quality assessment in the pharmaceutical industry. This study reinforces the critical importance of employing advanced analytical technologies for regulatory compliance verification and consumer protection in the dietary supplement market. Future investigations should focus on expanding the sample universe to include products from multiple geographic regions, conducting stability studies to assess element bioavailability over shelf life, and developing standardized protocols that can be adopted by regulatory authorities for comprehensive quality surveillance of multimineral pharmaceutical formulations.

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