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Trace Elemental Composition of *Bryophyllum pinnatum*: A Potential Anti-Urolithiatic Medicinal Plant Using the EDXRF Technique

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Abstract

In the present study, the elemental composition of *B.pinnatum* leaves was analyzed using Energy Dispersive X-ray Fluorescence (EDXRF), a fast,multi-elemental and non-destructive technique. The results revealed the presence of essential elements such as calcium (Ca), potassium (K), magnesium (Mg), iron (Fe), and zinc (Zn), all of which play an important role in maintaining in mineral balance and influencing urinary chemistry. These elements may contribute to help prevent kidney stone formation by inhibition of crystal formation and promotion the elimination of urinary excretion. The results provide a scientific basis for the traditional use of *B. pinnatum*in kidney stone and emphasize the significance of trace elements in kidney stone management. However, further research is needed to better understand how these elements are absorbed in the body, ensure their safety, and confirm to support their effectiveness through detailed pharmacological studies.

Keywords: *Bryophyllum pinnatum* EDXRF-technique, Trace elements, Anti-urolithiatic activity, Kidney-stones, Medicinal plants, Elemental analysis

1. Introduction

Kidney stone disease is an increasingly prevalent global health problem, affecting millions of individuals worldwide and imposing a considerable clinical and economic burden on healthcare systems (Francis et al., 2024). Its incidence has risen steadily over the past few decades, with recurrence rates reported to be as high as 50% within 5–10 years (Pedersen et al., 2022). In India, urolithiasis represents a significant public health concern, particularly in

regions with hot climates and limited water intake, where dehydration and dietary factors contribute to stone formation (Kumar et al., 2026). The disease is characterized by the formation of crystalline aggregates in the urinary tract, most commonly composed of calcium oxalate, calcium phosphate, uric acid, or struvite (Roy, 2015).Clinically, kidney stones present with symptoms such as severe flank pain, hematuria, nausea, vomiting, and urinary obstruction, often leading to significant patient discomfort and reduced quality of life (Pedersen et al., 2022). Current treatment strategies include pharmacological management, extracorporeal shock wave lithotripsy (ESWL), ureteroscopy, and surgical interventions. While these approaches are effective in stone removal, they are often associated with high recurrence rates and potential side effects. Common allopathic medications, including diuretics, potassium citrate, and analgesics, may lead to adverse effects such as electrolyte imbalance, gastrointestinal disturbances, hypotension, and long-term renal complications (Chaturvedi et al., 2015). These limitations have encouraged the search for safer, cost-effective, and sustainable therapeutic alternatives.

In this context, medicinal plants have gained considerable attention as potential sources of anti-urolithiatic agents. Traditional systems of medicine, such as Ayurveda, have long utilized plant-based formulations for the prevention and treatment of kidney stones (Allam et al., 2025). Several plants, including *Phyllanthus niruri*, *Tribulus terrestris*, *Aerva lanata*, and *Bergenia ligulata*, have demonstrated promising anti-urolithiatic properties through mechanisms such as inhibition of crystal nucleation, aggregation, and retention within the renal tubules (Hirwe et al., 2026). Recent studies have further explored the role of phytochemicals and bioactive constituents in these plants, highlighting their antioxidant, anti-inflammatory, and diuretic activities.

Among these medicinal plants, B.*pinnatum* (family: Crassulaceae) has emerged as a notable candidate due to its wide distribution and extensive use in traditional medicine. Commonly known as the “life plant” or “air plant,” *B.pinnatum* is a succulent herb characterized by fleshy leaves and the unique ability to propagate through leaf buds (Sharma et al., 2024). It is widely used for the treatment of kidney stones, urinary disorders, wounds, infections, and inflammatory conditions. Previous pharmacological studies have reported its diuretic, antimicrobial, antioxidant, and anti-inflammatory properties, which collectively support its role in urolithiasis management (Kamboj, 2009). However, despite its therapeutic importance, limited attention has been given to its elemental composition and the potential contribution of trace elements to its medicinal efficacy.

Trace elements play a vital role in maintaining human health, participating in numerous biochemical and physiological processes. Elements such as calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), zinc (Zn), and others are essential for enzymatic activity, metabolic regulation, and cellular homeostasis. In the context of kidney stone disease, these elements are particularly significant, as they influence urinary chemistry and crystal formation (Jyothsna et al., 2020). For instance, magnesium is known to inhibit calcium oxalate crystallization, while potassium helps maintain urinary pH balance. However, both deficiency and excess of these elements can have detrimental effects (Jyothsna et al., 2024). Deficiencies may impair metabolic functions and increase susceptibility to disease, whereas excess accumulation can contribute to toxicity and pathological conditions, including stone formation (Awuchi et al., 2020) Therefore, understanding the elemental composition of medicinal plants is crucial for evaluating their therapeutic potential and safety.

In recent years, advanced analytical techniques have been utilized to investigate the elemental profiles of biological samples. Among these, Energy Dispersive X-ray Fluorescence (EDXRF) has gained prominence due to its non-destructive nature, high sensitivity, and capability for multi-elemental analysis. EDXRF allows rapid and accurate quantification of trace and major

elements without extensive sample preparation, making it an ideal tool for studying medicinal plants. The technique is particularly advantageous for detecting elements present in low concentrations and provides valuable insights into their distribution and potential biological roles. The main aim of the present study is, to estimate the elemental composition of *Bryophyllum pinnatum* (B. *pinnatum)* leaves using the EDXRF technique. By identifying and quantifying essential elements, this work seeks to provide a scientific basis for the traditional use of this plant in kidney stone treatment and to explore the role of trace elements in its anti-urolithiatic activity. Furthermore, the findings may contribute to the development of novel plant-based therapeutic strategies for the effective management of urolithiasis.

2. Materials and Methods

2.1 Collection of plant material

The Plant sample of *Bryophyllum pinnatum* fresh and healthy leaves (as illustrated in figure 1) were collected from botanical garden of Botany department, Kakatiya University located in Warangal, Telangana state. After collection, the plant leaves were washed with tap water followed by DI water to remove dust and unwanted impurities and then air dried under shade at room temperature to preserve their biochemical integrity. To ensure complete removal of moisture, the dried samples were further subjected to mild heating in a hot air oven at 80 °C for 24 hours. The fully dried leaves were then finely ground into a homogeneous powder using clean agate mortar and pestle. The powdered sample was sieved to obtain uniform particle size and stored in airtight containers to prevent moisture absorption and contamination prior to further experimental analysis.

Figure 1. The image of B. *pinnatum* leaves

2.2 Experimental analysis of EDXRF spectrometer

Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer, a rapid and non-destructive technique for multi-element detection. The experimental analysis was carried out using an Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer at the UGC-CSR, DAE Kolkata Centre as shown in the figure 2.Table 1 represents the detailed information of the EDXRF spectrometer parameters. The dried powder was pressed into a uniform pellet and exposed to an X-ray beam, causing the emission of characteristic

fluorescent X-rays from the elements present in the sample. These emitted signals were detected and analyzed to determine both the type and concentration of elements. The instrument was calibrated using NIST 1515 apple leaf standard to ensure accuracy, and the obtained spectra were processed using suitable software for quantitative analysis.

Figure 2. EDXRF, EX-3600 spectrometer, at UGC, DAE, CSR Kolkata Centre

Table 1. Parameters of EDXRF spectrometer used for spectra acquisition

S. No	Parameter	e-1	e-2	e-3
1	Voltage (kv)	6	14	23
2	Current (mA)	200	900	200
3	Time (sec)	200	400	600
4	Atmosphere	Vacuum	Vacuum	Vacuum
5	Energy Range (keV)	0-10	0-10	0-40
6	Through output	Low	Low	Low
7	Filter	None	3 (Ti)	4 (Fe)

3. Results and Discussion

The present study estimates the EDXRF analysis of *Bryophyllum pinnatum* leaves, whichreveals that a significant presence of elements that are closely associated with kidney stone prevention and urinary health, thereby supporting its long-standing use in Ayurvedic medicine as an anti-urolithiatic plant. The EDXRF spectrometer was used to analyze 13 elements (such as P, S, Cl, K, Ca, Mn, Fe, Cu, Zn, Se, Br, Rb, and Sr) and to quantified their composition in B. *pinnatum* leaves at ppm level. Table 2 represents the elemental concentrations in B. pinnatum leaves, whereas compared with standard certified values and % of deviation. Among the observed elements, calcium (Ca) and potassium (K) were found in remarkably high concentrations (22500 ± 1100 ppm and 17800 ± 950 ppm, respectively). Although calcium is a major constituent of most renal calculi, dietary calcium plays a protective role by binding with oxalate in the gastrointestinal tract, thereby reducing oxalate absorption and subsequent urinary excretion (von Unruh et al., 2004). Potassium, on the other hand, is known to regulate urinary pH and enhance citrate excretion, which inhibits crystal aggregation and stone formation (Basavaraj et al., 2007). This aligns

with the traditional Ayurvedic concept of *Mutrala* (diuretic action), where increased urine output helps in flushing out stone-forming constituents.The presence of iron (240 ± 15 ppm) and zinc (32 ± 4 ppm) further enhances the therapeutic potential, as these elements contribute to enzymatic functions, antioxidant defense, and tissue repair in the urinary system. Manganese (85 ± 6 ppm), an essential cofactor for several enzymes, may also assist in reducing oxidative stress, which is often associated with kidney stone formation (Ferraro et al., 2018).

Table 2. Elemental concentrations of *Bryophyllum pinnatum* compared with NIST 1515 apple leaf.

Element	***Bryophyllumpinnatum* (ppm)**	**NIST 1515 Apple Leaf (ppm)**	**Deviation (%)**
P	1450 ± 120	1590	-8.81
S	1320 ± 95	1800	-26.67
Cl	2100 ± 150	580	+262.07
K	17800 ± 950	16100	+10.56
Ca	22500 ± 1100	15260	+47.45
Mn	85 ± 6	54	+57.41
Fe	240 ± 15	83	+189.16
Cu	7.5 ± 1.2	5.64	+32.98
Zn	32 ± 4	12.5	+156.00
Se	1.10 ± 0.2	0.05	+2100.00
Br	35 ± 2	3	+1066.67
Rb	18 ± 1.5	12	+50.00
Sr	210 ± 10	25	+740.00

Figure 2 shows the EDXRF spectrums of present plant leaves sample. Although some elements show variation when compared with the NIST 1515 standard, these differences can be attributed to environmental factors such as soil composition and plant growth conditions. Importantly, the elevated levels of essential elements associated with mineral metabolism and urinary regulation strongly support the traditional use of B.*pinnatum* in the prevention and management of kidney stones.

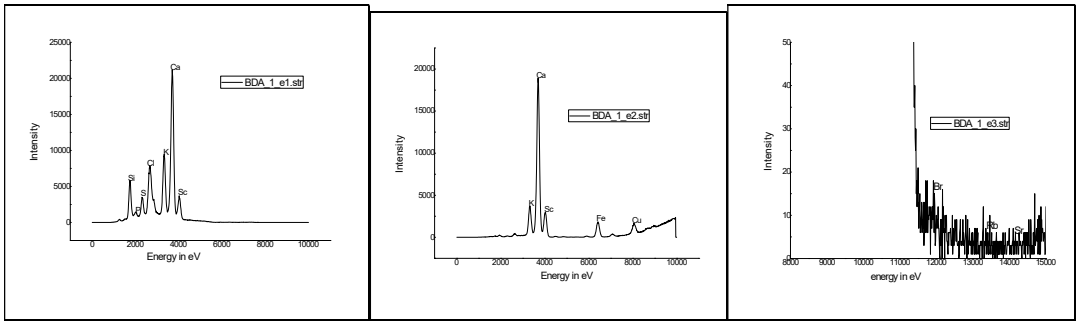

Figure 2. EDXRF spectrums of B. *pinnatum* leaves (at different energy ranges)

4. Conclusion

The present study demonstrates that *Bryophyllumpinnatum*(B. *pinnatum*) leaves are a rich source of essential elements, particularly Ca, K, Fe, Zn, and Mn, which are closely associated with kidney stone prevention and urinary health. The findings provide a scientific basis for its traditional Ayurvedic use as an anti-urolithiatic agent. The successful application of EDXRF also confirms its effectiveness as a rapid and reliable technique for elemental analysis of medicinal plants.

5. Future Scope

Further research is needed to explore the bioavailability and synergistic effects of these elements in the human body. Detailed pharmacological and clinical studies can help validate the anti-urolithiatic efficacy of *B.pinnatum*. Additionally, the development of standardized herbal formulations and nano-based delivery systems may enhance its therapeutic application in modern medicine, bridging traditional knowledge with contemporary scientific approaches.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the present research paper.

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