Review Article

Kalanchoe pinnata as an Herbal Medicine Having Anti-Urolithiatic Potentiality

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ABSTRACT

Urolithiasis, characterized by stone formation within the urinary tract, remains a major global health concern due to its high recurrence rate and associated morbidity. Although current surgical and pharmacological involvements are effective, their limitations and adverse effects have driven increased interest in plant-based therapeutic alternatives. This review evaluates the antiurolithiatic potential of medicinal plants, with particular emphasis on *Kalanchoe pinnata* (Syn: *Bryophyllum pinnatum*), a widely used ethnomedicinal herb. Evidence from in vitro and in vivo studies demonstrates that *K. pinnata* leaf extracts exhibit significant antiurolithiatic and nephroprotective activities. In ethylene glycol-induced urolithiatic rat models, treatment with *K. pinnata* resulted in marked reductions in serum urea, uric acid and creatinine levels, along with notable improvements in renal histoarchitecture. In vitro assays further confirmed inhibition of calcium oxalate crystal nucleation, growth and accumulation, as well as partial dissolution of kidney stones. Structural and compositional changes in crystals following extract treatment were validated using FTIR, SEM, and XRD analysis. These effects are attributed to bioactive constituents such as flavonoids, organic acids, and triterpenoids. Collectively, the findings highlight the therapeutic potential of *K. pinnata* as a natural antiurolithiatic agent and support the need for further clinical validation, standardization, and formulation development.

Keywords: *Kalanchoe pinnata*, Urolithiasis, Nephrolithiasis.

INTRODUCTION

The development of calculi in the excretory system is a common urinary tract condition known as urolithiasis. It is frequently accompanied by significant morbidity and a high risk of recurrence[1]. Reducing recurrence needs a thorough understanding of the pathophysiological mechanisms controlling stone development. About 2-3% of cases that proceed to end-stage renal disease is caused by nephrolithiasis, especially when nephrocalcinosis is present[2]. A serious global health concern, urinary stone disease is primarily caused by metabolic disorders and a variety of environmental variables[3]. Urolithiasis affects over 12% of people worldwide, and recurrence rates are higher in men (70–81%) than in women (47–60%). The main cause of this gender difference is elevated levels of calcium and oxalate in the urine, which lead to aberrant kidney mineralization[3].

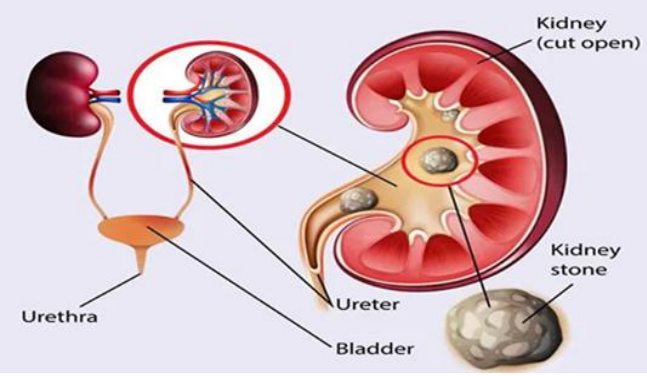

Figure 1: Visual representation of obstructing and non-obstructing Kidney[2]

Main Kidney stone types: - Based on differences in their composition and formation, kidney stones can be categorized into several groups.

- **Calcium Stones**: This is a type of stone which is mainly caused due to the calcium which forms due to the conjugation with phosphate, oxalate and uric acid. Many sources contain high concentration of oxalate such as several vegetables, fruits, nuts and chocolates. In adult the healthy level of oxalate is 20-40 mg/d[3].
- **Struvite stones:** Struvite stones are formed due to the composition of magnesium ammonium phosphate stones. This stones generally grow in the collecting system of the nephron, it is also known as partial or staghorn calculi. This is caused due to the chronic urinary tract infection which is caused due to Gram-negative urea-splitting rods including Proteus, Pseudomonas and Klebsiella species[4].
- **Uric Acid Stones:** It is mainly formed due to medications which contains high purine or high cell turnover (such as cancer), this is the most common cause of uric acid stone. The patients suffering from gout also frequently have these condition. If the pH pf urine is 5.5 or lower is mostly associated with the formation of uric acid stones. About five to ten percent of kidney stones are spherical, smooth, yellow-orange stones composed of uric acid[3].
- **Cysteine Stones**: The main cause of cysteine stones is due to hereditary intrinsic metabolic disorder called cystinuria which occurs because of the reabsorption of cystine in the renal tubule. They can be seen through X-rays because of high sulphur content.[4]

- **Drug-induced Stones:** Medications such as indinavir, atazanavir, sulphonamides, ceftriaxone, etc are used in the long-term treatment of drug induced stones. And other medications with poor solubility, high excretion rates, or high doses that start the crystallization process increases the risk of renal calculi. It is very common in patients who are prescribed with benzbromarone, salicylic acid, and probenecid.[3,4]

Sign and symptoms: The major sign and symptoms include:

a) A sudden need for urination.

b) A burning sensation when urinating.

c) Because of the RBC blood particles, the urine will be dark or crimson. Sometimes the hue of the blood is so faint that it is invisible to the unaided eye.

d) Nausea and vomiting sensations.

e) The tip of the penis hurts male patients[5].

Figure 2: *Kalanchoe pinnata* [6]

Plant Description-

- Botanical Name: *Kalanchoe Pinnata*
- Family: Crussulaceae
- Sanskrit: Pashanabheda
- Hindi: Patharchur[7]

Taxonomical tree:

- Kingdom: Plantae
- Division: Magnoliophyta
- Class: Magnoliopsida
- Order: Saxifragales
- Genus: Kalanchoe
- Section: Bryophyllum
- Species: K. pinnata[8,9]

Phytochemical constituents- Traditionally used as an herb, *Kalanchoe pinnata* is an aromatic medicinal plant with a subtle sweet-and-sour smell. The presence of essential oils dispersed throughout the leaves and other aerial parts of the plant is largely responsible for the distinctive scent seen in different K. pinnata species[10,11]. There are many significant chemical components and secondary metabolites of the plant that have been identified; the most prominent ones are flavonoids and bufadienolides[12]. Bufadienolides are a class of highly active compounds found in leaves[13]. There are many chemical constituents are there in it, the major chemical constituents are: -

I. **Bufadienolides**- Bryophyllin A (bryotoxin), Bryophyllin B, Bryophyllol, Bryophollone, Bryophollenone[13].

II. **Phenols, Phenylpropanoids and Flavanoids**: kaempferol, quercetin, syringate, luteolin, rutin[13].

III. **Triterpenoids and Steroids**: amyrin, α-amyrinacetate, β-amyrin, β-amyrinacetate, bryophollenone, bryophollone, taraxerol[13].

IV. **Fatty Acids, Minerals and Others**: The fatty acid fraction consists of methionine, tyrosine, phenylalanine, palmitic acid (89.3%), stearic acid (10.7%), and traces of arachidic and behenic acid hydrolysate[13].

Mineral elements like Na, Ca, K, P, Mg, Mn, Fe, Cu, and Zn are all abundant in the herb. Raffinose, lactose, sucrose, glucose, galactose, and fructose are among the sugars that are present. The plant also includes derivatives of phenanthrene, tannins, and alkaloids[14].

Among the phytochemicals found in *Kalanchoe pinnata*, the following have been shown to exhibit antiurolithiatic activity (preventing or treating kidney stone formation):

a) **Flavonoids: -** Quercetin, Kaempferol[15].

b) **Organic Acids: -** Citric, Malic, Tartaric acids[16].

c) **Triterpenoids: -** Bryophyllin A[17].

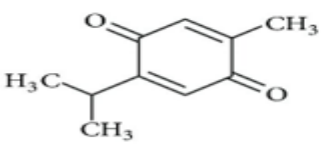

Figure 3: Quercetin[18]

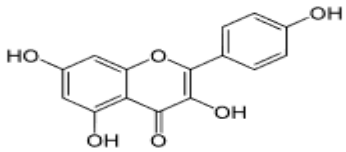

Figure 4: Kaempferol[19]

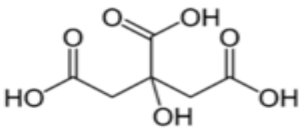

Figure 5: Citric Acid[20]

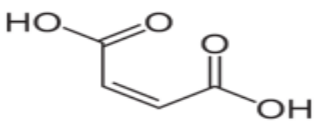

Figure 6: Malic Acid[21]

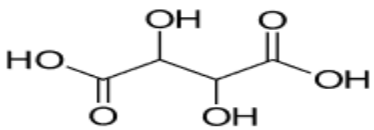

Figure 7: Tartaric Acid[22]

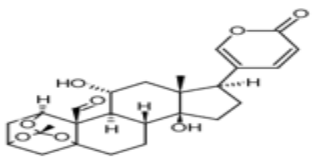

Figure 8: Bryophyllin A[23]

Mechanism of action- The most frequent component that causes urinary tract stones, calcium oxalate, may be significantly dissolved by kalanchoe pinnata. Numerous phytochemicals, including flavonoids, quercitrin, glycosides, carotenoids, saponin, kaempferol, and alkaloids, are present in the leaves[24]. The mechanism of action is as follows,

- **Flavonoids: -** Mechanism: Prevent calcium oxalate crystal nucleation, growth, and accumulation, which are the main steps in kidney stone formation. Exhibit antioxidant properties that protect renal epithelial cells from oxidative stress-induced injury, which can promote crystal adhesion[15]. Eg- Quercetin, Kaempferol
- **Organic Acids**: -Mechanism: Chelate calcium bind free calcium ions to reduce supersaturation and promote stone dissolution. Increase citrate excretion and urinary pH, both of which discourage calcium oxalate stone formation[16]. Eg- citric, malic, tartaric acids.
- **Triterpenoids: -** Mechanism: Anti-inflammatory and nephroprotective: these reduce renal inflammation, oxidative stress, and tubular injury, thereby preventing crystal retention. Support formation of less pathogenic crystal forms and protect kidney tissue[17]. e.g bryophyllin A

The flavonoids, saponins, organic acids, and triterpenoids found (Table-1) in *Kalanchoe pinnata* give it potent antiurolithiatic properties. These phytochemicals combine to prevent calcium oxalate crystals from forming and clumping together, boost urine production, chelate free calcium ions, and protect renal tissues from inflammation and oxidative stress.

Table 1: Compounds found in Kalanchoe Pinnata and their effect[24].

Compound	Properties
Flavonoids	Decrease the development of calcium oxalate stones and have antibacterial, diuretic, anti-inflammatory, and other therapeutic properties.
Quercitrin	Beneficial for reducing calcium oxalate crystal deposition in renal tubules and preventing stone-forming disorders.
Phenolics	More efficient than oxalate stones in dissolving calcium phosphate stones.
Kaempferol	Inhibit the nucleation, aggregation, and crystallization processes.
Glycoside	Reduce kidney damage and urinary problems.
Steroids	It can reduce the time it takes for stones to move through urine.

Pharmacological action- As it contains flavonoids, terpenoids, bufadienolides and phenolic compounds *Kalanchoe pinnata* exhibits a wide pharmacological profile. The actions are-

Antiurolithiatic Activity: - Urinary stones have long been treated with the plant. By preventing calcium oxalate crystal nucleation and aggregation, its extract helps to avoid the formation of stones[25].

Analgesic and anti-inflammatory Activity: - Kalanchoe pinnata's flavonoids, triterpenoids, and bufadienolides are the main causes of its notable anti-inflammatory and pain-relieving properties[26].

Wound Healing Activity: - The plant helps wounds heal faster by making them contract, epithelialize, and grow new tissue[27].

Anti-ulcer Activity: - The capacity of K. pinnata to lower stomach acid output and boost mucosal defense accounts for its gastroprotective properties[28].

Antiviral Activity: - In K. pinnata, phytochemicals like quercetin and bufadienolides have demonstrated efficacy against influenza and HSV viruses[29].

Antiurolithiatic Activity of *Kalanchoe Pinnata* In-vitro and In-vivo analysis- *Kalanchoe pinnata*, also known as Bryophyllum pinnatum, is widely recognized in traditional systems of medicine for its efficacy in treating urolithiasis. The plant is rich in phytoconstituents including flavonoids, phenolic compounds, and organic acids, which contribute significantly to its antiurolithiatic and nephroprotective actions.

***In Vivo* Antiurolithiatic and Nephroprotective Activity: -**

A study was conducted to evaluate the nephroprotective effects of the ethanolic leaf extract of K. pinnata in ethylene glycol-induced urolithiasis in Wistar rats[30]. Rats treated with 75 mg/kg body weight of the extract for 10 days showed significant reductions in serum levels of urea (from 59.00 to 36.16 mg/dL), uric acid (from 8.28 to 6.12 mg/dL), and creatinine (from 1.88 to 1.26 mg/dL). These improvements were comparable to those observed with the standard drug Cystone.

Additionally, serum enzyme markers such as SGOT, SGPT, ALP, and total protein levels were significantly reduced, suggesting protection against renal damage. Histopathological analysis confirmed the reduction in crystal deposition and restoration of normal kidney architecture in extract-treated animals[30].

The observed effects are likely due to the antioxidant potential of bioactive compounds in K. pinnata, such as flavonoids and triterpenoids, which counter oxidative stress and reduce calcium oxalate crystal retention in renal tissues [30]

***In Vitro* Antiurolithiatic Activity: -**

A study reported the in vitro antiurolithiatic effects of aqueous K. pinnata leaf extract using egg membrane dissolution models[31]. The study investigated the extract's effect on calcium oxalate and phosphate crystallization through:

- Nucleation and accumulation assays: The extract significantly inhibited both nucleation and aggregation of calcium oxalate crystals, indicating its potential to prevent early stone formation[31].

- Dissolution studies: In egg membrane models, the extract showed moderate but consistent dissolution of calcium oxalate stones. The effect was comparable to Cystone, which showed stronger dissolution for calcium phosphate stones[31].

Spectrophotometric analysis further validated the reduced concentration of undissolved calcium oxalate, confirming the litholytic activity of the plant extract[31]

Advanced In Vitro and Mechanistic Analysis: -

A recent study further validated the antiurolithiatic properties of K. pinnata using both supersaturated and synthetic urine models[32]. Key findings included:

- Crystal inhibition: Crystal growth was inhibited by 41% in supersaturated solution and 15% in synthetic urine with K. pinnata extract treatment.
- Stone dissolution: Mass of calcium oxalate monohydrate (COM) and surgically extracted kidney stones was reduced by 30% and 18%, respectively, after five extract washes.
- Organic acid contribution: Active compounds such as malic, syringic, caffeic, and p-hydroxybenzoic acids contributed significantly to the inhibitory effect (2.70–4.65% each), accounting for the observed total inhibition in synthetic urine[32].

Table 2: Medicinal uses

MEDICINAL USE	DESCRIPTION
Kidney Stone Treatment (Antiurolithiatic)	Helps dissolve or expel kidney stones by inhibiting crystal formation and increasing urine output[33]
Wound Healing	Promotes healing of cuts, burns, and wounds by enhancing tissue regeneration and reducing inflammation[34]
Anti-inflammatory & Pain Relief	Reduces swelling and pain in conditions like arthritis through inhibition of inflammatory mediators[35]
Antimicrobial & Antiviral	Exhibits activity against bacteria and viruses by disrupting microbial cell function[36]
Stomach Ulcer Protection (Antiulcer)	Protects the stomach lining, reduces gastric acid, and prevents ulcer formation[37]
Respiratory Relief	Used for coughs, asthma, and bronchitis as a bronchodilator and expectorant[38]
Liver Protection (Hepatoprotective)	Supports liver detoxification and reduces liver enzyme levels in toxicity models[37]
Antioxidant Activity	Scavenges free radicals, helping protect cells and slow degenerative changes[33]
Reproductive Health (Uterine Relaxant)	Used to manage uterine contractions and prevent preterm labor, especially in European phytotherapy[39,40]

Analytical techniques including FTIR, SEM, TGA, and XRD confirmed both the chemical composition and reduced size/morphology of calcium oxalate crystals upon treatment, supporting the extract's role in both prevention and treatment phases of stone formation.

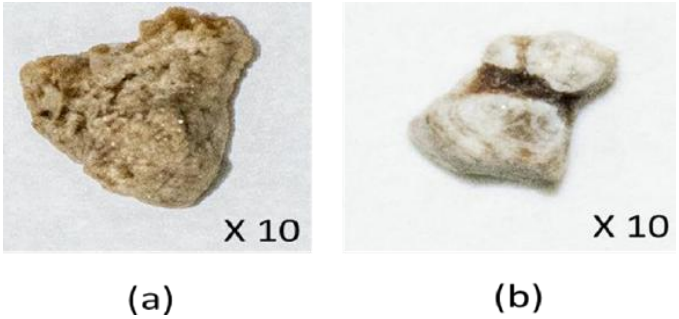

Figure 9: Pictures of a kidney stone (a) prior to and (b) following K. pinnata therapy [32]

Medicinal uses: The medicinal uses are listed in Table-2.

CONCLUSION

Urolithiasis remains a widespread clinical problem because of its high recurrence and long-term complications. Although conventional treatments are effective in acute management, their limitations have driven interest in safer, plant-based alternatives. This review highlights *Kalanchoe pinnata* as a promising antiurolithiatic medicinal plant. Preclinical evidence indicates that its bioactive constituents, including flavonoids, organic acids, and triterpenoids, inhibit calcium oxalate crystallization, reduce oxidative stress, and protect renal tissue. Both in vitro and in vivo studies demonstrate improvements in biochemical markers and kidney histology, supporting its role in preventing and managing stone formation. Despite encouraging experimental findings, clinical validation in humans remains limited. The development of standardized extracts and well-designed clinical trials is necessary to confirm its therapeutic value.

In conclusion, *Kalanchoe pinnata* represents a potential low-toxicity herbal option for urolithiasis, warranting further investigation for clinical application.

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