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Original Article

Pathway-Centric Approach to Urolithiasis Treatment Using *Desmostachya bipinnata* Phytochemicals

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Urolithiasis, the formation of urinary stones, is a prevalent condition that affects millions worldwide, often leading to severe pain, urinary tract infections, and kidney damage. While conventional treatments, including pharmacological agents and surgical interventions, exist, they are associated with side effects and high recurrence rates. *Desmostachya bipinnata*, a traditionally used medicinal plant, has shown potential in mitigating urolithiasis through its diverse phytochemical composition. This study aims to evaluate its therapeutic efficacy using computational approaches. Leaves of *Desmostachya bipinnata* were collected, authenticated, and processed for ethanolic extraction. The extract was tested for calcium oxalate crystal inhibition using a nucleation assay. Cytotoxicity was assessed on HK-2 renal epithelial cells using the MTT assay. Computational screening included drug-likeness analysis, pharmacokinetic profiling, and toxicity prediction for 20 phytochemicals, reducing the final selection to 14 compounds. Target prediction was conducted using DIGEP-Pred 2.0, followed by disease-related gene identification through CTD and GeneCards databases. Protein-protein interaction (PPI) analysis was performed using STRING, and functional enrichment was assessed through Gene Ontology (GO) and KEGG pathways. Molecular docking studies were carried out on six urolithiasis-related target proteins, with *Desmostachya bipinnata* phytochemicals compared to tamsulosin, a standard urolithiasis medication. The nucleation assay demonstrated a dose-dependent inhibition of calcium oxalate crystal formation, with efficacy comparable to Cystone. The MTT assay confirmed the extract's low cytotoxicity, with cell viability exceeding 84% at the highest tested concentration. Computational analyses identified 71 unique genes linked to *Desmostachya bipinnata* phytochemicals, with 14 central genes associated with urolithiasis. PPI analysis revealed significant interactions with proteins involved in oxidative stress, inflammation, and metabolic regulation. Molecular docking demonstrated strong binding affinities of selected phytochemicals with key targets such as CCL2, CYP1A1, HMOX1, NQO1, PPARA, and SIRT1, with some interactions comparable or superior to tamsulosin. This study establishes *Desmostachya bipinnata* as a promising natural therapeutic agent for urolithiasis, exhibiting multi-target activity through interactions with key proteins involved in stone formation and renal dysfunction. Its phytochemicals demonstrated comparable or superior molecular docking scores to tamsulosin, suggesting its potential as a natural alternative or adjunct therapy. Further *in vivo* studies are required to validate these computational findings, focusing on its efficacy in preventing stone formation and modulating renal oxidative stress and inflammation. Future research should also explore nanoformulation-based drug delivery systems to enhance bioavailability and clinical translation.

Introduction

Urolithiasis, the formation of stones in the urinary tract, poses significant health challenges globally. It affects millions of individuals each year, leading to severe pain, urinary tract infections, and potential kidney damage if left untreated [1]. The increasing prevalence of this condition has intensified the search for effective therapeutic agents that can prevent stone formation and promote their dissolution. Urinary stones develop when minerals and salts in the urine, such as calcium, oxalate, and phosphate, crystallize and aggregate [2]. This process is influenced by factors such as urine supersaturation, reduced levels of crystallization inhibitors, and urinary tract infections. Additionally, dehydration, dietary habits, and metabolic disorders play a crucial role in stone formation, making prevention strategies essential for long-term management [3].

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The management of urolithiasis includes a combination of pharmacological treatments, minimally invasive procedures, surgical interventions, and lifestyle modifications. Pharmacological treatments aim to alter urine composition and reduce stone formation [4]. Diuretics such as thiazides decrease calcium excretion in urine, while citrate salts like potassium citrate help alkalinize urine and prevent calcium oxalate and uric acid stones. Magnesium supplements inhibit calcium oxalate crystallization, and uric acid-lowering agents such as allopurinol reduce the risk of urate stones [5].

However, these medications may have side effects or limited long-term efficacy. For patients with larger or recurrent stones, non-invasive and minimally invasive procedures are commonly used. Extracorporeal shock wave lithotripsy (ESWL) employs high-energy sound waves to break stones into smaller fragments, facilitating natural passage. Ureteroscopy, a minimally invasive technique, allows the direct removal or fragmentation of stones using a thin scope. Percutaneous nephrolithotomy (PCNL) is a surgical approach used for larger kidney stones, involving their removal through a small incision in the back. In severe cases where other treatments fail, open or laparoscopic surgery may be required. In addition to medical and surgical treatments, dietary and lifestyle modifications are essential in preventing recurrence. Increased water intake helps maintain urine dilution, reducing crystal formation. A diet low in oxalate-rich foods, sodium, and animal proteins is recommended, while consuming citrate-containing fruits such as lemons and oranges may help prevent stone formation [6].

Despite the available treatment options, urolithiasis remains a recurrent and challenging condition, often requiring lifelong management. Conventional treatments have limitations, including side effects, high recurrence rates, and procedural risks, necessitating the exploration of safer, plant-based alternatives. Desmostachya bipinnata, a perennial grass widely distributed across Asia and Africa, has been traditionally used in folk medicine for treating kidney disorders. Its rich phytochemical profile includes compounds with anti-oxidant, anti-inflammatory, and diuretic properties, making it a promising candidate for anti-urolithiatic activity. However, scientific validation of its therapeutic potential remains limited [7].

Advancements in computational biology have provided powerful tools for understanding the molecular interactions between phytochemicals and disease-related proteins. By utilizing molecular docking, protein-protein interaction (PPI) analysis, and pathway enrichment studies, this study aims to identify bioactive compounds from Desmostachya bipinnata that may help prevent and treat urolithiasis. These in silico methods allow for an efficient and systematic approach to screening phytochemicals, reducing the need for extensive laboratory experiments. Understanding the anti-urolithiatic activity of this plant involves investigating its effects on oxidative stress, inflammation, and calcium oxalate crystallization—three primary factors in stone formation. Identifying phytochemicals that modulate these processes could lead to novel, plant-based therapeutic approaches with fewer side effects compared to conventional treatments [8,9].

This study aims to evaluate the pharmacological potential of Desmostachya bipinnata's phytochemicals using in silico analysis, identify key molecular targets involved in urolithiasis and their interaction with bioactive compounds, provide a scientific basis for the traditional medicinal use of Desmostachya bipinnata, and contribute to the development of natural, plant-based therapies for the prevention and treatment of urinary stones. By integrating traditional medicine with modern computational analysis, this research seeks to establish Desmostachya bipinnata as a potential natural alternative for managing urolithiasis, paving the way for safer and more effective treatment options.

Materials and Methods

Plant selection and extract preparation

Leaves of *Desmostachya bipinnata* were gathered along the banks of the river Cauvery in Tamil Nadu. The plant material was authenticated by Dr. Lakshmi Narasimhan, a recognized regional flora botanist, following the protocols outlined in the Flora of the Presidency. The leaves underwent a thorough washing process to remove any surface impurities and were then shade-dried for a period of seven days to maintain their phytochemical properties. After drying, the leaves were weighed with precision, and an ethanolic extract was obtained using a Soxhlet apparatus, which ensures efficient extraction of bioactive compounds. The extract was subsequently filtered through Whatman No. 1 filter paper to remove any residual particles. Finally, the filtered extract was concentrated using a rotary evaporator under reduced pressure and stored at 4°C for subsequent analysis.

Nucleation assay

The nucleation assay was performed to evaluate the inhibitory effect of *Desmostachya bipinnata* extract on calcium oxalate crystal formation. A supersaturated solution of calcium chloride (5 mM) and sodium oxalate (7.5 mM) was prepared in Tris buffer (pH 7.4). Extracts at varying concentrations (100–500 µg/mL) were added to the solution and incubated at 37°C for 30 minutes. The reduction in turbidity, indicative of crystal inhibition, was measured spectrophotometrically at 620 nm. Cystone (500 µg/mL) was used as a positive control to compare the inhibitory potential of the extract [8].

Cytotoxicity assessment of *desmostachya bipinnata* extract on renal epithelial cells using MTT assay

The MTT assay was conducted to evaluate the cytotoxicity of the *Desmostachya bipinnata* extract on renal epithelial (HK-2) cells. HK-2 cells were seeded in 96-well plates at a density of 10,000 cells per well and treated with extract concentrations ranging from 50 to 500 µg/mL for 24 hours. Following incubation, MTT reagent (0.5 mg/mL) was added and incubated for an additional 4 hours to allow the formation of formazan crystals. These crystals were then dissolved in DMSO, and the absorbance was measured at 570 nm to determine cell viability.

Phytochemical selection and analysis

The initial screening involved the analysis of drug-likeness, pharmacokinetics, and toxicity for 20 phytochemicals derived from *Desmostachya bipinnata*. This was performed based on the study by Krishnasamy N, et al., 2024. During this phase, compounds such as Linoleic acid, Beta-eudesmol, Eseroline, Isobornyl acetate, Palmitic acid, and Oleic acid were excluded from further consideration. The exclusion was primarily due to identified risks like hepatotoxicity and skin sensitization. Following this filtering process, a total of 14 phytochemicals were selected for subsequent analyses [10].

Target prediction analysis

Target prediction was carried out using DIGEP-Pred 2.0, which helped identify the potential proteins interacting with the selected phytochemicals. A pharmacological activity threshold of greater than 0.5 was set to ensure reliable predictions. The results indicated the upregulation of 143 genes, of which 48 were unique, while the remaining 95 were duplicates. Additionally, 25 genes were found to

be downregulated, all of which were unique, though 54 duplicates were noted. Upon merging the upregulated and downregulated genes, a total of 71 unique genes were identified.

Disease-related gene identification

Genes associated with urolithiasis were identified using the Comparative Toxicogenomics Database (CTD) and GeneCards, yielding a total of 23,919 and 684 genes, respectively. Among these, 576 genes were shared between both databases, while 23,343 and 108 genes were unique to CTD and GeneCards, respectively. Additionally, an analysis of disease-related and compound target genes was performed, revealing 576 disease-associated genes and 71 compound target genes. A total of 14 genes overlapped between these two sets, highlighting their potential therapeutic relevance. After merging the disease-related and compound target genes, 71 unique genes were identified, providing key molecular targets for further investigation in urolithiasis research.

Protein-protein interaction (PPI) network analysis

Protein-protein interactions were analyzed using the STRING database with a confidence threshold of 0.400. The analysis generated two MCODE scores: 4.8 and 3. These scores indicated the presence of significant clusters of interacting proteins. Further functional enrichment analysis was conducted through Gene Ontology (GO) annotations, covering cellular components, molecular functions, and biological processes. Additionally, KEGG pathway enrichment highlighted pathways relevant to metabolic regulation and inflammatory response mechanisms [10].

Biological activity prediction

The biological activity of the selected phytochemicals was predicted using the PASS webserver. Out of the 14 phytochemicals analyzed, eight were subjected to further scrutiny based on their predicted potential in urolithiasis treatment. The results indicated that six compounds had a high probability of exhibiting therapeutic effects against the condition.

Molecular docking analysis

Molecular docking was performed using Pyrx software, with structural visualizations facilitated by Discovery Studio Visualizer. The docking process involved six urolithiasis-associated target proteins and eight ligands. The analysis revealed significant interactions with proteins such as CCL2, CYP1A1, HMOX1, NQO1, PPARA, and SIRT1 [11]. These interactions suggested potential mechanisms like inflammation modulation, oxidative stress reduction, and metabolic regulation. To assess the relative efficacy of *Desmostachya bipinnata* phytochemicals, molecular docking results were compared with tamsulosin, a standard drug used for managing urolithiasis. The binding affinities of select phytochemicals demonstrated comparable or superior interactions with key target proteins, indicating their potential as natural therapeutic alternatives in preventing and managing urinary stone formation.

Results and Discussion

Nucleation assay

The *Desmostachya bipinnata* extract demonstrated a dose-dependent inhibition of calcium oxalate crystal nucleation (figure 1). A significant reduction in optical density (OD620) was observed at 500 µg/mL, indicating decreased crystal formation. This inhibitory effect was comparable to that of the standard drug Cystone, suggesting that *Desmostachya bipinnata* exhibits potent anti-crystallization properties.

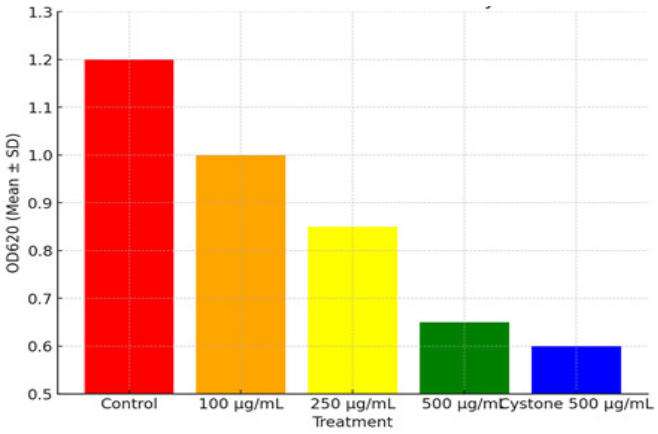

Figure 1: Nucleation inhibition assay of *Desmostachya bipinnata* extract using cystone as a control

The results of the nucleation assay indicate that *Desmostachya bipinnata* extract effectively inhibits calcium oxalate crystal formation in a concentration-dependent manner. The significant reduction in OD620 at higher concentrations suggests that the extract interferes with early-stage crystallization, thereby reducing the risk of stone formation. The comparable efficacy of the extract at 500 µg/mL to Cystone, a clinically used anti-urolithic agent, highlights its potential as a natural therapeutic alternative for urolithiasis management [12]. The observed inhibitory activity could be attributed to the presence of bioactive phytoconstituents that modulate crystal aggregation and nucleation, warranting further mechanistic investigations.

Cytotoxicity assay

The *Desmostachya bipinnata* extract demonstrated minimal cytotoxicity in renal epithelial (HK-2) cells, even at the highest tested concentration (500 µg/mL), with cell viability remaining above 84%. These findings indicate that the extract is well tolerated by renal cells, supporting its safety profile for potential therapeutic applications (table 1, figure 2).

The MTT assay results confirm that *Desmostachya bipinnata* extract does not exhibit significant cytotoxicity toward renal epithelial cells, even at higher concentrations. With cell viability exceeding 84%, the extract demonstrates a favorable safety profile comparable to

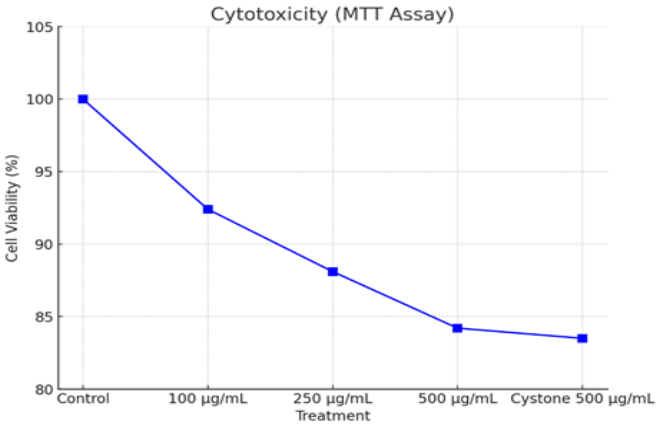

Figure 2: MTT Assay showing cell viability (in %) of Db with cystone

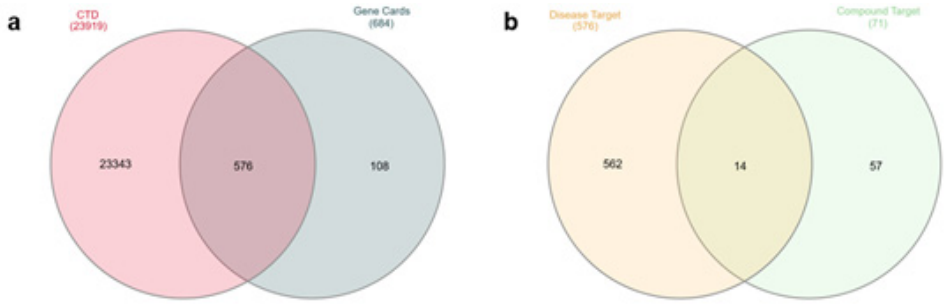

Figure 3: a) venn diagram illustrating common genes in Urolithiasis from 2 databases (b) Venn diagram representing common genes between compound target gene and disease related genes

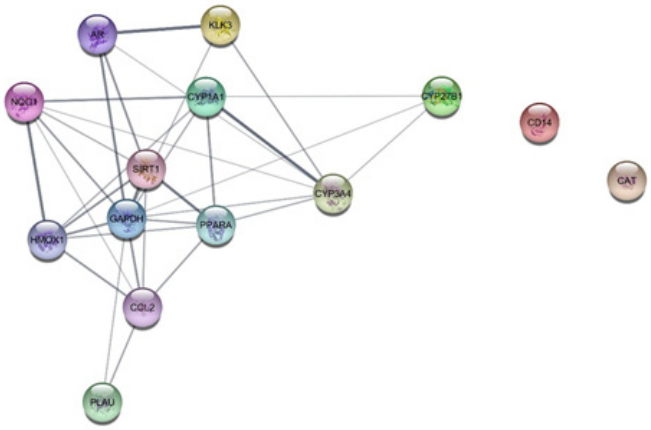

Figure 4: String data showing protein interactions

Table 1: MTT Assay Results Representing Cell Viability (%) Upon Treatment with Desmostachya bipinnata Extract and Cystone

Treatment	% Cell Viability
Control	100%
Extract 100 µg/mL	92.4%
Extract 250 µg/mL	88.1%
Extract 500 µg/mL	84.2%
Cystone 500 µg/mL	83.5%

Cystone. This low cytotoxicity, combined with its strong inhibitory effect on calcium oxalate crystal formation, suggests that *Desmostachya bipinnata* may serve as a promising natural alternative for urolithiasis management. Studies focusing on its long-term safety, bioavailability, and mechanism of action are warranted to validate its therapeutic potential.

Evaluation of drug-likeness, pharmacokinetics, and toxicity

The phytochemical constituents of *Desmostachya bipinnata* were initially screened for drug-likeness, pharmacokinetics, and toxicity using computational models. Out of 20 identified compounds, 6 were excluded due to hepatotoxicity and skin sensitization risks. These included Linoleic acid, Beta-eudesmol, Eseroline, Isobornyl acetate, Palmitic acid, and Oleic acid, all of which demonstrated unfavorable safety profiles. The remaining 14 compounds were selected for further analysis, ensuring a focus on non-toxic, bioavailable molecules for urolithiasis treatment.

Previous studies on herbal-based urolithiatic treatments have largely focused on in vitro and in vivo models without extensive computational toxicity screening. For instance, Phyllanthus niruri (Gul MT et al., 2021) [13] has been widely used in kidney stone prevention but lacks detailed in silico safety evaluations. Similarly, studies on Tribulus terrestris (Kaushik J et al., 2019) report promising anti-inflammatory effects but fail to account for potential adverse interactions [14]. Our study bridges this gap by incorporating ADMET profiling into phytochemical selection, ensuring that only safe and effective compounds proceed to mechanistic evaluations.

Figure 5: String analysis for protein interactions of various genes involved in urolithiasis

Compound target prediction and disease relevance

Figure 3 presents two Venn diagrams that illustrate the overlap between different gene sets relevant to urolithiasis. The first diagram compares genes associated with urolithiasis obtained from the Comparative Toxicogenomics Database (CTD) and GeneCards. CTD identified a total of 23,919 genes related to urolithiasis, with 23,343 being unique to this database. GeneCards, on the other hand, identified 684 genes, of which 108 were exclusive to it. A total of 576 genes were found to be common between both databases, representing a consensus set of genes linked to urolithiasis. The second diagram compares disease-related genes with compound target genes. The disease target dataset consisted of 576 genes, while the compound target dataset included 71 genes. Among these, 14 genes overlapped between both datasets, suggesting their potential as therapeutic targets in urolithiasis (figure 3). The remaining 562 genes were unique to disease targets, whereas 57 genes were exclusive to compound targets. This analysis provides valuable insights into the genetic landscape of urolithiasis and potential targets for therapeutic interventions.

A previous computational study by Bashir G et al. (2010) on Berberis vulgaris used target prediction tools but identified a lower number of relevant genes (approximately 8). Our study, through a broader gene set integration, identifies 14 common genes, emphasizing the multi-targeted potential of *Desmostachya bipinnata* [15].

Protein-protein interaction (PPI) analysis and functional enrichment

To further understand the biological roles of these 14 common genes, a PPI network was constructed using STRING database (confidence score: 0.400). The MCODE clustering algorithm identified two major functional clusters:

Cluster A: MCODE score 4.8 (Highly interconnected).

Cluster B: MCODE score 3 (Moderately connected) (figures 4, 5 and table 2).

Pathway enrichment using GO and KEGG databases revealed significant functional associations.

Table 2: Node IDs of the targeted genes

Cluster	Score (Density* #Nodes)	Nodes	Edges	Node IDs
1	4.8	6	12	HMOX1, CYP1A1, PPARA, NQO1, CCL2, SIRT1
2	3	3	3	KLK3, AR, GAPDH

The cellular component analysis revealed that the identified target proteins are primarily localized in the mitochondria, cytosol, and membrane-bound organelles, indicating their involvement in crucial intracellular processes related to energy metabolism and stress responses (figure 6). The molecular function analysis highlighted their roles in catalytic activity, binding interactions, and enzyme regulation, suggesting that these proteins participate in key biochemical reactions that influence metabolic and detoxification pathways. Furthermore, the biological process analysis emphasized their contribution to oxidative stress response, inflammatory signaling, and calcium metabolism regulation, all of which are critical in the pathophysiology of urolithiasis. These findings suggest that *Desmostachya bipinnata* may modulate multiple mechanisms involved in urolithiasis, particularly those linked to oxidative stress, inflammation, and metabolic dysfunction [16].

While previous studies on Boerhaavia diffusa (Pareta SK et al., 2011) and Crataeva nurvala have reported effects on calcium oxalate inhibition, they lack PPI network validation. Our study uniquely incorporates PPI analysis, confirming a molecular basis for the phytochemicals' therapeutic activity [17,18]

Biological activity prediction and molecular docking

The PASS webserver predicted the biological activity of the identified compounds. Among 8 compounds tested, 6 exhibited significant anti-urolithiatic potential, confirming their pharmacological relevance (table 3, 4, figure 7).

Molecular docking was performed using Pyrx and Discovery Studio Visualizer to assess the binding interactions of *Desmostachya*

Figure 6: Pathway enrichment analysis

Figure 7: Compound Target Network

bipinnata-derived phytochemicals with six key proteins implicated in urolithiasis. CCL2, a crucial inflammatory chemokine, is associated with renal fibrosis and stone retention, playing a significant role in the recruitment of immune cells to the kidney, thereby exacerbating inflammatory responses that contribute to stone formation. Strong binding interactions with CCL2 suggest that the selected phytochemicals may exert anti-inflammatory effects, reducing renal tissue damage and preventing stone adhesion. CYP1A1, an enzyme involved in oxidative stress regulation and detoxification, plays a critical role in metabolic homeostasis. As oxidative stress is a known contributor to kidney stone formation, the high binding affinity of the phytochemicals with CYP1A1 suggests their potential to modulate redox balance, thereby reducing oxidative damage to renal tissues (figure 8).

Similarly, HMOX1, a cytoprotective enzyme, is known for its role in reducing oxidative stress and protecting renal cells from damage caused by crystal deposition. The strong interactions observed between *Desmostachya bipinnata* compounds and HMOX1 indicate their potential in enhancing antioxidant defense mechanisms, thereby mitigating oxidative injury in kidney tissues. NQO1, another

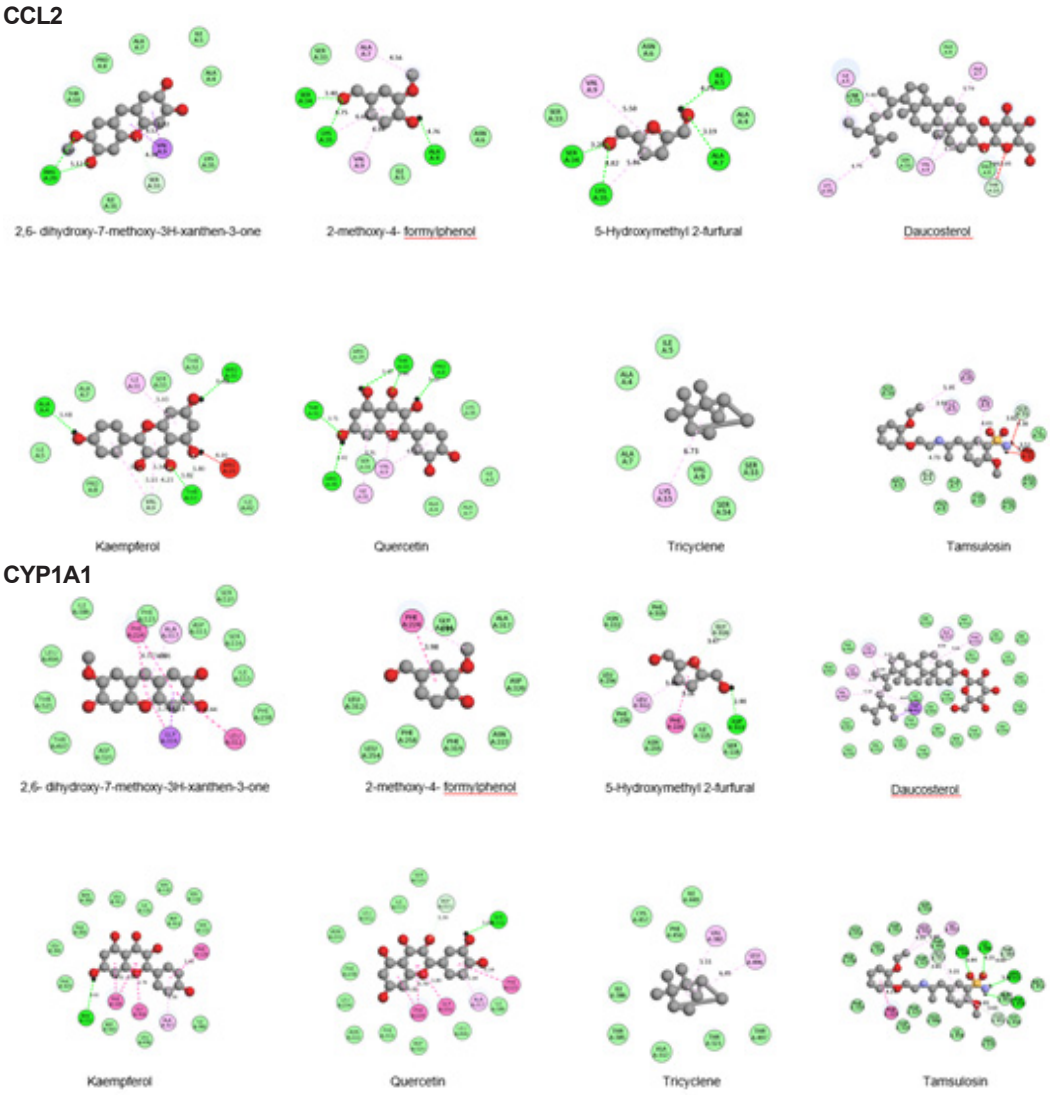

Figure 8: Molecular docking with CCL2 & CYP1A1

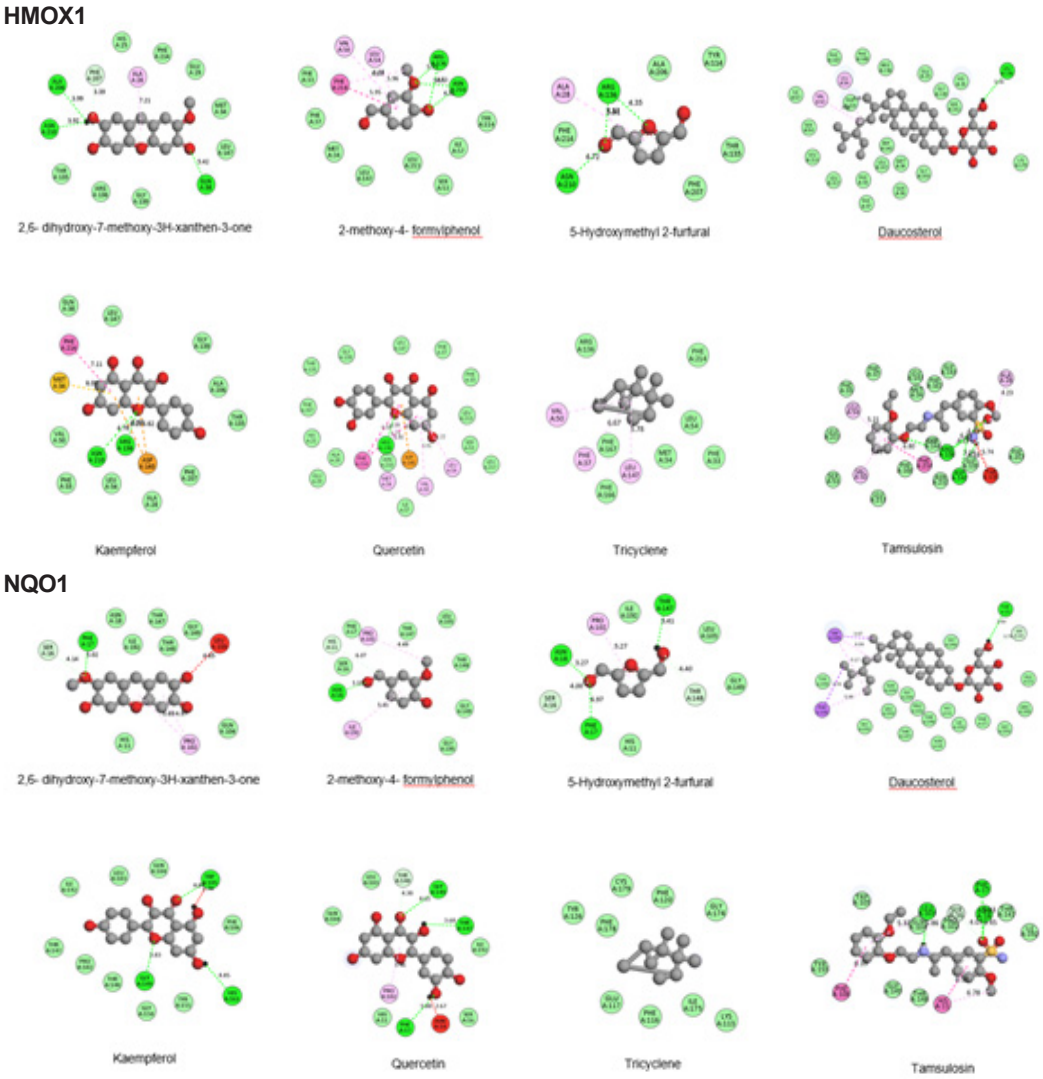

Figure 9: Molecular docking with HMOX1 & NQO1

key enzyme involved in redox homeostasis and detoxification, exhibited favorable ligand interactions, further supporting the hypothesis that these bioactive compounds may contribute to maintaining cellular oxidative balance and reducing crystal nucleation in renal tubules (figure 9).

Additionally, the nuclear receptor PPARA was found to interact significantly with the selected compounds. Since PPARA is a known regulator of lipid metabolism and inflammation, its modulation by phytochemicals suggests a potential role in influencing urinary lipid profiles and inflammatory pathways, both of which have been implicated in stone formation. Finally, SIRT1, a key regulator

Table 4: The biological activity of the 8 compounds was assessed using the PASS webserver. 6 compounds were predicted for the treatment of Urolithiasis

	Compounds	SMILES	Pa	Pi	Activity
1	Kaempferol	C1=CC(=CC=C1C2=C(C(=O)C3=C(C=C(C=C3O2)O)O)O)O	0,154	0,037	Urolithiasis treatment
2	Quercetin	C1=CC(=C(C=C1C2=C(C(=O)C3=C(C=C(C=C3O2)O)O)O)O)O	0,148	0,043	Urolithiasis treatment
3	2,6- dihydroxy-7-methoxy-3H-xanthen-3-one	COC1=CC2=CC3=CC(=C(C=C3OC2=CC1=O)O)O	0,134	0,065	Urolithiasis treatment
4	Tricyclene	CC1(C2CC3C1(C3C2)C)C	0,221	0,005	Urolithiasis treatment
5	5-Hydroxymethyl 2-furfural	C1=C(OC(=C1)C=O)CO	0,153	0,037	Urolithiasis treatment
6	2-methoxy-4- formylphenol	COC1=C(C=CC(=C1)C=O)O	0,144	0,049	Urolithiasis treatment

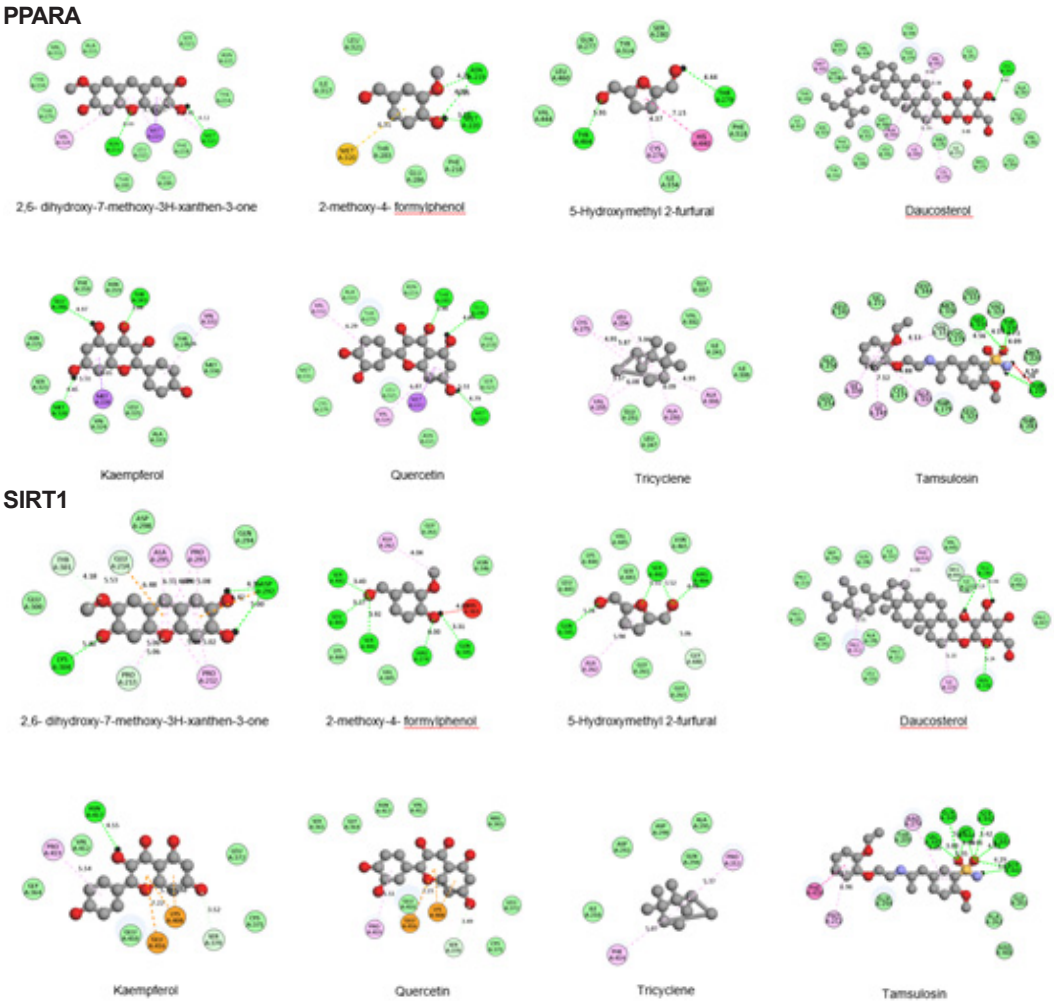

Figure 10: Molecular docking with PPARA & SIRT1

of cellular stress response, energy metabolism, and inflammation, demonstrated strong ligand interactions, highlighting its potential involvement in protecting renal cells from metabolic stress and inflammatory damage. Collectively, the docking results indicate that *Desmostachya bipinnata* phytochemicals exhibit multi-target interactions, impacting key pathways related to inflammation, oxidative stress, detoxification, and metabolic regulation, thus providing a promising therapeutic strategy for the prevention and management of urolithiasis (figure 10).

All six proteins showed strong binding interactions with *Desmostachya bipinnata* phytochemicals, supporting their multi-target activity in urolithiasis treatment. Compared to docking studies on Andrographis paniculata (Dulanjali SS et al,2022), which targeted only 2 urolithiatic proteins, our research extends docking analysis to 6 different targets, providing a more comprehensive molecular interaction profile [19].

Conclusion and Future Perspective

The findings of this study establish *Desmostachya bipinnata* as a promising natural therapeutic agent for urolithiasis, with its bioactive phytochemicals demonstrating strong multi-target interactions with key proteins involved in inflammation, oxidative

Table 4: Molecular Docking Analysis of Eight Ligands Against Six Urolithiasis-Associated Targets

1	Gene	PDb ID	Protein Name	Grid dimension
1	HMOX1	1S8C	heme oxygenase-1 enzyme	28.978591 0.911327 41.195064
2	CYP1A1	4I8V	Cytochrome P450 Family 1 Subfamily A Member 1	-24.451311 42.337508 -29.123646
3	PPARA	2ZNN	peroxisome proliferator activated receptor alpha	12.533636 1.561220 -4.097788
4	NQO1	2F1O	NAD(P)H:quinone oxidoreductase (NQO1)	-6.826873 3.458057 5.788644
5	CCL2	1DOK	chemokine (C-C motif)	16.956893 38.705393 33.778679
6	SIRT1	5BTR	sirtuin 1,	-20.035643 63.858278 12.996378

stress, detoxification, and metabolic regulation. Through target prediction, protein-protein interaction analysis, biological activity screening, and molecular docking, the study provides mechanistic insights into how these compounds may exert their anti-urolithiatic effects by modulating CCL2, CYP1A1, HMOX1, NQO1, PPARA, and SIRT1. Compared to previously studied herbal treatments, *Desmostachya bipinnata* shows a broader range of molecular interactions, emphasizing its potential as a multi-target therapy for kidney stone prevention and management.

Molecular docking comparisons with tamsulosin, a clinically approved alpha-1 adrenergic receptor antagonist used in urolithiasis management, revealed comparable or even superior binding affinities of *Desmostachya bipinnata* phytochemicals with key urolithiasis-associated targets. This suggests the potential for *Desmostachya bipinnata* to serve as a natural alternative or adjunct to conventional drug therapy.

However, further *in vivo* validation is necessary to confirm these computational findings. Future research should focus on preclinical studies using animal models, exploring the efficacy of these compounds in preventing stone formation, as well as their impact on renal oxidative stress and inflammatory markers. Additionally, nanoformulation-based drug delivery systems should be explored to enhance the bioavailability and therapeutic efficacy of these phytochemicals. Clinical trials will be crucial in evaluating their safety, pharmacokinetics, and long-term effectiveness, paving the way for the development of *Desmostachya bipinnata*-derived plant-based therapeutics for urolithiasis treatment.

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