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Water Hyacinth Extract in Herbal Medicine Development: Literature Review

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ABSTRACT

Indonesia is a country with an extraordinary wealth of flora, one of which is water hyacinth (Eichhornia crassipes) which has been known as an invasive aquatic weed. Recent studies have shown this plant has potential as a raw material for herbal medicine. The purpose of this review is to evaluate the pharmacological activity and phytochemical content of water hyacinth based on current scientific literature. The method used was journal search and selection from 2021 to 2025 through PubMed, Google Scholar and ResearchGate databases with the keywords "Eichhornia crassipes", 'pharmacology', and "bioactivity". The results review showed water hyacinth extract has anti-inflammatory activity through decreasing proinflammatory cytokines, antidiabetic through activating SUR-1, GLP-1R, AMPK, and OCT-1 receptors and antibacterial against Prevotella intermedia and Staphylococcus aureus. In addition, anticancer activity was demonstrated through binding of active compounds to MCF-7 cancer cell receptors, as well as cytoprotective activity against oxidative stress in rat liver cells.

Keywords : *Eichhornia crassipes*, Pharmacology and Bioactivity.

INTRODUCTION

Indonesia is a megabiodiversity country with an extraordinary wealth of flora, much of which has yet to be fully explored for pharmaceutical purposes. Water hyacinth (Eichhornia crassipes) is one such plant with hidden potential that is often overlooked. This aquatic plant is widely known as an invasive weed that impedes water flow, disrupts transportation, and reduces aquatic biodiversity. However, this negative stigma is starting to shift along with scientific discoveries that show that water hyacinth is not just a weed but also a promising natural resource for the health sector, especially in the development of herbal medicines.

The global trend towards the use of natural based medicines is increasing, driven by public perception of higher safety and minimal side effects compared to synthetic drugs. This approach encourages intensive research on medicinal plants as a source of new bioactive compounds (Sabrina et al., 2025). Water hyacinth, with its rapid growth and abundant availability, offers a sustainable and economical solution as a potential raw material in the pharmaceutical industry. This mini-review aims to collect and synthesize current information from various scientific literatures regarding the phytochemical profile and pharmacological activities of water hyacinth extracts, as well as discuss the challenges and future prospects in the development of herbal medicines.

METHODS

The method used in preparing this review is the search, collection, and selection of literature that reports the pharmacological activity of water hyacinth plant extracts from 2021 to 2025. The databases used to search for literature are PubMed, Google Scholar, and ResearchGate using the keywords “water hyacinth", “Eichhornia crassipes”, "Pharmacology", and “Bioactivity”. This review summarizes 10 journals that discuss various pharmacological activities of water hyacinth plants.

RESULTS

Based on the 10 journals analyzed, various potential activities were found in water hyacinth plants. The results of the literature analysis can be seen in Table 1.

Table I. Pharmacological effects of water hyacinth extracts

No	Phytochemicals	Part Plant	Type of assay	Biological activity
1	Linoleic acid, 2-Hidroxy- 1,4-naphthoquinone, b-stigmasterol, octadecanoic acid, pentadecanoic acid, hexadecanoic acid, caprylic acid, vaccenic acid, malonic acid, nonanoic acid, myristic acid, and squalene.	All parts of the plant	In vivo	The extract significantly decreased erythema, edema, and arthritic score in RA rats, comparable to piroxicam. The extract also decreased the expression of pro-inflammatory TNF α, IL 1β, IL 6, NF κB, and VEGF, and suppressed the enzyme activities of MMP 2 & MMP 3, suggesting anti-arthritic potential and joint tissue protection.
2	stigmasterol, chlorogenic, and luteolin	Leaf	Molecular docking	Stigmasterol compounds show antidiabetic potential with high affinity to SUR1 receptor (ΔG -9.8 kcal/mol), interacting with the ARG1300 residue. This interaction can stimulate insulin release and help control blood sugar levels. Chlorogenic compounds show antidiabetic potential through binding to SUR1 (ΔG -6.2 kcal/mol), interacting with THR1242, ILE381, and MET429. These compounds are also known as antioxidants and protect the pancreas from oxidative stress. And the letolin compound has activity against GLP-1R (ΔG -7.9 kcal/mol) with an interaction at residue ASN239. It can increase glucose-dependent insulin secretion and lower blood sugar levels.
3.	Gossypetin, orientin, tricin, caffeic acid, luteolin, and azaleatin	Leaf	In silico docking and OCT-1	Gossypetin showed good affinity to AMPK receptors with a negative ΔG, indicating a potential activation that could enhance glucose metabolism. Orientin was able to bind strongly to both AMPK and OCT 1, suggesting a dual mechanism in both the regulation of glucose metabolism and glucose transport to cells. Tricin showed stable binding and negative

No	Phytochemicals	Part Plant	Type of assay	Biological activity
				energy towards both targets, supporting the possibility of enhancing glucose uptake and regulation in cells. Caffeic acid showed good affinity to AMPK, indicating potential activation of alternative glucose metabolism pathways. Luteolin has high potential in binding AMPK and OCT 1, supporting more efficient glucose regulation through two different mechanisms. Azaleatin showed strong interaction with OCT 1, signaling its ability to enhance glucose uptake through specific transporters.
4.	Flavonoid, Tanin, saponin, asam folat, alkaloid, steroid dan triterpenoid	Leaf	In Vitro	Water hyacinth leaf extract showed antibacterial activity with the diameter of the inhibition zone increasing as the concentration increased. This activity proves its potential as a natural antibacterial agent against oral pathogenic bacteria.
5.	Flavonoid, alkaloid, tanin, saponin, dan steroid	Leaf	In Vitro	The water hyacinth leaf extract showed antibacterial activity against S. aureus with a clear zone of inhibition in the m-test, indicating its potential as a natural antiseptic agent. The antibacterial activity will increase as the concentration of water hyacinth leaf fraction increases.
6.	Stigmasterol, dan phytol	Leaf	In vitro MTT MCF 7 cells and In silico docking	Stigmasterol in vitro can reduce the viability of MCF 7 cancer cells with IC_{50} around 9,876 µg/mL, inducing apoptosis through caspase activation as well as regulation of P53, Bax, and Bcl 2 genes. In silico, it produced the best binding affinity of 9.4 kcal/mol towards the complement C1q receptor (also known as 1QR1 receptor), indicating a stable and specific molecular interaction. Phytol showed strong affinity towards target proteins such as complement C1q receptor and erbB 2, with binding affinity values of -5.8 to -5.3 kcal/mol, supporting its anticancer potential.
7	Flavonoid, steroid, alkaloid, saponin, dan triterpenoid	Petioles	In Vitro MTT assay	Petiole extract has potent antiproliferative activity against PC3 prostate cancer cells, reducing cell viability at rather high doses ($IC_{50} \approx 199.5$ µg/mL). Shows potential as a chemotherapeutic agent in treating androgen-resistant prostate cancer.
8.	Flavonoid and Fenol	Flower	In Vitro	Pre-treatment with the extract significantly increased cell viability, indicating cellular protective ability against oxidative stress. The extract also decreased lipid peroxidation and

No	Phytochemicals	Part Plant	Type of assay	Biological activity
				LDH leakage and increased catalase activity and GSH levels, proving the cytoprotective effect through antioxidant mechanisms.

DISCUSSION

BIOLOGYCAL ACTIVITIES AND PHYTOCHEMICAL PROFILE OF WATER HYACINTH EXTRACT

1. Antiinflamator

Inflammation refers to the enlargement of a body region that happens as a response from the body's defense mechanism when there is tissue injury. Signs of inflammation encompass elevated body temperature, discomfort, redness, and swelling. Rheumatoid arthritis (RA) is an autoimmune disease or disorder of connective tissues, such as joints, builders, and cartilage, that causes disability and other systemic disorders. The effects of the disease are synovial inflammation, proliferation, hyperplasia, and distortion of bone and cartilage. Based on the results of research (Sattar et al., 2023), it is known that water hyacinth plant extract has anti inflammatory activity in RA disease. Methanol extracts from water hyacinth showed significant anti-inflammatory effectiveness in a rat model of rheumatoid arthritis (RA) by reducing levels of proinflammatory cytokines such as TNF-α, IL-1β, IL-6, as well as NF-κB and VEGF expression. The decrease in these inflammatory biomarkers had a direct impact on the improvement of RA clinical symptoms, including reduced edema, erythema, arthritis score, and joint tissue damage.

2. Antidiabetic

Diabetes is a chronic disease characterized by high blood sugar levels (hyperglycemia) as a result of the body not being able to produce enough insulin or not being able to use insulin effectively. Research indicates that water hyacinth extract possesses antidiabetic properties in the case of type 2 diabetes mellitus. The results of a study (Zeki et al., 2024) revealed that this extract is rich in active constituents such as stigmasterol, chlorogenic, and luteolin, which may serve as potential antidiabetic agents by stimulating SUR-1 and GLP-1R. As well as in the study (Al Muhdar et al., 2023), compounds such as gossypetin, orientin, tricin, caffeic acid, and luteolin showed promising binding affinity to AMPK receptors-this was seen from competitive free binding energies and significant amino acid residue interactions, signaling the potential activation of glucose metabolism pathways. In addition, orientin, gossypetin, azaleatin, luteolin, and tricin were also able to bind strongly to the OCT-1 transporter, suggesting that water hyacinth has the potential to enhance the uptake and distribution of antidiabetic compounds through modulation of cellular transport.

3. Antibacterials

Antibacterials are substances that can interfere with the growth and even kill bacteria. Based on the results of the study, it is known that water hyacinth extract has antibacterial properties. In a study (Padmarini et al., 2022) water hyacinth leaf extract, which is rich in

bioactive compounds such as tannins, flavonoids, alkaloids, and terpenoids, was tested for its ability to inhibit the growth of Prevotella intermedia, a bacterium that causes periodontal disease, in vitro. The results showed that the extract showed significant antimicrobial activity at a concentration of 3.125% (MIC_{90}), and at a concentration of 6.25% it had achieved a bactericidal effect ($MBC_{99,9}$). As well as from the results of research (Qur'an et al., 2021) using water hyacinth leaf fraction extracts containing flavonoids, alkaloids, polyphenols, and saponins, successfully showing significant antibacterial (bacteriostatic) activity against Staphylococcus aureus bacteria at effective concentrations starting from 10% with exposure for 2 hours based on time kill assay. In addition, from the biofilm formation inhibition test, extract concentrations of 10% to 20% were able to inhibit biofilm formation effectively, equivalent to the positive control (chlorhexidine 0.1%) based on ANOVA and LSD tests.

4. Anti Cancer

Cancer is a condition where body cells experience abnormal growth due to changes in DNA. Based on the results of the study, water hyacinth leaf extract has anti cancer activity. In the results of the research reported (Johannes et al., 2021) Water hyacinth leaf extract successfully triggered MCF-7 cell death significantly in the MTT assay, which was largely attributed to the main active compounds such as stigmasterol and phytol. The results of in silico studies supported these findings, with the binding affinity value of stigmasterol to the target receptor (PDB ID: 1QR1) reaching -9.4 kcal/mol, suggesting a strong molecular interaction and a concrete potential antitumor mechanism. As well as in research (Noufal et al., 2022) which examines the anticancer potential of water hyacinth leaf extract through a computer simulation approach (in Silico) active compounds in water hyacinth extract show strong affinity for target proteins that play a role in the development of cancer cells and in testing water hyacinth leaf extract against MCF-7 type breast cancer cells with in vitro methods show that water hyacinth leaf extract is able to significantly inhibit cancer cell growth, especially at certain concentrations that show cytotoxic effects against MCF-7 cells.

5. Cytoprotective Activity

Cytoprotective activity refers to the ability of a substance to protect cells from damage or death due to exposure to harmful compounds, such as oxidizing agents. One of the main causes of cellular damage is oxidative stress, which is a condition of imbalance between the production of free radicals (such as hydrogen peroxide) and the ability of the body's antioxidant system to neutralize them. Based on the results of research (Rajarajan et al., 2021) that tested water hyacinth flower extract, it is known that water hyacinth flower extract has cytoprotective activity against rat liver cells (BRL 3A) exposed to hydrogen peroxide. The test results showed that the extract was able to significantly increase cell viability and reduce the level of cell damage due to oxidative stress. This proves that hyacinth flower has potential as a natural cytoprotective agent, which can protect cells from the damaging effects of free radicals.

CHALLENGES AND PROSPECTS FOR HERBAL MEDICINE DEVELOPMENT OF WATER HYACINTH

The use of water hyacinth (Eichhornia crassipes) extracts in herbal medicine development faces significant challenges. One of them is the difficulty in standardization as the content of bioactive compounds can vary greatly depending on the growing location, harvesting season, and extraction method used. These variations impact the quality and effectiveness of the extracts, making consistent formulation difficult. In addition, although crude extracts have shown promising biological activities such as antioxidant and cytotoxic, identification and isolation of the specific active compounds responsible for such effects is still

limited, which hinders a deeper understanding of their mechanism of action. Another challenge lies in the generally low bioavailability of active compounds, which requires innovative approaches such as microwave-assisted extraction methods to improve efficacy and absorption in the body (Ganorkar et al., 2023).

The prospect of utilizing water hyacinth extract (Eichhornia crassipes) in the development of herbal medicine is increasingly promising along with the discovery of various potential pharmacological activities of this plant. The study by Ganorkar et al. (2023) showed that ethanol extract of water hyacinth contains active compounds such as flavonoids and phenolics that are able to provide antioxidant and cytotoxic effects against cancer cells in vitro, opening up opportunities for development as a natural therapeutic agent, as well as confirming that water hyacinth leaf extract does not show acute toxicity in animal models, supporting its safety as a candidate herbal medicinal material. On the other hand, innovations in extraction methods such as microwave-assisted extraction studied by Ganorkar et al. (2022) successfully improved the recovery of bioactive compounds from this plant, which not only supports its pharmacological effectiveness but also strengthens the competitiveness of water hyacinth as a phytopharmaceutical source. With a more mature and diverse scientific approach, water hyacinth, which was previously considered an aquatic weed, is now starting to be viewed as a high-value biological resource in the development of sustainable herbal medicines.

CONCLUSION

Recent studies indicate that water hyacinth (Eichhornia crassipes) possesses considerable pharmacological promise due to the presence of active compounds like flavonoids, alkaloids, tannins, saponins, and sterols. The extract demonstrated notable anti-inflammatory, antidiabetic, antibacterial, anticancer, and cytoprotective effects in vitro, in silico, and in animal experiments. These benefits arise from the engagement of active compounds with significant molecular targets in the body, including the SUR-1 receptor, GLP-1R, and AMPK, along with efficacy against harmful bacteria and cancerous cells. Given the plentiful raw materials and encouraging pharmacological attributes, there is a strong potential for water hyacinth to be utilized as a base for standardized herbal formulations, though more research is necessary regarding its safety, efficiency, and clinical assessments.

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