Phytochemical and anti-inflammatory potential of the Jharkhand ecotype of Ipomoea Aquatica.

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1. Abstract

Fruits and vegetables are becoming popular worldwide because they are healthy, affordable, and full of nutrients. Ipomoea aquatica (water spinach) is one such leafy vegetable rich in vitamins, minerals, proteins, fiber, carotenes, and flavonoids. Although it often grows like a weed in ponds and lakes, many people overlook it due to a lack of awareness. Studies highlight that this plant can act as a natural remedy, a nutraceutical, and a functional food because of its many health benefits.[2] Ipomoea aquatica grows widely in India, Sri Lanka, tropical Asia, Africa, and Australia. Traditionally, it has been used to reduce gas, lower inflammation, and treat fever, jaundice, bronchitis, and liver problems. Its high nutrient content makes it valuable for both food and medicine. Research aims to explain its pharmacognostic, phytochemical, and pharmacological properties. [3] Recent studies show that I. aquatica contains over 65 compounds, including polyphenols, alkaloids, terpenoids, fatty acids, and sugars. It has powerful antioxidant, antibacterial, antiviral, anticancer, and liver-protective effects. It also helps control blood sugar by inhibiting enzymes like α-amylase and α-glucosidase. Overall, regular intake of water spinach supports glycemic control and promotes overall health.

Keywords - Ipomoea aquatica, Water spinach, Phytochemical constituents, Antioxidant activity, Antidiabetic potential, Nutraceutical properties

2. Introduction

Ipomoea aquatica, commonly known as water spinach, is a widely eaten green leafy vegetable in many countries across Asia, Africa, Australia[2]. It usually grows in ponds, marshy lands, and other places where water is easily available. The plant grows slowly during winter but spreads fast during monsoon season[3].

In Northeast India, different varieties of this plant are commonly used as leafy vegetables. People value it for its dietary composition and health coverages. It is easy to grow, does not require much care and can indulge harsh climates better than many other vegetables[1].

Traditionally, *Ipomoea aquatica* has been used to help tolerate diabetes. In Ayurveda, its leaves are also recommended for managing blood sugar levels. Research suggests that the plant may support that the plant may support liver health, help lower blood sugar, and even reduce the risk of certain diseases like cancer. These effects are mainly linked to the natural compounds present in the plant. However, its chemical composition can vary depending on the region where it grows, and only a few varieties have been studied in detail[4].

Since modern medicines do not always completely control these health issues, more attention is now being given to prevention. Studies indicate that wild leafy vegetables such as *Ipomoea Aquatica* may slow down the activity of enzymes like α-amylase and α-glucosidase, which are involved in breaking down carbohydrates into sugar. These enzymes break carbohydrates into glucose, so slowing them helps prevent a sudden rise in blood sugar after meals[5]. This is important in reducing the risk of type 2 diabetes. Lifestyle-related diseases such as diabetes, fatty liver, heart problems, anxiety, and depression are increasing quickly, especially in city populations. One traditional way to prevent these problems is by eating wild edible plants, a practice followed for many generations. Many of these plants, once common in old diets, are becoming important again because they contain useful plant compounds, vitamins, minerals, and natural antioxidants[6]. These help protect the body from harmful substances and support overall health. Some wild plants also contain bioactive compounds or phytopharmaceuticals, which can naturally help prevent or manage lifestyle diseases.[7]

2.1 Role of plant-based bioactive compounds in managing inflammation

The phytochemical analysis of *Ipomoea Aquatica* showed that the methanol extract contained a wide scope of essential compounds such as alkaloids, carbohydrates, glycosides, flavonoids, phenolics, saponins, quinones, tannins, terpenoids, proteins, and amino acids. In compare, the hexane extract had only small quantity of flavonoids, phenolics, terpenoids, and tannins, while numerous compounds were absent. Above studies too reported similar results, although small differences may happen due to geographical variation. Overall, methanol proved to be a better solvent for extracting phytochemicals. The plant was found to contain important carotenoids such as lutein and β-carotene, along with polyphenols like quercetin and kaempferol. These natural compounds show that the plant is not only nutritious but also useful for health and medicinal purposes.[4]

The inflammation reducing property of the plant was checked by a rat paw swelling test. leaf extracts were prepared utilizing Ethanol and water, and both types were tested for their ability to reduce inflammation. The outcome showed that both extracts were effectual. Amount of approx 200 mg/kg, Ethanolic extracts reduced swelling by about 55%, while the water extract reduced it by closely 49%. For comparison, the standard anti-inflammatory drug indomethacin reduced swelling close to 64%.When the dose was increased to 400 mg/kg, the effect becomes stronger. The Ethanolic extract reduced swelling by around 81%, and the water extract showed about 76% reduction. These findings suggest that *Ipomoea Aquatica* has strong anti-inflammatory activity, and its effect better with a higher dose. Among the two, the Ethanolic extract showed slightly improved outcomes. [5]

2.2 Botanical overview of *Ipomoea Aquatica*

2.2.1 Taxonomy & Classification

- Belongs to Kingdom Plantae, Order Solanales, and Family Convolvulaceae.
- The scientific name of water spinach is *Ipomoea Aquatica Forssk*. It refers as water spinach or kangkong in many regions.
- Be a part the genus *Ipomoea*, a group of plants that mostly cover trailing or climbing herbs.
- This plant shows floral features that are typical of the morning-glory family, like
- funnel-shaped flowers.

2.2.2 Morphology

- A semi-aquatic, fast-growing herb with hollow, creeping stems that root at nodes.
- Shows strong adaptability to wetlands, shallow water, and moist soils.
- Leaves are simple, alternate, and variable—ranging from sagittate to ovate.
- Possesses long petioles and soft, glabrous leaf surfaces.
- Flowers are funnel-shaped, white to pale violet, borne singly or in small clusters.
- Fruit is a small globose capsule containing 1–4 brownish seeds.

- Roots are adventitious, supporting buoyancy and rapid vegetative spread.
- Overall morphology supports nutritional, ecological, and ethnomedicinal significance.[12]

2.2.3 Cultivation and distribution

Ipomoea Aquatica is commonly fatten in many Asian countries such as China, Indonesia, Thailand, Vietnam, Myanmar, Philippines, Bangladesh, and India. It grows best in warm weather, especially when the temperature is above 25°C. Farmers can grow it either from seeds or simply by planting fragment of its stem.[6-7]

There's three common ways to cultivate this plant. The first method is growing is directly in water, in such ponds or lakes. The second method is growing it in wet water-logged soil without much land preparation. The third method is dry-land farming, which is similar to how other leafy vegetables are grown. However, this method needs regular watering and more fertilizers. Even though dry-land farming is well-liked, it can be expensive, especially in place like Hong Kong.[8-9]

2.2.3 traditional use

Traditionally, rural communities relied on healers like vaidyas and hakims who used *Ipomoea Aquatica* to treat various ailments. The plant acts as a laxative and is used for piles, constipation, headaches, sleeplessness, liver disorders, diabetes, high blood pressure, mental illness, infections, and inflammation. Its juice treats poisoning, paste cures itching, buds help in ringworm, and leaf preparations aid jaundice, snakebite, and malarial fever.[10-11]

3. Aim of the review

The aim of this review is to summarize the phytochemical profile and inflammatory potential of *Ipomoea Aquatica*, especially the Jharkhand variety, based on evidence from authentic published journals.

3.1 Objectives

- To list the main phytochemicals found in *Ipomoea Aquatica*, like flavonoids and phenolic compounds.
- To understand how these phytochemicals may help reduce inflammation in the body.
- To explain how the plant acts as an antioxidant and protects body cells from damage.
- To highlight why the Jharkhand variety of *Ipomoea Aquatica* is important by discussing its traditional uses and health value.

4.Phytoconsituents of jharkhand ecotpye of ipomoea aqutica

4.1 Phytochemical screening

The freshly prepared leaf extract of IAF was qualitatively tested for the presence of chemical constituents. Phytochemical screening of the extract was performed using the following reagents and chemicals: Alkaloids with Mayer's, Hager's and Dragendorffs reagent;

Flavonoids with the use of sodium acetate, ferric chloride, amyl alcohol; Phenolic compounds and tannins with lead acetate and gelatin; carbohydrate with Molish's, Fehling's and Benedict's reagent; proteins and amino acids with Millon's, Biuret and xantho protein test.[12-17] Saponins were tested using hemolysis method; Gum was tested using Molishs reagent and Ruthenium red; Coumarin by 10% sodium hydroxide and Quinones by Concentrated Sulphuric acid. These were identified by characteristic color changes using standard procedure. These were identified by characteristic colour changes using standard procedures.[14,15] The qualitative phytochemical investigation of experimental extracts of water spinach revealed the presence of different biologically active phytoconstituents. As evident, flavonoids, tannins, steroids were present, but saponins were absent in all the experimental extracts, while alkaloids were only present in the crude extract and aqueous fraction. Similarly, glycosides were present in the crude extract and n-hexane fraction. [16-17]

4.1.1 Quantitative Analysis of Phytochemicals

Quantitative determination of specific phytochemicals was conducted using established methods. The total phenolic content was measured using the Folin-Ciocalteu method, while the total flavonoid content was determined using the aluminium chloride colorimetric method. Alkaloid content was determined using the gravimetric method after extraction. The total saponin content was measured by the foaming index method.

4.1.2 Determination of Total Flavonoid Content (TFC)

Reagent for TFC was prepared by dissolving 0.3325 g AlCl3 and 1 g CH3COONa in 100 ml DI water. Stock solution (0.2 ml) was taken in a test tube followed by the addition of DI water (4.8 ml) and AlCl3 reagent (2.5 ml) and was incubated for 5 min. Standard solution (20— 100 µg/ml) of quercetin was prepared to construct a calibration curve and absorbance was taken at 430 nm using a UV–VIS spectrophotometer (Thermo Scientific, Model: Evolution 300). Total Flavonoid Content was expressed as mg of Quercetin equivalent (QE) /g of dry extract . [19]

4.1.3 Determination of Total Tannin Content (TTC)

A stock solution (0.5 ml), DI water (8.5 ml) and Folin Ciocalteu phenol reagent (0.5 ml) were sequentially added to a 15 ml test tube and kept at room temperature for 5 min. Then 1 ml sodium carbonate solution (35%) was added followed by a 20 min incubation period. A set of standard solution (20—100 µg/ml) of tannic acid were used for the calibration curve (r2 = 0.995) and the absorbance was measured at 725 nm. The TTC was expressed as mg of Tannic acid equivalent (TAE) /g of dry extract.[19]

4.1.4 Determination of Total Phenolic Content (TPC)

The stock solution (0.5 ml) and DI water (8.5 ml) were taken in a test tube followed by the addition of Folin Ciocalteu phenol reagent (0.5 ml) and kept at room temperature for 30 min. Then 1 ml of sodium carbon ate solution (35%) was added and incubated for 20 min. In this experiment, gallic acid was used as standard to prepare a calibration curve and the detection range. Food Production, Processing and Nutrition was 20— 100 µg/ml. The absorbance was recorded at 765 nm and the results of the TPC were expressed as mg of gallic acid equivalents (GAE) /g of dry extract [19]

4.1.5 Determination of Total Antioxidant Activity (TAA)

The stock solution (0.5 ml) was mixed with 3.0 ml of reagent solution and incubated for 90 min at 95^0 C. The absorbance of the solution was measured at 695 nm. Ascorbic acid was used as standard, where20—100 µg/ml concentration range was selected for the calibration curve construction. TAA was mentioned as mg equivalent of Ascorbic acid (AAE) /g of dry extract.

5. Extraction of phytochemicals:

The extraction of phytochemicals involved the dissolution of the dried extract with 80% MeOH into solution form. 5.55g of the extract was dissolved in 40ml of MeOH to come with a concentration of 0.16g/ml(138.75mg/ml) which was used for the standard qualitative tests.[16]

5.1 Extraction:

First, the edible parts of the vegetables were cleaned well. Then they were freeze-dried at – 40 °C using a freeze dryer. After drying, the vegetables were ground into a fine powder using a grinder. A single mixed sample was prepared by combining powder from the same type of plant, and this was stored at 4° C. [19]

Next, 20 grams of the powdered sample were soaked in 200 ml of ethanol and shaken for 48 hours. After shaking, the mixture was centrifuged and filtered. The remaining liquid was then concentrated by evaporating the Ethanol using a rotary evaporator. The final Ethanolic extracts of *Ipomoea Aquatica* were stored at –20° C. All measurements were taken based on the dry weight of the extract.[19]

5.1.1 Solvent- solvent partition of crude extract:

With the help of a separating funnel, the crude Ethanolic extract (5 g) was partitioned into n-hexane and aqueous ethanol fractions. The crude extract was mixed properly with a 10% ethanol aqueous mixture solvent. Here, n-hexane was added and mixed thoroughly. Then, the separated layers in the separating funnel, the upper layer being the n-hexane part and the lower layer being the ethanol aqueous part, were separated. This process was performed three times using a total of 100 ml of each solvent. Thereafter, from the separated layered part, the solvent was evaporated, and the dried fractionated extract (1.5 g aqueous and 1.38 g n-hexane fraction) was found. The samples were then kept at 4^o C until further analysis.

5.1.2 High-Performance Liquid Chromatography (HPLC) Analysis

The chromatogram revealed several distinct peaks corresponding to known standards, notably Quercetin (RT ≈ 8.9 min) , a prominent flavanol with strong antioxidant, anti-inflammatory, and Vaso protective properties; Caffeic acid (RT ≈ 6.4 min), phenolic acid with reported antimicrobial, hepatoprotective, and antioxidant effects; Chlorogenic acid (RT ≈ 5.1 min), known for its glucose lowering and neuroprotective activity; Kaempferol (RT ≈ 10.5 min), a flavonoid linked to anticancer and cardioprotective benefits.[16]

5.1.3 Gas Chromatography–Mass Spectrometry (GC-MS) Analysis

Characterisation of *Ipomoea Aquatica* extract was carried out using Gas Chromatography–Mass Spectrometry (GC-MS), to identify volatile and semi-volatile phytochemicals. The GCMS chromatogram revealed several peaks at specific retention times (RT), each corresponding to distinct chemical constituents of the extract. The identified compounds include various fatty acid esters, aromatic ketones, terpenoids, and other bioactive metabolites. These compounds were matched against NIST library spectra for confirmation.[16]

The GC-MS analysis of *Ipomoea Aquatica* extracts revealed a diverse profile of bioactive compounds, including fatty acid esters, terpenoids, phytosterols, and alkaloids. These compounds are widely recognized for their roles in modulating oxidative stress, inflammation, and metabolic health. Notably, Phytol, a diterpene alcohol identified in the extract, has demonstrated anti inflammatory, antioxidant, and anticancer activities in previous studies (de Moraes et al., 2014). Its presence suggests a potential role in scavenging reactive oxygen species and supporting immune modulation.[16]

5.1.4 Quantification of Bioactive Compounds

The quantification of bioactive compounds revealed that *Ipomoea Aquatica* extract contained 28.7 ± 1.9 mg GAE/g of total phenolics and 15.3 ± 1.2 mg QE/g of total flavonoids. These results indicate a rich phytochemical profile, consistent with the plant's traditional use for promoting health and preventing disease. The high phenolic and flavonoid content may contribute to the observed antioxidant and anti-inflammatory activities, supporting its use as a functional food or nutraceutical ingredient.[16]

6. Anti inflamatory activity:

The Ethanol and aqueous leaf extracts of *Ipomoea Aquatica* showed significant anti-inflammatory effect with carrageenin-induced rat paw edema model. The percentage inhibition of paw edema with methanolic leaf extracts (200 mg/kg), aqueous leaf extracts (200 mg/kg), and standard (indomethacin 5 mg/kg) was 55.07%, 49.27%, and 63.76%, respectively. The percentage inhibition of paw edema with methanolic leaf extracts (400 mg/kg), aqueous leaf extracts (400 mg/kg), and standard was 81.17%, 76.47%, and 89.41%, respectively. The results impacted that methanol leaf extracts have potential anti-inflammatory activity compared to aqueous leaf extracts. Pre-treatment with a single dose of *Ipomoea Aquatica* produced significant dose-dependent anti-inflammatory effects on carrageenin-induced rat hind paw edema.[13]

6.1 In vitro evidences:

Antioxidant and radical scavenging activity 2, 2 Diphenyl-1-picryhydrazl (DPPH) Radical Scavenging Assay Antioxidant activity was determined by the DPPH method [14]. Test samples were diluted in EtOH/H2O (1:1) from 10 mg/100 µL stocks prepared in DMSO. A total of 5 µL of each sample were placed into each well of a 96well plate, followed by the addition of 120 µL oof Tris-HCl buffer (50 mM, pH 7.4) and 120 µL of freshly prepared DPPH solution (0.1 mM in EtOH). The plate was incubated for 20 min at room temperature, with the absorbance read at 513 nm. The percentage of DPPH radical scavenging was calculated as ((A - B/A) x 100) where A represented the absorbance in the absence of test samples and B represented the absorbance in the presence of test samples. Ascorbic acid was used as a positive control (EC50 = 24.07 µg/mL).

6.2 The Ferric Reducing Antioxidant Power (FRAP) assay

The principle of this method is based on the reduction of a ferric-tripyridyl triazine complex to its ferrous, coloured form in the presence of antioxidants. In summary, the FRAP reagent comprised of 2.5 ml of a 10 mmol/L 2,4,6- tripyridyl-s-triazine (TPTZ) solution in 40 mmol/L HCl plus 2.5 mL of 20 mmol/L FeCl3 and 25 ml of 0.3 mol/L acetate buffer, pH 3.6 and was prepared freshly and warmed at 37°C. Aliquots of 40 L sample supernatant were mixed with 0.2 ml distilled water and 1.8 ml FRAP reagent and the absorbance of reaction mixture at 593 nm was measured using a spectrophotometer after incubation at 37°C for 10 min. The 1 mmol/L FeSO4 was used as the standard solution. The final result was expressed as the concentration of antioxidants having a ferric reducing ability equivalent to that of 1 mmol/L FeSO4.[16]

6.3 Invivo antioxidant enzyme activity assay animals

Wister albino rats (male) were used for the study of the Crude extracts. The animals were kept at 27 + 2ºC, relative humidity 44 – 56% and light and dark cycles of 10 and 14 hours respectively for one week before and during the experiment. Animals were provided with standard diet (Mouse cubes – Top feed, Anyigba) and the food was withdrawn 18 – 24 hours before the start of the experiment and watered adlibitum. All the experiments were performed early in the morning according to the current guidelines for the care of the laboratory animals and the ethical guidelines for the investigation of experimental pain in conscious animals.[18]

6.4 Nutritional Analysis

Nutritional analysis of the leaf extract was conducted using an array of standardised methods outlined below. Vitamins (A, C, E, K, B_1, B_2, B_3, B_5, B_6, and B_9) were quantified using High-Performance Liquid Chromatography following AOAC Official Methods. Mineral content (Calcium (Ca), Potassium (K), Magnesium (Mg), Sodium (Na), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), and Phosphorus (P)) was determined following AOAC Official Methods (2012) using Atomic Absorption Spectroscopy (AAS). Antioxidant activity was determined by the DPPH method and also the FRAP method as described by Guo et al. 2003. The plant extract was characterised was conducted using standard spectrometric and spectroscopic methods to qualitatively assess their nutritional and potential health benefits.[16]

Table:1 nutritional composition on *Ipomoea Aquatica* [16]

Nutrient	Concentration (Mean ± SD, mg/g dry weight)	Interpretation
Proteins	18.5 ± 1.2	Moderate protein content
Carbohydrates	56.8 ± 3.1	Rich in carbohydrates
Lipids	4.2 ± 0.5	Low-fat content

6.4.1 Vitamins

Vitamin analysis confirmed the presence of both fat-soluble (A, E) and water-soluble (C, Complex) vitamins (Table 2). Vitamin C was the most abundant, at 8.2 ± 0.6 mg/g, reinforcing the extract's antioxidant profile and immune-enhancing potential. The presence of vitamin A (1.8 ± 0.2 mg/g) supports vision and epithelial regeneration, while vitamin E (1.6 ± 0.1 mg/g) further strengthens the plant's role in antioxidant defence and cardiovascular health. Complex vitamins were present at moderate levels, contributing to energy metabolism and neurological function. These results are consistent with earlier studies identifying *Ipomoea Aquatica* as a rich source of vitamins, especially vitamin C and B-complex groups.[16]

Table:2 vitamin composition of *Ipomoea Aquatica* [16]

Vitamin	Concentration (Mean ± SD, mg/g dry weight)	Interpretation
Vitamin A	1.8 ± 0.2	Supports vision and immune function

Vitamin B1 (Thiamine)	0.54 ± 0.04	Important for energy metabolism
Vitamin B2 (Riboflavin)	0.72 ± 0.05	Supports cellular function
Vitamin B3 (Niacin)	1.3 ± 0.1	Aids in enzyme function
Vitamin B6 (Pyridoxine)	0.89 ± 0.06	Important for brain health
Vitamin B9 (Folate)	0.48 ± 0.03	Crucial for DNA synthesis
Vitamin C	8.2 ± 0.6	Strong antioxidant, boosts immunity
Vitamin E	1.6 ± 0.1	Supports skin health; protects against oxidative stress

6.4.2 Micronutrients (Vitamins and Minerals)

Vitamins (A, C, E, K, B_1, B_2, B_3, B_5, B_6, and B_9) were quantified using High-Performance Liquid Chromatography following AOAC Official Methods (2012). Separation was achieved on a reversed phase C18 column with appropriate mobile phases, and detection was performed using UV/Vis or fluorescence detectors depending on the vitamin class. Results were expressed as mg of vitamin per 100 g dry sample.[16]

Mineral content (Calcium (Ca), Potassium (K), Magnesium (Mg), Sodium (Na), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), and Phosphorus (P)) was determined following AOAC Official Methods (2012) using Atomic Absorption Spectroscopy (AAS) and, where higher sensitivity was required, Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Samples were first subjected to wet digestion with nitric and perchloric acids to obtain clear solutions. AAS was performed with element-specific hollow cathode lamps at optimised wavelengths, while ICP-MS provided multi element quantification with high sensitivity. Results were expressed as mg of mineral per 100 g dry sample.[16]

6.4.3 Traditional uses

Ipomoea Aquatica used as carminative agent and lessens inflammation, and is useful in fever, jaundice, biliousness, bronchitis, and liver complaints in Unani system of medicine used in nervous and general debility of female in Assam; dried juice has purgative properties; stem and leaves used in febrile delirium in Cambodia while in Burma, the juice is used as an emetic in cases of arsenic or opium poisoning. It is used also for piles, leukoderma, leprosy, and as anthelmintic. It is effectively used against nosebleed and high blood pressure. It is supposed to possess an insulin-like principle according to indigenous medicine in Sri Lanka.[13]

7. Jharkhand Variety: Regional Context

7.1. Ecological Conditions of Jharkhand and Possible Phytochemical Variation

The phytochemical profile of *Ipomoea Aquatica* is highly influenced by the ecological conditions in Jharkhand. The climate of the region is tropical-subtropical, with heavy monsoon rainfall, forests, and lateritic and alluvial soils rich in mineral, which affect the metabolism of plants and the synthesis of secondary metabolites including phenolics, flavonoids, tannins, alkaloids, and terpenoids.[20]

Water spinach thrives best in wetland habitats, and plants in wet water environments usually generate greater amounts of antioxidant compounds to act as defense against oxidative stress, microbes and fluctuating oxygen levels. Moreover, minerals such as iron and manganese could be available in the soil, and this could promote enzymatic pathways that take part in the synthesis of phytochemicals. [21]

Stress-induced metabolites production is further spurred by seasonal temperature variations, sunlight fluctuations, and interactions between microorganisms which can enhance anti-inflammatory and antioxidant molecules. The high biodiversity of the forests of Jharkhand also encourages the special interaction between plants and microbes that facilitate the synthesis of bioactive substances. All in all, these ecological reasons indicate that the Jharkhand type of *Ipomoea Aquatica* could have a unique, and potentially valuable phytochemical composition.[22-24].

7.2. Role of Local Diet and Ethnomedicinal Practices

In Jharkhand, *Ipomoea Aquatica* is commonly eaten as a leafy vegetable and forms an important part of traditional diets, especially among tribal communities. It is prepared in dishes such as stir-fries, soups, and herbal preparations, reflecting its recognized nutritional and health value.[23]

Ethnomedicinal practices in the region use the plant to manage inflammation, digestive problems, fever, swelling, and skin issues. These traditional uses support the idea that the plant contains bioactive compounds with anti-inflammatory properties. [22]

Regular consumption of phytochemical-rich vegetables like *Ipomoea Aquatica* contributes to preventive healthcare by helping reduce the risk of chronic diseases such as diabetes, cardiovascular disorders, and inflammatory conditions In Jharkhand, *Ipomoea Aquatica* is a popular leafy vegetable and a significant component of local cuisines, particularly in tribal societies. It is known to have a nutritional and health value and is therefore prepared in dishes like stir-fries, soups, and herbal preparations.[23]

The plant is used in ethnomedicinal practices in the region to treat inflammation, digestive problems, fever, swelling and skin problems. Such conventional applications are in favour of the fact that the plant has bioactive compounds that have anti-inflammatory effects. [23]

7.3. Differences Compared to Other Indian or Southeast Asian Varieties

The *Ipomoea Aquatica* is common in India and Southeast Asian countries like Thailand, Vietnam, Malaysia and Indonesia. Despite the botanical similarity, the differences in climate, soil and water conditions cause changes in the phytochemical composition.

The plant prospers in humid coastal and riverine regions with increased temperatures and some saline effects in the tropics of Southeast Asia, linked to increased levels of carotenoid and vitamin C because of high sun radiation and oxidative stress. Conversely, those plants cultivated in semi tropical Indian areas tend to exhibit greater amounts of phenolics and flavonoids due to the stress of the season and mineral rich soils. [24]

Their varieties of South India are typically grown in irrigated wetlands through controlled agricultural conditions, and can yield consistent yet possibly lower stress-induced metabolites than semi-wild plants. The Jharkhand form can be an intermediate ecological evolution that has combined natural wetland development and mineral-enriched soil with seasonal stress. This mixture can increase the diversity and concentration of bioactive compounds attributed to the activity of antioxidants and anti-inflammatory. Nevertheless, the fact that comparative profiling of regional varieties has not been done much, indicates that more studies on Jharkhand accessions are necessary. [25]

7.4 Critical Discussion

7.4.1. Correlation Between Phytochemical Richness and Anti-Inflammatory Activity

The anti-inflammatory activity of medicinal plants is attributed to phenolics, flavonoid, tannin and alkaloids, which are major phytochemicals. These compounds act by antioxidant activity, anti-inflammatory enzyme, and anti-inflammatory cytokine activities. Phenols neutralize free radicals, which decreases oxidative stress, leading to inflammation. Flavonoids also play a role in inhibiting enzymes like cyclooxygenase and lipoxygenase and immunomodulatory effects. [26]

This activity can be increased by tannins and alkaloids that stabilize the cell membranes and inhibit the denaturation of the proteins. The synergistic effect of these phytochemicals is an anti-inflammatory effect. The expression of phytochemical abundance and anti-inflammatory activity is very high in the presence of *Ipomoea Aquatica* of Jharkhand, and can be validated by laboratory tests like protein denaturation and membrane stabilization.

8.Future Prospects

8.1 Potential for developing nutraceuticals or herbal formulations.

Ipomoea Aquatica is widely recognized as a nutritious aquatic plant with considerable medicinal importance. It provides essential nutrients along with diverse phytochemicals, including flavonoids, alkaloids, tannins, phenolic compounds, and saponins. These constituents play an important role in its biological activity. Experimental findings suggest that extracts of this plant possess significant antioxidant capacity, indicating its usefulness as a natural source of protective compounds. Because of these properties, *Ipomoea Aquatica* may serve as a valuable raw material for the development of nutraceuticals and herbal products. Further investigation focusing on isolation of active molecules and evaluation of their mechanisms could strengthen its future applications in healthcare and preventive medicine.[30-35]

8.1.1 Nutritional Value

The plant is packed with vitamins (like A and C), minerals, proteins, fibers, carotenoids, and flavonoids, making it a prime candidate for functional foods targeting malnutrition or daily health supplements. These components support its use as a vegetable with inherent nutraceutical benefits, especially in tropical regions like India.[31]

8.1.2 Bioactive Compounds

Phytochemicals such as flavonoids and carotenes drive its pharmacological effects, including antioxidant, anti-inflammatory, antidiabetic, and hepatoprotective activities. Studies highlight extracts inhibiting oxidative stress and apoptosis, ideal for formulations against liver injury or diabetes[32-34].

8.1.3 Formulation Opportunities

Nanoformulations from Ipomoea aquatica enhance bioavailability, boosting anticancer, antioxidant, and antidiabetic efficacy over crude extracts. Herbal products could target allergies, hypertension, or infections, with its traditional uses in fever and jaundice providing a foundation for modern polyherbal blends.[33, 34]

FIG:1 Jharkhand variety *Ipomoea Aquatica*

8.2 Scope for bioprospecting and conservation of Jharkhand variety.

The variety of *Ipomoea Aquatica* found in Jharkhand represents an important natural resource due to its rich nutritional profile and pharmacologically active constituents. It contains vitamins, minerals, proteins, and several beneficial phytochemicals that contribute to antioxidant and therapeutic effects. This makes the plant a promising candidate for bioprospecting and discovery of new natural agents. However, environmental factors and unsustainable harvesting practices may reduce its availability. Therefore, conservation strategies such as sustainable cultivation, habitat protection, and responsible utilization are essential to ensure its continued availability and effective use. [35-37].

8.2.1 Bioprospecting Scopes

Ipomoea Aquatica from Jharkhand, which is an underused ethnomedicinal weed, has primary metabolites like carbohydrates and proteins, as well as secondary metabolites like alkaloids, flavonoids, glycosides, and phenols. These are great for testing new bioactive compounds. These support prospects in antioxidant, anti-inflammatory, and antimicrobial agents, which is in line with how they have been used in East Singbhum for fever, jaundice, and infections. This kind of regional hydrophyte shows ethnobotanical symmetry for herbal drugs and nutritional supplements.[38-40]

8.2.2 Variety Characterization

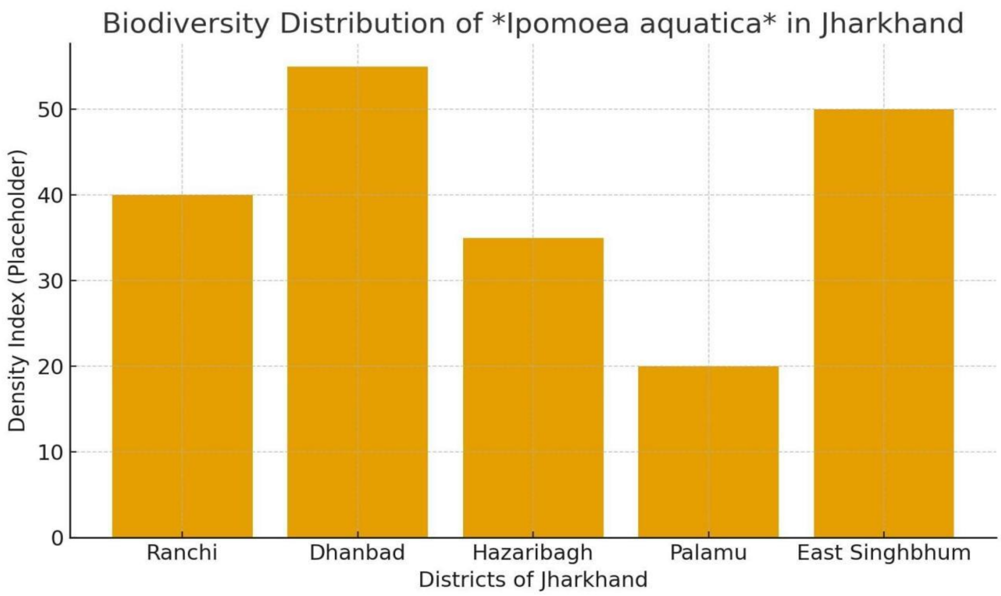
The Jharkhand variant has a lot of minerals (like iron, zinc, and calcium) and may protect DNA. It is similar to collections from Assam but is better for growing in local soils. Phytochemical screening shows that it has a higher bioactive yield than other Ipomoea species, such as I. batatas, which makes it possible to bio prospect in specific areas.[39]

8.2.3 Conversion Strategies

Conversion into value-added products entails aqueous/methanolic extracts for nutraceuticals aimed at diabetes and liver health, or biofuels through biorefinery processes due to its abundant aquatic biomass. Genetic optimization and nano formulations could help Jharkhand strains grow bigger and better for commercial herbal formulations, making use of the area's rich biodiversity.[40]

8.2.4 Challenges and Outlook

Standardization and clinical validation are still major problems, but Jharkhand's wild habitats are a great place for bioprospecting for sustainable conversion. More surveys in places like East Singbhum could lead to 4–5 patented formulations.[41-45]



Graph:1 - Biodiversity distribution of Ipomoea Aquatica in Jharkhand [44]

8.3 Importance of integrated research approaches

Comprehensive evaluation of Ipomoea aquatica requires a combination of laboratory, animal, computational, and clinical research methods. Laboratory studies help identify biological activity and mechanisms, while animal studies provide evidence of therapeutic effects under physiological conditions. Computational approaches assist in predicting molecular interactions, and clinical studies are necessary to confirm safety and effectiveness in humans. The integration of these approaches provides reliable scientific evidence supporting its medicinal potential. [42-44]

8.3.1 Combining qualitative and quantitative insights

An integrated research approach systematically combines qualitative and quantitative methods, addressing the shortcomings of each when used independently. Quantitative data offer generalizability and statistical robustness, whereas qualitative data furnish context, significance, and profundity; collectively, they yield more comprehensive and dependable conclusions.[45]

8.3.2 Addressing complex real-world problems

A single discipline can't explain many of today's problems, like public health crises, the effects of climate change, or problems with urban development. Integrated research combines social, technical, and environmental viewpoints so that researchers can see how causes, actors, and effects are all connected.[46]

8.3.3 Enhancing validity and robustness

Integrated designs improve the validity and reliability of findings by cross-checking data from surveys, interviews, experiments, and secondary sources. Cross-checking results from different methods lowers the chance of bias and helps find patterns or contradictions that studies using only one method might not see.[47]

8.3.4 Fostering innovation and the creation of new theories

Integration encourages innovation as researchers utilize concepts, tools, and theories from various disciplines, resulting in new frameworks or classifications. Comprehensive reviews and mixed-method studies frequently yield advanced insights that can contribute to the development of new theories or the enhancement of existing ones.[48]

8.4 Role of sustainable cultivation and community health benefits.

Adoption of sustainable cultivation practices is essential for preserving biodiversity and ensuring long-term availability of Ipomoea aquatica. Proper agricultural techniques, including controlled harvesting and use of environmentally friendly inputs, can protect natural ecosystems while improving productivity. Additionally, the plant contributes to nutritional security in many regions by providing essential nutrients and supporting community health and economic stability. [49-50]

8.4.1 Sustainable cultivation in marginal and wetland ecosystems

Growing crops in wetlands and other marginal ecosystems in a way that is good for the environment Ipomoea aquatica (water spinach) is a leafy vegetable that grows quickly and can live in waterlogged soils, ponds, and wetlands. This makes it a good choice for growing sustainably with little input. It can be grown in areas that are not being used or are flooded, which will ease the pressure on fertile arable land. It can also be used in diverse farming systems like aquaponics and floating-bed agriculture, which will make land use more efficient.[51-58]

8.4.2 Contribution to water and soil quality

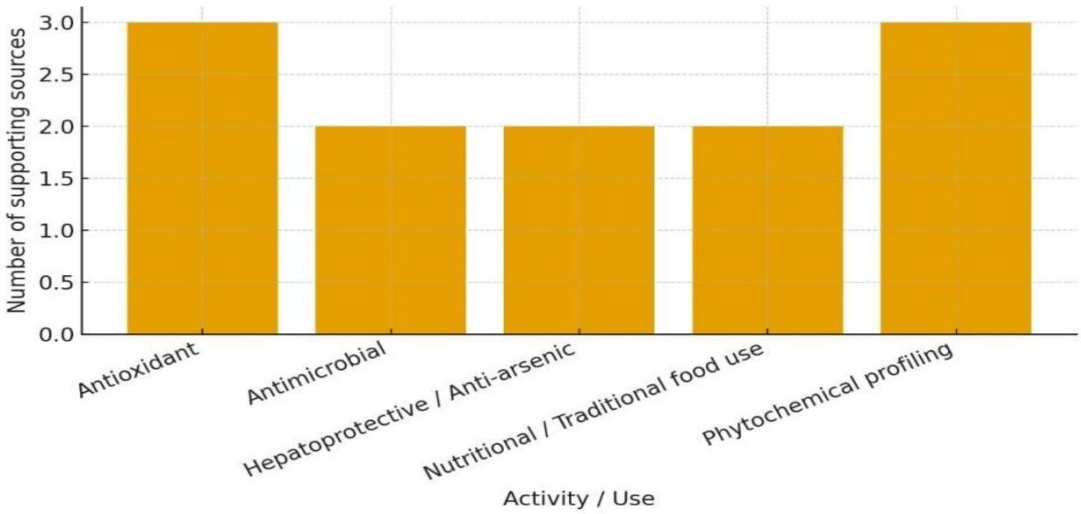
aquatica helps make water cleaner when grown in floating-bed systems by taking up extra nutrients like nitrogen and phosphorus. This lowers turbidity and eutrophication in ponds and irrigation channels. This phytoremediation potential helps make water cleaner for people, animals, and small-scale aquaculture, which lowers the risk of waterborne diseases and improves the health of the environment in riparian communities.[52,56,57]

8.4.3 Nutritional value and community-level food security

Nutritional value and food security at the community level Ipomoea aquatica is a leafy green vegetable that is high in vitamins (A, C, E, and B-complex), minerals (calcium, iron, magnesium, and manganese), dietary fiber, and carotenoids. Adding this vegetable to local diets on a regular basis can help fix micronutrient deficiencies, raise iron levels, and help children grow and mothers stay healthy, especially in rural and low-income areas where people don't have easy access to animal-source foods.[53,57,58]

8.4.4 Preventive health and lowering the risk of chronic diseases

Phytochemical research indicates that I. aquatica comprises flavonoids, phenolic compounds, and antioxidants exhibiting anti-inflammatory, antidiabetic, and hepatoprotective properties. Eating this vegetable has been linked to better blood sugar control, better lipid profiles, and protection against oxidative stress. This suggests that it could help lower the number of people in the community who have type-2 diabetes, heart disease, and liver problems.[54,55]



Graph 2: Activities reported by *Ipomoea Aquatica.[46]*

9. Conclusion

9.1 *Ipomoea Aquatica* is a nutritionally rich, medicinally valuable plant.

Ipomoea Aquatica is a significant leafy vegetable that enhances nutrition and provides a number of therapeutic advantages, supporting its designation as a nutrient-dense and medicinally valuable plant. Its incorporation into food items and pharmaceutical formulations has great potential to improve human health. Because of its combination of vital nutrients, antioxidants, and demonstrated therapeutic qualities, Ipomoea aquatica stands out as a nutritionally rich, medicinally significant plant that helps prevent disease and promotes health. This justifies its long-standing traditional use and encourages more clinical research.

9.2 Strong evidence for antioxidant and anti-inflammatory potential.

Ipomoea aquatica is a rich source of antioxidant phytochemicals that have been shown to scavenge free radicals, inhibit radicals, and reduce inflammation by downregulating oxidative stress and inflammatory mediators. It is a promising candidate for medicinal and nutraceutical applications because of its bioactive compounds, which have been validated by numerous in vitro and in vivo studies and support its therapeutic potential against diseases related to oxidative stress and inflammation.

9.3 Explored and properly studies Jharkhand variety including its systematic phytochemical and pharmacological evaluation.

The phytochemical richness and pharmacological potential of the Ipomoea aquatica variety found in Jharkhand validate traditional Ayurvedic and local ethnomedical uses. The plant is a promising candidate for therapeutic formulation and nutraceutical development because its bioactive compounds collectively contribute to antioxidant, anti-inflammatory, hepatoprotective, antidiabetic, and hematogenic effects.

9.4 Could serve as a candidate for future drug/nutraceutical development.

Ipomoea Aquatica's potential as a nutraceutical and drug development candidate for antioxidant, neuroprotective, hepatoprotective, antidiabetic, and anti-inflammatory applications is established by the variety of phytochemicals that support its many therapeutic qualities.

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