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Phytochemical Evaluation of Hygrophila difformis with Preliminary Anti-Obesity Activity

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Abstract: *Obesity is a major global health problem associated with various metabolic disorders such as diabetes, cardiovascular diseases, hypertension, and dyslipidemia. The increasing prevalence of obesity and the adverse effects of synthetic anti-obesity drugs have encouraged researchers to explore safer herbal alternatives. Medicinal plants are widely recognized for their therapeutic potential due to the presence of bioactive phytoconstituents with fewer side effects. Hygrophila difformis, an aquatic medicinal plant belonging to the family Acanthaceae, has gained attention for its diverse pharmacological properties. The plant contains several important phytochemicals including flavonoids, tannins, saponins, phenolic compounds, and terpenoids, which are known for their antioxidant and metabolic regulatory activities. Phytochemical evaluation of Hygrophila difformis indicates the presence of compounds that may contribute to lipid-lowering and anti-obesity effects. Preliminary studies suggest that the plant may help in obesity management through mechanisms such as inhibition of lipid accumulation, antioxidant action, and regulation of fat metabolism. This review highlights the phytochemical profile and preliminary anti-obesity potential of Hygrophila difformis and emphasizes the need for further pharmacological and clinical investigations.*

Keywords: Phytochemical Evaluation of Hygrophila difformis with Preliminary Anti-Obesity Activity

I. INTRODUCTION

Obesity is a chronic metabolic disorder characterized by excessive accumulation of body fat that may impair health and increase the risk of various diseases. It has become one of the most serious global public health concerns due to rapid changes in dietary habits, sedentary lifestyles, reduced physical activity, and genetic predisposition [1]. According to the World Health Organization (WHO), obesity is commonly assessed using Body Mass Index (BMI), where a BMI greater than 30 kg/m² is considered obese [2]. The prevalence of obesity has increased dramatically over the past few decades in both developed and developing countries, affecting individuals of all age groups.

Obesity is associated with numerous health complications and metabolic abnormalities. Excessive fat accumulation can lead to disorders such as type 2 diabetes mellitus, hypertension, cardiovascular diseases, dyslipidemia, stroke, osteoarthritis, and certain types of cancer [3]. Obesity also contributes to insulin resistance, oxidative stress, chronic inflammation, and hormonal imbalance, thereby reducing quality of life and increasing mortality rates [4]. Adipose tissue acts as an endocrine organ that releases inflammatory cytokines and adipokines, which further aggravate metabolic disturbances [5]. Due to these complications, obesity is considered a major risk factor for several chronic non-communicable diseases.

Various synthetic drugs such as orlistat, sibutramine, and liraglutide are currently used for the management of obesity. These drugs mainly act by suppressing appetite, inhibiting fat absorption, or regulating metabolism [6]. However, long-term use of synthetic anti-obesity drugs is often associated with adverse effects including gastrointestinal disturbances, insomnia, hypertension, headache, anxiety, liver toxicity, and cardiovascular complications [7]. Some anti-obesity

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drugs have also been withdrawn from the market because of severe side effects and safety concerns. Therefore, there is an increasing demand for safer and more effective alternatives with minimal adverse effects.

Medicinal plants have gained considerable attention in recent years due to their therapeutic efficacy, affordability, and lower toxicity. Herbal medicines contain a wide range of phytoconstituents such as flavonoids, tannins, saponins, terpenoids, and phenolic compounds that exhibit antioxidant, anti-inflammatory, hypolipidemic, and anti-obesity activities [8]. Several medicinal plants have been reported to reduce body weight, inhibit lipid accumulation, suppress appetite, and improve lipid metabolism through different mechanisms [9]. Natural products are therefore considered promising candidates for the development of novel anti-obesity therapies.

Hygrophila difformis, commonly known as water wisteria, is an aquatic medicinal plant belonging to the family Acanthaceae. The plant is widely distributed in tropical and subtropical regions and is traditionally used for various medicinal purposes [10]. It possesses several pharmacological activities such as antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, and antidiabetic effects due to the presence of bioactive phytochemicals [11]. Preliminary phytochemical investigations have revealed the presence of flavonoids, tannins, glycosides, and phenolic compounds in the plant [12]. These phytoconstituents may contribute to its potential anti-obesity activity by regulating lipid metabolism and reducing oxidative stress. Although limited studies are available regarding the anti-obesity potential of Hygrophila difformis, its rich phytochemical composition suggests that it may serve as a promising natural therapeutic agent for obesity management. Therefore, detailed phytochemical and pharmacological evaluation of this plant is essential to explore its therapeutic potential.

Figure 1 : Hygrophila difformis

II. PLANT PROFILE

2.1 Taxonomy

Hygrophila difformis is an aquatic medicinal herb belonging to the family Acanthaceae. The plant is commonly known as water wisteria and is widely cultivated in aquatic environments due to its medicinal and ornamental importance [13]. The taxonomical classification of Hygrophila difformis is presented below:

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Table 1: Taxonomical Classification of Hygrophila difformis

Taxonomical Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Acanthaceae
Genus	Hygrophila
Species	Hygrophila difformis

The genus Hygrophila consists of several medicinally important species traditionally used in herbal medicine for treating various disorders such as inflammation, liver diseases, urinary disorders, and metabolic abnormalities [14].

2.2 Morphology

Hygrophila difformis is a fast-growing aquatic or semi-aquatic herb characterized by soft stems and highly variable leaf morphology. The plant generally grows in freshwater habitats such as ponds, marshes, wetlands, and slow-moving streams [15].

The stem of the plant is elongated, flexible, and light green in color. It may grow either submerged or partially emerged depending on environmental conditions. The leaves are one of the most distinctive features of the plant. Submerged leaves are finely divided, feathery, and deeply lobed, whereas emerged leaves are broader and less dissected [16]. This variation in leaf structure is mainly influenced by water availability and environmental adaptation.

The plant possesses a fibrous root system that helps in anchoring it to muddy or aquatic substrates. Flowers are generally small, pale blue to lavender in color, and borne in the leaf axils. The fruits are capsule-like structures containing small seeds [17]. Due to its rapid growth and dense foliage, the plant is commonly cultivated in aquariums and aquatic gardens.

Morphologically, Hygrophila difformis is recognized for:

- Soft green stems
- Deeply divided submerged leaves
- Broad aerial leaves
- Fibrous roots
- Small bluish flowers

These characteristics contribute to its adaptability in aquatic ecosystems and support its medicinal significance.

2.3 Geographical Distribution

Hygrophila difformis is widely distributed in tropical and subtropical regions of Asia. The plant is commonly found in India, Bangladesh, Sri Lanka, Thailand, Malaysia, and other Southeast Asian countries [18]. It grows naturally in freshwater habitats including marshes, paddy fields, ponds, lakes, canals, and riverbanks.

In India, the plant is frequently observed in regions with high humidity and abundant water resources. It thrives well in warm climatic conditions with adequate sunlight and nutrient-rich soil or water environments [19]. Due to its adaptability and rapid propagation, the plant is also cultivated in aquariums worldwide as an ornamental aquatic species.

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The geographical distribution of Hygrophila difformis plays an important role in its availability for traditional medicinal applications. Environmental conditions such as temperature, water quality, and soil nutrients may influence the phytochemical composition of the plant [20].

2.4 Traditional Uses

Medicinal plants have been utilized in traditional systems of medicine for centuries, and Hygrophila difformis is no exception. Different parts of the plant have been traditionally used for the treatment of various ailments due to their therapeutic properties [21].

Traditionally, the plant has been used as:

- An anti-inflammatory agent
- A diuretic
- A hepatoprotective remedy
- An antimicrobial agent
- A general health tonic

In folk medicine, preparations of the plant are used to manage liver disorders, urinary tract infections, edema, and inflammatory conditions [22]. The antioxidant properties of the plant are believed to help reduce oxidative stress and improve overall metabolic health.

Certain traditional healers also use the plant in the management of diabetes and obesity-related complications due to its potential role in regulating lipid metabolism and improving digestion [23]. The presence of phytochemicals such as flavonoids, tannins, and phenolic compounds may contribute to these medicinal properties.

The growing interest in herbal medicine and natural therapeutics has encouraged researchers to investigate the pharmacological potential of Hygrophila difformis. Its traditional usage provides a scientific basis for further phytochemical and anti-obesity studies.

III. PHYTOCHEMICAL EVALUATION

Phytochemical evaluation is an important step in identifying the bioactive constituents present in medicinal plants. These phytochemicals are responsible for various pharmacological activities including antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and anti-obesity effects. Hygrophila difformis contains several secondary metabolites that contribute to its therapeutic potential. Phytochemical investigation generally involves extraction, preliminary screening, and identification of major phytoconstituents [24].

3.1 Extraction Methods

Extraction is the process of separating bioactive compounds from plant materials using suitable solvents. Different extraction methods are used depending on the nature of phytochemicals and solvent polarity. In Hygrophila difformis, leaves, stems, and whole plant parts are commonly used for extraction purposes [25].

3.1.1 Maceration

Maceration is a simple extraction technique in which powdered plant material is soaked in solvents such as ethanol, methanol, or water for a specific period with occasional shaking. The solvent penetrates the plant tissues and dissolves the phytochemicals present in the material [26]. This method is widely used because it is economical and suitable for heat-sensitive compounds.

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3.1.2 Soxhlet Extraction

Soxhlet extraction is a continuous hot extraction method used for efficient isolation of phytoconstituents. In this process, the solvent repeatedly passes through the plant material, resulting in better extraction efficiency [27]. Methanol and ethanol are commonly used solvents for extracting flavonoids, alkaloids, and phenolic compounds from Hygrophila difformis.

3.1.3 Aqueous Extraction

Aqueous extraction involves the use of water as a solvent to obtain water-soluble phytochemicals. This method is commonly employed in traditional herbal preparations and decoctions [28]. The aqueous extract may contain tannins, glycosides, saponins, and phenolic compounds.

3.1.4 Hydroalcoholic Extraction

Hydroalcoholic extraction uses a mixture of alcohol and water to extract both polar and moderately non-polar compounds. This method is considered effective for obtaining a broad range of phytochemicals from medicinal plants [29].

The efficiency of extraction depends on factors such as solvent type, extraction time, temperature, and particle size of plant material.

3.2 Preliminary Phytochemical Screening

Preliminary phytochemical screening is performed to detect the presence of different classes of secondary metabolites in plant extracts. Various qualitative chemical tests are used to identify phytochemicals present in Hygrophila difformis extracts [30].

Common Phytochemical Tests

Table 2: Preliminary Phytochemical Screening Tests for Hygrophila difformis

Phytochemical	Test Used	Observation
Flavonoids	Shinoda test	Pink/red color
Tannins	Ferric chloride test	Blue-black color
Saponins	Foam test	Persistent foam
Phenolics	Ferric chloride test	Dark green coloration

These phytochemical tests confirm the presence of important bioactive compounds responsible for therapeutic activities.

3.3 Major Phytoconstituents

3.3.1 Flavonoids

Flavonoids are polyphenolic compounds widely distributed in medicinal plants. They possess antioxidant, anti-inflammatory, antidiabetic, and anti-obesity activities [31]. Flavonoids help in scavenging free radicals and reducing oxidative stress associated with obesity and metabolic disorders. They may also regulate lipid metabolism and inhibit fat accumulation in adipose tissues.

3.3.2. Tannins

Tannins are phenolic compounds with strong antioxidant and antimicrobial properties. They help in reducing oxidative stress and preventing lipid peroxidation [33]. Tannins may also reduce intestinal absorption of lipids and contribute to anti-obesity effects.

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3.3.2 Saponins

Saponins are glycosidic compounds that possess hypocholesterolemic and anti-obesity properties. They can bind with cholesterol in the digestive tract and reduce lipid absorption [34]. Saponins also exhibit antioxidant and anti-inflammatory activities that may help in obesity management.

3.3.3 Phenolic Compounds

Phenolic compounds are important plant metabolites known for their potent antioxidant activity. These compounds protect cells from oxidative damage caused by free radicals [35]. Phenolics also play a role in regulating glucose metabolism, lipid metabolism, and inflammatory pathways associated with obesity.

The combined presence of flavonoids, tannins, saponins, and phenolic compounds indicates the therapeutic significance of Hygrophila difformis and supports its potential use in the management of obesity and related disorders.

IV. PHARMACOLOGICAL ACTIVITIES

Medicinal plants possess various pharmacological properties due to the presence of biologically active phytochemicals. Hygrophila difformis contains several secondary metabolites such as flavonoids, tannins, saponins, and phenolic compounds that contribute to its therapeutic potential. Various studies on medicinal plants belonging to the family Acanthaceae have demonstrated significant antioxidant, anti-inflammatory, antidiabetic, and antimicrobial activities [36]. These activities may play an important role in the prevention and management of obesity and associated metabolic disorders.

4.1 Antioxidant Activity

Antioxidants are substances that protect cells from oxidative damage caused by free radicals and reactive oxygen species (ROS). Oxidative stress is considered one of the major factors involved in obesity, diabetes, cardiovascular diseases, and aging [37]. Plant-derived antioxidants neutralize free radicals and reduce cellular damage.

Hygrophila difformis contains flavonoids and phenolic compounds that exhibit strong antioxidant properties. These phytochemicals donate electrons to unstable free radicals and stabilize them, thereby preventing lipid peroxidation and oxidative stress [38]. Antioxidant activity is commonly evaluated using assays such as DPPH radical scavenging assay, hydrogen peroxide scavenging assay, and reducing power assay.

The antioxidant potential of medicinal plants may help in:

- Reducing oxidative stress
- Preventing cellular damage
- Improving metabolic functions
- Protecting against obesity-related complications

Phenolic compounds and flavonoids present in Hygrophila difformis are considered major contributors to its antioxidant activity.

4.2 Anti-inflammatory Activity

Inflammation is a protective biological response against injury and infection. However, chronic inflammation is associated with obesity, insulin resistance, arthritis, and cardiovascular diseases [39]. Excess adipose tissue in obese individuals releases inflammatory mediators such as cytokines and adipokines, which contribute to metabolic disturbances.

Medicinal plants rich in flavonoids and phenolics possess anti-inflammatory properties by inhibiting inflammatory mediators and reducing oxidative stress [40]. Hygrophila difformis may exhibit anti-inflammatory activity due to the presence of these bioactive constituents.

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The anti-inflammatory effects of plant phytochemicals may occur through:

- Inhibition of prostaglandin synthesis
- Reduction of inflammatory cytokines
- Stabilization of cell membranes
- Suppression of oxidative stress

These activities may help reduce obesity-induced inflammation and associated metabolic complications.

4.3 Antidiabetic Activity

Diabetes mellitus is a chronic metabolic disorder characterized by elevated blood glucose levels resulting from impaired insulin secretion or insulin resistance [41]. Obesity is one of the major risk factors for type 2 diabetes mellitus. Therefore, medicinal plants with antidiabetic properties are considered beneficial in obesity management.

Phytochemicals such as flavonoids, tannins, and saponins are known to improve glucose metabolism and insulin sensitivity [42]. Hygrophila difformis may help regulate blood glucose levels through antioxidant activity and enhancement of insulin action.

Possible mechanisms of antidiabetic activity include:

- Enhancement of insulin secretion
- Improvement of insulin sensitivity
- Inhibition of carbohydrate-digesting enzymes
- Reduction of oxidative stress

Natural antioxidants present in the plant may also protect pancreatic β-cells from oxidative damage and improve metabolic functions.

4.4 Antimicrobial Activity

Microbial infections caused by bacteria and fungi remain a major health concern worldwide. Medicinal plants have been extensively studied for their antimicrobial properties because of increasing antibiotic resistance [43].

Plant extracts containing tannins, flavonoids, and phenolic compounds exhibit antimicrobial activity against various pathogenic microorganisms [44]. These compounds may damage microbial cell walls, inhibit enzyme activity, and interfere with microbial metabolism.

Studies on medicinal plants of the Acanthaceae family have shown antibacterial and antifungal activities against several microorganisms including:

- Escherichia coli
- Staphylococcus aureus
- Pseudomonas aeruginosa
- Candida albicans

The antimicrobial activity of Hygrophila difformis may be attributed to the synergistic action of its phytoconstituents. Such activity may support overall health and reduce infection-related complications.

V. ANTI-OBESITY ACTIVITY

Obesity is a metabolic disorder characterized by excessive accumulation of body fat resulting from an imbalance between energy intake and energy expenditure. It is associated with several health complications including diabetes mellitus, hypertension, cardiovascular diseases, and dyslipidemia [45]. In recent years, medicinal plants have gained significant attention for obesity management due to their safety, effectiveness, and presence of bioactive phytochemicals.

Phytochemicals such as flavonoids, tannins, saponins, and phenolic compounds play an important role in controlling obesity through different biological mechanisms [46]. These compounds may help reduce body weight, improve lipid metabolism, inhibit fat absorption, and decrease oxidative stress associated with obesity.

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5.1 Role of Phytochemicals in Obesity Control

Medicinal plants contain various secondary metabolites that contribute to anti-obesity activity. Flavonoids and phenolic compounds possess antioxidant properties that reduce oxidative stress and inflammation associated with obesity [47]. Saponins may decrease cholesterol absorption in the intestine, while tannins may inhibit digestive enzymes involved in fat metabolism [48].

Phytochemicals help in obesity management through:

- Reduction of lipid accumulation
- Enhancement of energy expenditure
- Suppression of appetite
- Regulation of adipocyte differentiation
- Improvement of glucose and lipid metabolism

The phytochemical constituents present in Hygrophila difformis may contribute to these beneficial effects and support its potential as a natural anti-obesity agent.

5.2 Possible Mechanisms of Anti-Obesity Activity

5.2.1 Lipase Inhibition

Pancreatic lipase is an important digestive enzyme responsible for the breakdown of dietary fats into absorbable fatty acids and glycerol [49]. Inhibition of pancreatic lipase reduces fat digestion and decreases lipid absorption from the intestine.

Several plant-derived phytochemicals, particularly flavonoids and tannins, have shown lipase inhibitory activity [50]. By inhibiting pancreatic lipase, medicinal plants may help prevent excessive fat accumulation and body weight gain. This mechanism is similar to the action of certain synthetic anti-obesity drugs such as orlistat.

5.2.2 Reduced Fat Absorption

Certain phytochemicals reduce intestinal absorption of dietary fats and cholesterol. Saponins can bind with cholesterol and bile acids in the gastrointestinal tract, thereby decreasing lipid absorption and promoting cholesterol excretion [51].

Reduction in fat absorption may help:

- Lower body weight
- Reduce serum cholesterol levels
- Improve lipid profile
- Prevent obesity-related complications

This mechanism contributes significantly to the anti-obesity potential of medicinal plants.

5.2.3 Antioxidant Effects

Oxidative stress plays a major role in the development of obesity and metabolic disorders. Excessive production of free radicals can damage cells and alter metabolic pathways [52]. Antioxidants present in medicinal plants neutralize free radicals and reduce oxidative stress.

Flavonoids and phenolic compounds in Hygrophila difformis may provide antioxidant protection by:

- Scavenging reactive oxygen species
- Preventing lipid peroxidation
- Protecting cellular components
- Reducing inflammation

These antioxidant effects may help improve metabolic health and reduce obesity-associated complications.

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5.2.4 Regulation of Lipid Metabolism

Lipid metabolism involves the synthesis, storage, and breakdown of fats in the body. Obesity is commonly associated with abnormal lipid metabolism and excessive fat accumulation in adipose tissues [53].

Plant phytochemicals may regulate lipid metabolism through:

- Reduction of triglyceride synthesis
- Enhancement of fatty acid oxidation
- Decrease in adipogenesis
- Regulation of cholesterol metabolism

Flavonoids and phenolic compounds may influence enzymes and hormones involved in lipid metabolism, thereby helping in body weight management and improvement of metabolic disorders.

The presence of these bioactive compounds in Hygrophila difformis suggests its potential role in obesity control and supports the need for further pharmacological investigations.

VI. FUTURE SCOPE

Although Hygrophila difformis has shown promising pharmacological and phytochemical properties, extensive scientific studies are still required to establish its therapeutic potential in obesity management. Future research should focus on the identification, isolation, and characterization of bioactive compounds responsible for its anti-obesity activity [54]. Advanced analytical techniques such as HPLC, GC-MS, and LC-MS may be used for the purification and structural elucidation of active phytoconstituents.

Further experimental and preclinical studies are necessary to understand the exact mechanism of action of the plant in obesity control. Detailed toxicological evaluation and safety assessment should also be carried out to ensure safe therapeutic use [55].

Clinical studies on human subjects are essential to evaluate the efficacy, safety, dosage, and long-term effects of Hygrophila difformis in obesity management. Clinical trials may provide scientific evidence regarding its effectiveness as a natural anti-obesity agent and support its application in modern medicine [56].

The development of herbal formulations containing Hygrophila difformis may provide safer and cost-effective alternatives to synthetic anti-obesity drugs. The plant may be utilized in the preparation of nutraceuticals, and functional foods for obesity and metabolic disorders [57]. Combination formulations with other medicinal plants may also enhance therapeutic efficacy through synergistic action.

Therefore, further phytochemical, pharmacological, and clinical investigations are required to explore the full medicinal potential of Hygrophila difformis and to develop effective herbal therapies for obesity management.

VII. CONCLUSION

Hygrophila difformis is an important medicinal plant possessing significant phytochemical and pharmacological properties. The plant contains various bioactive constituents such as flavonoids, tannins, saponins, and phenolic compounds that contribute to its therapeutic potential. These phytochemicals exhibit antioxidant, anti-inflammatory, antidiabetic, antimicrobial, and possible anti-obesity activities.

Obesity is a major global health concern associated with several metabolic disorders, and the limitations of synthetic anti-obesity drugs have increased interest in herbal medicines as safer alternatives. The phytochemical constituents present in Hygrophila difformis may help in obesity management through mechanisms such as lipase inhibition, reduction of fat absorption, antioxidant action, and regulation of lipid metabolism.

Preliminary studies indicate that the plant possesses promising medicinal value; however, detailed pharmacological, toxicological, and clinical investigations are still required to confirm its efficacy and safety. Further research focusing on the isolation of active compounds and development of herbal formulations may help establish Hygrophila difformis as a potential natural therapeutic agent for obesity and related metabolic disorders.

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