3 *Achyranthes aspera* L.: A Study of Phytochemistry, Biological Activity, and Sustainable Uses

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Abstract

Achyranthes aspera L., commonly known as the "prickly chaff flower", belongs to the family "Amaranthaceae". It is widely used in ancient medicinal practices because of its diverse therapeutic features. The plant has been employed in traditional medicine across Asia and Africa for the treatment of inflammation, diabetes, infections, and liver disorders. This chapter provides a brief description of the phytochemical composition and medicinal uses of *A. aspera*. Phytochemical analysis has revealed the existence of different bioactive molecules in *A. aspera*, including alkaloids, flavonoids, saponins, tannins, terpenoids, steroids, and phenolics. Important components found in it include achyranthine, oleanolic acid, ecdysterone, and rutin, which are identified to show antioxidant and anti-inflammatory effects. Multiple studies have been conducted on this species due to its medicinal uses. The studies have suggested that the species has potent anti-inflammatory, antidiabetic, antioxidant, antimicrobial, hepatoprotective, and anticancer properties. Some new studies have also suggested its immunomodulatory and wound healing activities. There have been many explorations done regarding its biological activity. Due to inconsistency in extraction procedures and lack of standardized formulations, its pharmaceutical significance is less explored. Further study is required to elucidate its biological mechanism and increase its efficacy. Therefore, it is evident that *Achyranthes aspera* is a promising medicinal plant with a lot of biomedical significance.

Keywords: *Achyranthes aspera*, Phytochemicals, Pharmacological Activities, Antioxidant, Medicinal Plants.

Introduction

Plant based natural remedies have a rich historical foundation, and their effectiveness makes them valuable candidates for disease treatment. *Achyranthes aspera* is one of the most invaluable plants among various plants having therapeutic benefits.

The genus *Achyranthes* includes approximately 21 species distributed widely over the tropical and subtropical regions including Eastern, South, and Southeast Asia, as well as Central and Southern Africa and Latin America (He et al., 2017). *Achyranthes bidentata* and *Achyranthes aspera* have been most commonly used as the medicinal plant especially in India and China (He et al., 2017).

Achyranthes aspera is a healing herb which grows as a weed all over the Indian region (Srivastav et al., 2011). Distinct plant parts (leaves, roots, stems, seeds, and inflorescence) and the entire plant have therapeutic uses (Ndhlala et al., 2015).

Taxonomic Classification

Achyranthes aspera L., widely called “Apamarga, Latjeera or prickly chaff flower”, is a medicinally important weed of the “Amaranthaceae” family. It is a well-documented herb in pharmacognostic and phytochemical research because of its various biological actions and folklore medicinal value (Baraik et al., 2014; Kumar et al., 2024; Rehman et al., 2018).

Kingdom: Plantae

Subkingdom: Tracheobionta (Vascular plants)

Superdivision: Spermatophyta (Seed plants)

Division: Magnoliophyta (Flowering plants)

Class: Magnoliopsida (Dicotyledons)

Subclass: Caryophyllidae

Order: Caryophyllales

Family: Amaranthaceae

Genus: *Achyranthes*

Species: *aspera* (Srivastav et al., 2011)

ISBN: 978-93-49468-43-6

Figure 1: *Achyranthes aspera* in our college campus (BCAS,DU)

Source: Photograph captured by the authors.

Morphology of *Achyranthes aspera*

It is an upright herbaceous plant, either annual or perennial that attains a height of 0.3-1 metres, with rigid branches.

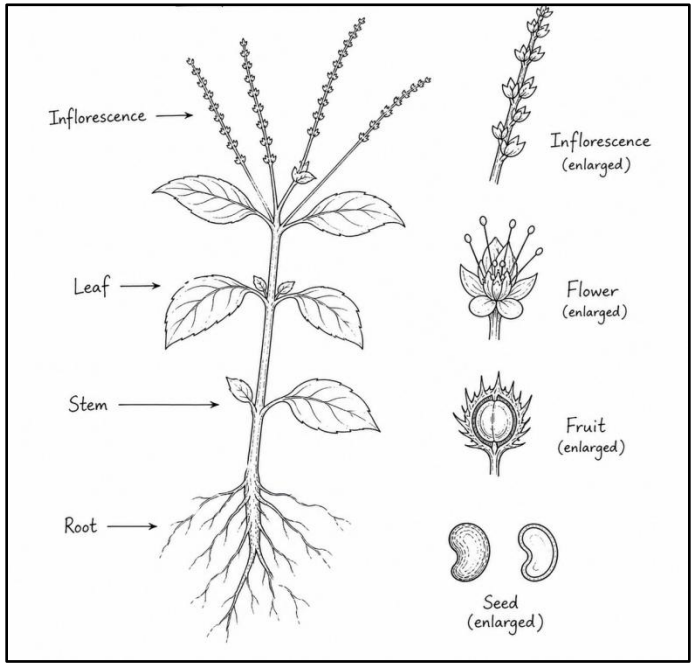

Figure 2: Morphological diagram of *Achyranthes aspera* L., drawn using Picsart and Canva Applications. Specifications used as per already published data (Srivastav et al., 2011).

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- **Root:** A well-developed taproot system is present, which becomes woody with age (Dhale & Bhoi, 2013; Sinan et al., 2020; Srivastav et al., 2011).
- **Stem:** The stem is herbaceous, erect, cylindrical, green often pubescent, and may be ribbed or angular with occasional purplish tinge (Dhale & Bhoi, 2013; Srivastav et al., 2011).
- **Leaf:** They are simple, arranged oppositely, ranging from egg-shaped to elliptic or oval-lanceolate, around 3–6 cm long, with entire margins and an abruptly pointed apex. They are petiolate, pubescent softly on both surfaces, membranous, semi-ovate to elliptic in shape (Dhale & Bhoi, 2013; Manandhar et al., 2021; Srivastav et al., 2011).
- **Flower:** Inflorescence consists of small, green-white, bisexual, tetracyclic, and actinomorphic blossoms. Inflorescences are dense, occurring at the tips or leaf axils, often long, reflexed, with persistent bracts, and borne on a long peduncle (Ganesh et al., 2021; Sinan et al., 2020; Srivastav et al., 2011).
- **Fruit:** The fruit is a non-splitting utricle enclosed in a persistent perianth and bracteole. Seeds are small, reniform to subcylindrical, reddish-brown, and truncate at the apex (Dhale & Bhoi, 2013; Ganesh et al., 2021; Srivastav et al., 2011).

Phytochemical Composition

A. aspera has several bioactive compounds known to be essential for various therapeutics uses. Phytochemical screening of the plant has shown existence of secondary metabolites like “alkaloids, flavonoids, saponins, tannins, steroids, and terpenoids”, along with additional phytochemicals. (Dinakarkumar et al., 2025; Ganesh et al., 2021; Ha et al., 2024; Rehman et al., 2018)

Approximately 25 phytochemical compounds were identified during GC-MS (Gas Chromatography- Mass Spectrometry) profiling from the leaf ethanolic extract of *A. aspera* (Mary & Giri, 2018).

- **Alkaloids**- An important class of nitrogen containing metabolites reported in *A. aspera* through phytochemical screening. Specific alkaloids such as achyranthine and betaine along with others have been extracted from *A. aspera* (Dhital, 2018; Ganesh et al., 2021).
- **Flavonoids-** Flavonoids are widely present in leaves and aerial parts of *A. aspera*. Flavonoids such as quercetin and kaempferol are some compounds that have been found in the plant. Total flavonoid content analysis confirms their widespread presence as metabolites (Dhital, 2018; Ganesh et al., 2021).
- **Saponins-** Triterpenoid saponins are among the major group of glycosidic molecules found in the *A. aspera* plant (Ganesh et al.,2021; Kiuchi, 2022).

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Two major saponins are Saponin A and Saponin B which are isolated from the roots. Derivatives such as oleanolic acid have also been found in seed extracts. Saponins are essential due to their complex glycosidic structures, contributing to their phytochemical activity (Kiuchi, 2022).

- **Tannins-** Tannins are high molecular weight polyphenolic compounds identified in *A. aspera* during phytochemical screening (Dhital, 2018; Ganesh et al., 2021). Both hydrolysable and condensed tannins are present in the plant, especially the leaves.
- **Terpenoids and Triterpenes-** Triterpenes serve as the precursors of saponin molecules. Presence of triterpenes such as oleanolic acid shows the importance of terpenoid metabolism in the plant (Ganesh et al., 2021; Kiuchi, 2022).
- **Steroids-** Plant steroids such as beta-sitosterol contribute to the sterol profile of the plant *A. aspera* (Dhital, 2018; Ganesh et al., 2021).
- **Other compounds -** Compounds such as phytol, squalene, oleamide and hexadecanoic acid (palmitic acid) were also identified from the extract of the plant (Mary & Giri, 2018).

Table 1: Phytochemicals Identified in *Achyranthes aspera* and their biological activities

Plant Part	Phytochemicals / Bioactive Compounds	Analytical Method	Function / Biological Activity	References
Leaves (Ethanolic extract)	The detected compounds comprised Cyclohexane derivatives (Cyclohexane, 1-methyl-4-(2-hydroxyethyl)); aromatic hydrocarbons (1-methylpropylbenzene, 1,3-diethylbenzene, 2-methylnaphthalene, 1,7-dimethylnaphthalene, 1,2,3-trimethylbenzene); oxygenated monoterpenes (Cis-p-mentha-1(7),8-dien-2-ol); ester derivatives; and fatty acids such as oleic acid and eicosanoic acid.	GC-MS	Antimicrobial, antioxidant, anti-inflammatory, cytoprotective	(Mary & Giri, 2018)
Leaves	Flavonoids	Colorimetric assay / Phytochemical screening	Antioxidant, anti-inflammatory, cardioprotective	(Dhital, 2018; Ganesh et al., 2021)
Leaves	Rutin, p-hydroxycinnamic acid, 3,4,5-trihydroxybenzoic acid, Protocatechuate, Ferulate	UPLC (Ultra Performance Liquid Chromatography)	Antioxidant, anti-inflammatory, blood vessel protection, antimicrobial, free radical scavenger and cellular protection	(Sinan et al., 2020)

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Leaves / Aerial parts	Ecdysterone, Achyranthine, Betaine, Pentatriacontane, Hexatriacontane, 6-Pentatriacontanone, Tritriacontane	Methanol extraction / Spectroscopic analysis/ Nuclear Magnetic Resonance analysis (NMR)	Hormonal modulation, antimicrobial, antioxidant	(He et al., 2017; Sinan et al., 2020)
Aqueous leaf extract	Alkaloids, Flavonoids, Saponins, Tannins, Carbohydrates, Glycosides, Amino acids, Proteins	Phytochemical screening	Antimicrobial, antioxidant, cytoprotective, wound healing	(Dhale & Bhoi, 2013; Pandey et al., 2014)
Aqueous extract of vegetative parts	Tannins, phlobatannins, terpenoids, flavonoids, cardiac glycosides, phenolic compounds, and alkaloids	Phytochemical screening	Antioxidant, cardioprotective, anti-inflammatory	(Manandhar et al., 2021; Rehman et al., 2018)
Methanol & ethanol extracts (all parts)	Triterpenoids and sterols (ursolic acid, oleanolic acid, β-sitosterol), along with triterpenoid saponins, alkaloids, flavonoids, tannins, phenols, glycosides, steroids, terpenoids, carbohydrates, proteins, amino acids, volatile oils, vitamins, and minerals.	Soxhlet, Sequential solvent extraction, GC-MS, HPTLC (High Performance Thin Layer Chromatography), UPLC	Antidiabetic, anti-inflammatory, antioxidant, antimicrobial, antifungal, anthelmintic, anti-asthmatic, wound healing, immunomodulatory, hypolipidemic	(Ahmad et al., 2022; Ganesh et al., 2021; Kiuchi, 2022; Owk et al., 2014)
Shoot	36,47-Dihydroxyhenpentacontan-4-one, Tritriacontanol	Methanol extraction / Spectroscopic analysis	Growth regulator, cytoprotective	(Sinan et al., 2020)

Therapeutic Uses

- **Inflammation Suppressing Effects**

The leaf ethanolic extract derived from *A. aspera* shows inflammation-modulating activity, when tested or in combination. The alcoholic root extract reportedly shows inflammation suppressing effects in experimental studies done using wistar rats (Ganesh et al., 2021; Srivastav et al., 2011).

- **Anti-diabetic Activity**

The plant also shows therapeutic potential in treatment of diabetes mellitus. The triterpenoid compounds such as ursolic along with oleanolic acid extracted from *A. aspera* have shown significant blood sugar lowering activity in diabetic rat models induced by streptozotocin (Ganesh et al., 2021). Studies have also indicated the protective effect against streptozotocin (STZ) induced hyperglycemia exhibited by the *A. aspera* (Une et al., 2021).

- **Helminthicidal Effect**

The ethanol based extract obtained from the *A. aspera* stems evaluated shows effective antihelminthic activity (Ganesh et al., 2021;Verma et al., 2021).

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- **Analgesic Activity**

The *A. aspera* extracts showed pain relieving effects when the leaves and seeds of the plant were tested for analgesic activity. Extracts from both leaf and seed parts demonstrated analgesic potential in mice determined through the use of "acetic acid–induced writhing and hot plate models". Leaf extracts alone also show significant analgesic activity (Verma et al.,2021; Srivastav et al., 2011).

- **Antioxidant Activity**

Aqueous leafy extracts of *A. aspera* has shown antioxidant potential because of the presence of phenolic and flavonoid compounds (Ganesh et al., 2021; Pandey et al., 2014; Rehman et al., 2018).

- **Hepatoprotective Activity**

Methanolic stem extracts of *A. aspera* represented hepatoprotective effects against rifampicin induced hepatotoxicity in albino rats. Ethanolic extracts of the seeds have also shown hepatoprotective effects in albino rats (Verma et al., 2021).

- **Anticancer Activity**

*A. aspera*extracts has been reported for its antitumor and anticarcinogenic potential in various studies (Pandey et al., 2014; Rehman et al., 2018).Among various extracts tested, ether extract showed better antitumor effects than the other extracts (Verma et al., 2021).

- **Diuretic Activity**

Saponins extracted from *A. aspera* seeds demonstrated promotion of urine excretion tested on mature male albino rats. In various experimental researches, plant extract was administered in albino rats at different doses through an intraperitoneal route showing increased urine output, indicating diuretic potential of the extract (Verma et al., 2021).

- **Antimicrobial Activity**

Aqueous and organic solvent extracts of *A. aspera* have been investigated for its antibacterial and antifungal potential using diffusion and dilution methods. Antibacterial activity was assessed by measuring the zones of inhibition generated by the extracts. Antifungal activity was assessed using the poisoned food technique showing broad-spectrum fungal inhibition (Ahmad et al., 2022; Baraik et al., 2014; Mishra et al., 2020; Ndhlala et al., 2015; Owk et al., 2014; Pandey et al., 2014). Among thetested aqueous and organic solvent extracts, organic solvent extracts, especially methanolic and ethanolic extracts, exhibited higher antimicrobial potential compared to aqueous extracts.

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- **Larvicidal and Insecticidal Activity**

Crude extracts of *A. aspera* showed strong larvicidal and insecticidal activity by disrupting larval feeding and development in insects and mosquito larvae (Khade et al., 2021; Sharma et al., 2022).

Therapeutic Potential of Bioactive Compounds

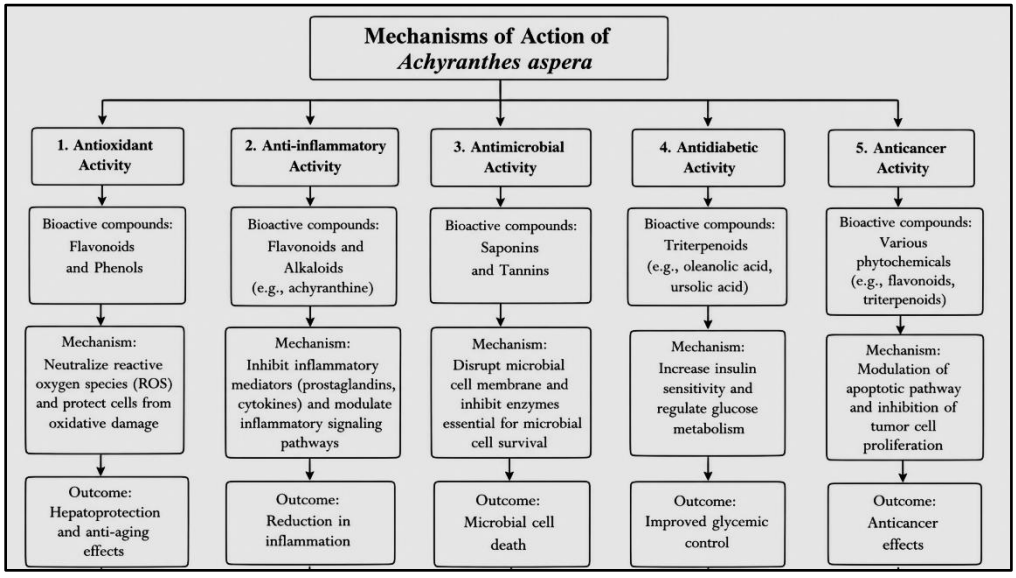

Figure 3: Flowchart showing Therapeutic potential of Bioactives from *Achyranthes aspera*.

Compilations done after literature study (Khade et al., 2021; Sharma et al., 2022; Manandhar et al., 2021; Srivastav et al., 2011).

Pharmacological actions exerted by *A. aspera* can be explained from biochemical perspectives. Presence of flavonoids in *A. aspera* extracts is capable of neutralizing Reactive Oxygen Species and protecting cells from oxidative damages. Because of flavonoids, the extracts can also provide hepatoprotection and anti-aging activity (Manandhar et al., 2021).Anti-inflammatory activity can also be shown due to the presence of flavonoids.

The presence of alkaloids such as achyranthine inhibits the inflammatory signaling pathways which reduces inflammation (Srivastav et al., 2011). Saponins and tannins are involved in disrupting the microbial cell membrane and inhibiting enzymes that lead to microbial cell death and contributing to its antimicrobial potential (Asfaw et al., 2023). Triterpenoids, including oleanolic and ursolic acids, are responsible for the antidiabetic potential of this plant (Rehman et al., 2022). Triterpenoids and flavonoids give strength to the extract for its anticancer activity.

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The anticancer activity of the plant relies on the modulation of apoptotic pathway and inhibition of tumor cell proliferation (Sinan et al., 2020).

Multidisciplinary Significance of *Achyranthes aspera*

A. aspera is a plant of significant ethnomedicinal importance because of its diverse bioactive compounds that contribute to various biological activities. The plant has been found to contain chemical classes such as “alkaloids, flavonoids, saponins, tannins, and terpenoids” (Srivastav et al., 2011; Ganesh et al., 2013). *A. aspera* traditionally known as Apamarga is a well-known Ayurvedic medicinal plant as mentioned in ancient medicinal scriptures like Charaka Samhita and Sushruta Samhita (Jajili et al., 2020). Modern studies have also validated its pharmacological properties which supports the integration of traditional knowledge with sustainable biomedical and agricultural applications(Jadav et al., 2015; Pal et al., 2023).

- Biomedically, *A. aspera* exhibits hepatoprotective, and anticancer potentials. The occurrence of flavonoids, including quercetin and rutin, together with triterpenoids, such as oleanolic and ursolic acids, contributes to the antioxidant and anti-inflammatory characteristics of the plant (Sinan et al., 2020; Rehman et al., 2022). Such characteristics have made the plant effective in treating chronic diseases and metabolic disorders.
- The presence of several allelochemicals in *A. aspera* plant extracts suggests its diverse applications in agriculture which can be an ecofriendly approach towards nature, for example the use of extracts as an antifungal, insecticidal, and larvicidal uses in various agricrops(Safdar et al., 2021). Presence of saponins and tannins is involved in disruption of the membrane structure of microbes and pests (Baraik et al., 2014; Sharma et al., 2022).
- Horticulturally, the plant is commonly referred to as a weed, and consequently uprooted during sanitation processes, the biomass of the plant can be used for several research purposes (Tavares et al., 2021).

Therefore, *A. aspera* can be considered as a versatile bioresource.

Future Prospects

Regardless of many studies that have been conducted till date, there are some areas which need additional attention to explore all the potentials of *A. aspera*.

Clinical testing is important for establishing the safety and efficacy of these herbs. Future research efforts should focus on the formulation of standardized drugs. Moreover, it is worth considering the application of new delivery systems such as nanotechnology to improve their effectiveness.

The exploitation of this plant as an invaluable source for its medicinally active phytoconstituents will be an eco-friendly and sustainable approach because it grows abundantly as weed.

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The interdisciplinary aspects of this plant in agriculture and veterinary application can be another area worth exploring.

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