

A Comprehensive Review on Phytopharmacological Activities of *Drynaria quercifolia* L.

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ABSTRACT

Drynaria quercifolia belongs to the family of Polypodiaceae, is native to tropical areas of Africa, Asia, Australia and Oceania and cultivated mostly as a medicinal plant. It plays an important medical role in many countries, especially in Asia. The plant is used to treat various health problems and is known to have no side effects. Various phytochemicals like 3,4-dihydroxybenzoic acid, friedelin, epifriedelinol, β -amyrin, β -sitosterol and β -sitosterol 3- β -D-glucopyranoside has been isolated from the plant. The rhizome is reported to have anti-fertility, anti-inflammatory and antipyretic, antimicrobial, antioxidant, hepatoprotective, wound healing and antiulcer properties. This review has been designed to provide scientific information regarding phytochemical composition, medicinal uses and pharmacological potentials of *Drynaria quercifolia* L.

Keywords: *Drynaria quercifolia*, medicinal plant, phytochemical, pharmacological

INTRODUCTION

Medicinal plant is defined as any substance with one or more of its organ containing properties that can be used for therapeutic purpose or which used as precursor for the synthesis of various drugs¹. Over the years, medicinal plants have been found useful in the treatment and management of various health problems. In recent years, there has been an increasing interest by researchers in the use of naturally occurring biologically active compounds of medicinal value². Medicinal plants contain numerous phytoconstituents such as flavonoids, alkaloids, tannins, saponins, quinines, terpenoids, glycosides, polyphenols and fats and oils which are responsible for their pharmacological activities. A large number of medicinal plants remain to be investigated till date, for their possible pharmacological value. So there is need to search the medicinal plants which are multi beneficial activities. Fern comprise the largest group of pteridophyta, also known as vascular cryptogams and at present about 4000 species are known. These are generally most abundant in shady tropical forests although they are found in temperate regions also. Ferns are highest type of flowerless plants, having well developed vascular and tegumentary systems, and exhibiting a complete differentiation into root, stem and leaf. The leaves are large and compound and are known as fronds. Out of large assemblage of these highly ornamental plants, however, only some 10 to 12 are of interest from the economic or medicinal point of view³. *Drynaria quercifolia* is one of the medicinal fern, which has great medicinal value against various diseases. Hence in the present study, an attempt has been made to provide comprehensive information about the phytochemical and

pharmacological properties of *Drynaria quercifolia* and it can be used for further research work. *Drynaria* is a genus of ferns, can be either epiphytic (they grow on trees) or epipetric (they grow on rocks). They are known to have nectar-secreting structures, found at the base or the underside of the frond lobes. They produce nectar which is rich in amino acids and sugars. It is because of this, it plays an important economical role in many countries, especially in Asia. *Drynaria quercifolia* reproduces through spores, is not poisonous but is used frequently as a medicine in many cultures and has many medicinal purposes.

Common names

Oak – leaf fern or basket fern

Distribution

They are a terrestrial fern found among rocks in crevices, shelves or in the soil among boulders also epiphytic on tree trunks in open forests and rainforests. It is native to tropical areas of Africa, Asia, Australia, Oceania, Western Australia as well as India, Southeast Asia, Malaysia, Indonesia, the Philippines and New Guinea. It is cultivated and used in many Asian countries, such as China, Vietnam, Thailand and Taiwan.

Botanical Description

Leaves (fronds)

Basket ferns are characterized by the presence of two types of fronds, fertile foliage fronds and sterile nest fronds. The dark green foliage fronds are large, 2–4 feet (0.61–1.22 m) long, with elongated stalks. They are deeply lobed or pinnate, winged, and bear sori (structures producing and containing spores) on the bottom surfaces⁴. The nest fronds are smaller rounded leaves basal to the foliage fronds. They do not bear sori and are persistent, not being shed

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after turning brown and dying⁴. They form a characteristic 'basket' that collect litter and organic debris, hence the common name⁵. The collected debris decomposes into humus, providing the plants with nutrients it would otherwise not have received from being suspended above the ground^{6,7}. Both frond types grow from rhizomes typically anchored to a tree or a rock^{8,9}.

Rhizome

The Rhizomes are 2cm thick and wooly. The rhizomes of *Drynaria* are creeping and densely covered in brown scales⁴ and are 20-25mm long and 0.7-2.5mm wide and soft. Stipeses are winged at the base and lamina is not separated into distinct leaflets. Sori are round and circular in shape. Spores 37.5-55um long, 22.5-37.5um wide.

Habitat

In open forest, rainforest margins and in dry rainforest.

Partsutilized

Rhizomes and leaves.

Medicinal uses

Consumption of *Drynaria quercifolia* can help heal and strengthen broken bones. It can also be used to promote treatment of sprains, stress fractures, or weak loins and knees. It helps increase the bone density, prevents osteoporosis and promotes the healing of injured ligaments. On the hole, it is very good for bones

Tonic prepared from *Drynaria* is beneficial to liver and kidney

They can help to treat bleeding gums or toothaches, and regular consumption will strengthen teeth. It can also be used for tinnitus, a condition of the ears

Drynaria plants can be used topically as a hair tonic which stimulate hair growth and to improve hair condition. Mixed with the plant *Asparagus racemosus*, applied to the head for calming effect and to reduce hair loss

The whole plant of *Drynaria* was reported to be used against tuberculosis, hectic fever, and dyspepsia and cough¹⁰

The pounded fronds (leaves) were used as poultice over inflammatory regions¹¹

The macerated paste of rhizome was applied on fore head, relives headache¹²

The whole plant of *Drynaria* was used as anthelmintic, expectorant, pectoral in treatment of chest and skin diseases¹³

Tonic of the plant act astringent to the bowels during typhoid fever as per Ayurvedic concept, some medico folklore reports highlighted on it to be used against phthisis and hay fever¹⁴

It is used in traditional medicinal system by different groups of people to treat various kinds of health problems including urinary tract infection¹⁵.

In Ayurvedic system of medicine, it is called 'Ashwakatri' and it is used as pectoral, expectorant and anthelmintic agent. It is also used in the treatment of chest diseases, cough, and hectic fever, and dyspepsia, loss of appetite, chronic jaundice and cutaneous affections¹⁶.

In Tamil Nadu, used to treat arthritis

In Bangladesh, rhizomes used in the treatment of excited mental disorders

In South East Asia rhizome decoction of *Drynaria* uses as antipyretic preparation¹⁷

In Malasia, fronds are used as poultice on swelling¹⁸

In Tripura, the leaves and rhizome are used for the treatment of intestinal worms and abdominal pain¹⁹

In Vietnam, the rhizome is used for the treatment of tuberculosis¹⁸ rheumatism, osteodynia and dentagia²⁰

Pounded fronds are used as poultice for swellings. Peeled rhizome with sugar is prescribed for urinary disorders and in spermatorrhoea²¹.

Tribals in Kalakad Mundanthurai Tiger Reserve, India, used the rhizome of this fern to cure rheumatism²².

The rhizome of this fern is one of the twelve ingredients of a drug to treat cancer²³

Side Effects

Drynaria species are considered to be safe. There are no known side effects when it comes to consuming the plants.

ChemicalConstituents

Phytochemicals like phenols, tannins, alkaloids, proteins, xanthoproteins, carboxylic acid, coumarins and saponins. catechin, flavonoids, steroids, and triterpenes are present in *Drynaria quercifolia*. Dried rhizomes contain friedelin, epifriedelinol, beta-amyrin, beta-sitosterol, beta-sitosterol 3-Beta-D-glucopyranoside, 3, 4 di hydroxyl benzoic acid, acetyl lupeol, aglycone naringinin and flavones glycoside naringin.

Phytochemistry

The extracts of *Drynaria quercifolia* were subjected to preliminary phyto-chemical investigation. The proximate analysis was carried out for the plant rhizome powder. The total cash value was 9.93%, Acid insoluble ash value was 4.49%, and water-soluble ash value was 6.96% and extractive values of alcohol and water was found to be 9.87% and 13.94%. The materials were subjected to successive extraction with solvents. The solvents used were petroleum ether, chloroform, methanol and water in the ascending order of polarity. All the extract was subjected for qualitative chemical evaluation to detect the phyto-constituents present in them. Pet ether extract revealed the presence of phytosterols and fixed oils and fats. Chloroform extract revealed the presence of sterols, methanolic extract showed the presence of alkaloids, sterols and tannins and the water extract has shown the presence of tannins, proteins, amino acids, carbohydrates, gums and mucilages. To identify the constituents, present in different extracts, the TLC was performed²⁵. Padmaselvi et al., (2016) have studied the physicochemical, fluorescence, histochemical and phytochemical analysis of methanol extract of *Drynaria quercifolia* rhizome. In physicochemical analysis, parameters such as moisture content (3%) water soluble ash (6%) sulphated ash (5%) alcohol soluble extractive value (7%) and water soluble extractive value (9%) of plant were determined. In fluorescence analysis, different colours of fluorescent were observed under UV and visible light. The histochemical analysis indicates the presence of lignin, flavonoids, alkaloids and polyphenol based on colours. Quantitative phytochemical analysis revealed the significant amount of flavonoids (32.84 mg/g), saponin (32.74 mg/g), phenols (84.56 mg/g), tannins (45.23 mg/g) and alkaloids (6.38

mg/g)²⁶. Pharmacognostical parameters for the histological and physico-chemical standardization of *D. quercifolia* have been reported²⁷. The physico-chemical parameters were performed as per standard procedures of WHO guidelines on quality control methods for medicinal plant materials. Morpho anatomy, venation pattern, trichomes distribution, stomatal morphology, paradermal sections and powder microscopical examination of plant's leaf were studied by employing bright field light for the normal observations and polarized light for the study of crystals, starch grains, and lignified cells. Microscopic descriptions of tissues were supplemented with photographs of different magnifications employing Motic DMBA 300 microscopic unit. Additionally, reliable quantitative HPTLC and HPLC methods were successfully developed and validated as per ICH guidelines for the determination of marker phytochemical (naringin; a flavanone glycoside) in the plant material and formulations. The physico-chemical, anatomical parameters, and HPTLC & HPLC standardization may be proposed as parameters to establish the authenticity of *D. quercifolia* and further assist in standardization of plant viz., quality, purity, and sample identification. The bioactive compounds of *Drynaria quercifolia* were extracted using different solvents – ethanol, methanol, chloroform and petroleum ether. Preliminary screenings showed the presence of compounds like saponins, flavanoids, steroids, coumarin, tannins and terpenoids in ethanol extract. In methanol extract, saponins, steroids, coumarin, tannins and terpenoids were identified. Similarly, steroids, and tannins were identified in chloroform and petroleum ether extracts²⁸. Phenolic profiles and phytochemical screening of different extracts of *Drynaria quercifolia* leaves were carried out. The phytochemical screening revealed the potent source of different phytochemical constituents on different extractives including alkaloid, glycosides, tannin, saponins, proteins and amino acids, flavonoids, triterpenes, phenols, phytosterols and carbohydrate. In the determination of phenolic profiles, different extractives showed a significant content of phenolic compounds ranging from 103.43 -132.23 mg of GAE/g of extractive²⁹. Phytochemical analysis gave positive tests for catechin, coumarins, flavonoids, phenolics, saponin, steroids, tannins, and triterpenes. The total phenolics in DQ were 244 mg/g and naringin content was 0.048%³⁰. Preliminary phytochemical and GC-MS analysis of *Drynaria quercifolia* rhizome was studied. Methanolic extract showed the presence of phytoconstituents like alcohol, carbohydrates, phytosterols, phenols, tannins, flavonoids, proteins and aminoacids, steroids, saponins, cholinergic acids, glycosides, and resins. In GC-MS analysis, thirty compounds have been identified. Some of them found in high concentration which was identified by high peak values³¹. Ultraviolet-visible (UV-VIS) and Fourier transform-infrared (FT-IR) spectrum profile of rhizome of *Drynaria quercifolia* was investigated. The result of UV-VIS profile showed the peaks at 279 and 214 nm with the absorption 0.921 and 2.607, respectively. The result of FT-IR profile confirmed the presence of amines, alkanes, denatured amines, alkynes, carboxylic acids, alkenes,

alkanes and alkenes which shows the peaks at 3436, 2197, 2360, 2125, 1772, 1626, 1447 and 815, respectively³².

Reported in vitro pharmacological studies

Antimicrobial activity

Phytochemical and antimicrobial studies were carried out on *Drynaria quercifolia* rhizome. Friedelin, epifriedelinol, beta-amyrin, beta-sitosterol, beta-sitosterol 3-Beta-D-glucopyranoside, and naringin were isolated from the dried rhizome of *Drynaria quercifolia*. The methanol extract showed broad and concentration-dependent antibacterial activity³³. 3, 4-dihydroxybenzoic acid and acetyl lupeol were isolated from *Drynaria quercifolia* rhizome. In sub-acute toxicity studies, 3, 4-dihydroxybenzoic acid showed no significant effect in comparison to that of control group. In addition, acetyl lupeol was isolated from rhizome who's in vitro antibacterial activity was insignificant³⁴. Antibacterial activity of *Drynaria quercifolia* was studied against infectious disease causing bacterial pathogens such as *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Salmonella paratyphi A*, *Salmonella paratyphi B*, *Salmonella marscence*, *Staphylococcus aureus* and *Bacillus subtilis* by agar diffusion method. Six different organic solvents such as ethanol, methanol, petroleum ether, hexane, benzene and chloroform were used to screen the antibacterial activity. The ethanolic extract of *Drynaria quercifolia* was more effective against 80% of the organisms tested followed by methanolic extract (70%), benzene (50%) and chloroform extract (40%). Petroleum ether and hexane extract of *Drynaria quercifolia* did not show any antibacterial activity against any of the pathogenic bacteria tested³⁵. Anti-microbial activity of the whole plant *Drynaria quercifolia* was evaluated and the result of antimicrobial screening showed that ethyl acetate and carbon tetra chloride fractions exhibit mild anti-microbial activity³⁶. Muraleedharan nair et al., (2012)³⁷ have worked on the antibacterial activity of *Drynaria quercifolia* on clinically isolated Urinary Tract Infecting (UTI) bacteria by disc diffusion method. Among the six different extracts tested against eight different UTI bacteria, acetone extract was effective against *Enterococcus faecalis* and *Streptococcus pyogenes*, while ethanol extract was effective against *Pseudomonas aeruginosa*. Three different concentrations of methanol extract of *Drynaria quercifolia* (125, 250 and 500mg) were tested for antimicrobial activity using agar well diffusion method against two Gram-positive bacteria- *Bacillus subtilis*, *Staphylococcus aureus*; two Gram-negative bacteria - *Escherichia coli*, *Salmonella* sp and two fungal strains- *Microsporum gypseum*, *Trichophyton rubrum*. Zone of inhibition of extracts were compared with that of standard antibiotic like streptomycin for antibacterial activity and fluconazole for antifungal activity. The results showed the remarkable inhibition of the microbial growth of tested organisms in dose dependent manner³⁸. Ecofriendly activity of *Drynaria quercifolia* against bacterial and fungal species were studied. Bacterial species namely *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoneae*, *Escherichia coli* and *Bacillus subtilis*. Rhizome of *D. quercifolia* showed

Figure 1: *Drynaria quercifolia*Table 1: Scientific Classification and Vernacular Names of *Drynaria quercifolia*

Scientific Classification		Vernacular Names	
Kingdome	Plantae	Bengali	Pankhiraj, Pankha, Garur
Division	Filicophyta	Bangladesh	Fo lo rere, Chilo vasa
Class	Pteridopsida	Hindi	Asvakatri, Katikapan, Basingh
Order	Polypodiales	Malayalam	Matilpanna, Pannakizhangu, Pannikizangu
Family	Polypodiaceae	Tamil	Attukkal kizhangu
Genus	<i>Drynaria</i>	Sanskrit	Asvakatri
Species	<i>D. quercifolia</i>	Common Name	Oak (leaf fern or basket fern)

antibacterial activity against both gram positive and gram negative bacteria. MET showed high level of zone of inhibitions with *Klebsiella pneumonia* and *Escherichia coli* and AQ showed low level of inhibitions. However, fungus species showed resistance to AQ, DCM, MET and PET extract³⁹. Pargavi and Sivakumar, (2014) have studied antibacterial and antifungal activities of different solvents of ethanol, methanol and chloroform and petroleum ether extracts of *Drynaria quercifolia* were examined by disc diffusion method. Ethanol extract showed greater antibacterial and antifungal activity followed by methanol extract and others²⁸.

Anti dermatophytic activity

Anti dermatophytic activity of different extract of *Drynaria quercifolia* were evaluated using four different solvents such as ethanol, methanol, acetone, di-ethyl ether and water. Agar dilution and disc diffusion methods were used to screen the antidermatophytic activity against infectious disease causing pathogenic fungi such as *Trichophyton mentagrophytes*, *Microsporum canis*, *Microsporum gypseum*, *Trichoderma rubrum* and *Epidermophyton floccosum*. Di-ethyl ether with semi-polarity only gave clear zone to antifungal activity compounds. Also high performance thin layer chromatography studies confirmed that the ethyl acetate extracts of rhizome of *D. quercifolia* contains triterpenes and coumarins⁴⁰.

Antioxidant activity

Polyphenolic composition and antioxidant properties of methanol extract of rhizome of *Drynaria quercifolia* (L.) Sm. was evaluated. The extract yielded total phenolic content (TP) of 240 ± 0.01 mg gallic acid equivalents (GAE)/100g of fresh mass (FM) and total flavonoid content (TF) of 150 ± 0.02 mg quercetin equivalents

(QE)/100g of fresh mass (FM). The extract of *D. quercifolia* rhizome exhibited remarkable scavenging capacity towards DPPH, $\cdot\text{OH}$, NO, H_2O_2 and ABTS. The antioxidant capacities of the extract were comparable and stronger than that of the antioxidant standard, butyl hydroxy toluene (BHT). Significant and positive correlations were observed between polyphenolic contents and the antioxidant capacities, indicating that the phenolics were major contributors of the antioxidant property⁴¹ (Jinu et al., 2014). Both methanol (MEDQ) and aqueous (AEDQ) extracts of rhizome of *Drynaria quercifolia* exhibited antioxidant property against DPPH, super oxide radicals and reducing power activity. The maximum 95.972 μg Gallic acid equivalents total phenolic content and 81.03 μg Quercetin equivalent flavonoids content in MEDQ were estimated that was 20 fold (phenolic content) and 3 fold (flavonoids) more than AEDQ⁴². Anti-oxidant activities of the different fractions were assayed by the DPPH free radical scavenging activity. The ethyl acetate, carbon-tetrachloride fractions showed very potent antioxidant activity by the DPPH free radical scavenging method³⁶. Antioxidant activity of methanol extract of *Drynaria quercifolia* rhizome was studied at different concentrations (100, 200 and 300 $\mu\text{g}/\text{ml}$) in various *in vitro* models. Results were compared with standard ascorbic acid. Antioxidant activity of extract was increased with the increasing concentration. The order of antioxidant potential according to models were found to be highest in nitric oxide scavenging activity followed by total antioxidant activity, reducing power assay and hydrogen peroxide scavenging activity and IC_{50} values were found to be 180, 230, 230 and 240 $\mu\text{g}/\text{ml}$ respectively⁴³. Concentration dependent antioxidant effect was observed in methanoilc extract of *Drynaria quercifolia* rhizome in

DPPH radical scavenging assay and ferric reducing antioxidant power (FRAP) assay⁴⁴.

Anti-lipid peroxidative activity

In vitro anti-lipid peroxidative properties were investigated in ethanol extract of rhizomes of *D. quercifolia* (DQ), ethyl acetate extract (EDQ) and hexane extract (HDQ). The result showed significant reduction in FeCl₂-AA induced lipid peroxidation in rat liver *in vitro*. The High Performance Liquid Chromatography (HPLC) studies showed that naringin was found to be 1.6% in EDQ. Naringenin was found to be 0.53% in DQ and 0.15% in EDQ. The total phenolic content was found to be very high, DQ 244mg/g and EDQ 416mg/g equivalent of gallic acid⁴⁵.

Anti-inflammatory activity

In vitro anti-inflammatory activity of the methanolic extract of *Drynaria quercifolia* rhizome was investigated by Human Red Blood Cell (HRBC) Membrane stabilization method. Different concentration (100, 200 and 300 mcg) of rhizome extract were used and the potency of extract was compared with standard Diclofenac (100, 200 and 300 mcg). Plant extract exhibited notable anti-inflammatory activity in a dose dependent manner. The maximum membrane stabilization was found to be 34.94% for plant extract and 41.62% for standard diclofenac at a dose of 300 mcg⁴⁶.

Hepatoprotective activity

Devika and Prasanna (2016) had studied the *in vitro* hepatoprotective activity of methanol rhizome extract of *Drynaria quercifolia* L. For cytotoxicity screening, primary hepatocytes monolayer cultures were treated with CCl₄ and different concentrations (100, 250, 500µg/ml) of extracts of *Drynaria quercifolia* L. rhizome. Protection against CCl₄ was determined by MTT assay. The result showed that dose dependent increase in percentage of viability at the doses of 100, 250, 500µg/ml against CCl₄. CCl₄ induced cell damage was well manifested by significant increase of MDA, SGOT, and SGPT and decrease of GSH and protein. Plant extracts along with CCl₄ treated hepatocytes reversed all the above parameters near to normal which showed the hepatoprotective activity of *Drynaria quercifolia*⁴⁷.

Thrombolytic activity

Ramjan Ali *et al.*, (2014) have studied *in vitro* thrombolytic activity of *Drynaria quercifolia*. Aqueous soluble fraction and pet-ether soluble fraction of *D. quercifolia* exhibited highest thrombolytic activity by clot lysis of 34.38% and 34.27% respectively. And also *D. quercifolia* showed significant percentage (%) of clot lysis compared to standard streptokinase (41.05%) while the negative control water revealed 3.31 % lysis of clot⁴⁸.

Mosquito repellent activity

Mosquito repellent activity of *Drynaria quercifolia* L. Smith was evaluated against adult female mosquitoes. Experiments were conducted for checking mosquito repellency of the rhizome of *D. quercifolia* and extracts exhibit high repellent (as high as 90 100%) to adult mosquito species *C. quinque fasciatus* and *Aedes aegypti* with increase in concentration of (160, 170, 180 mg) of AQ, DCM, MET. PET 500 ppm extracts concentration of

rhizome showed significant decrease in the larva population of same spp. as compared to other three extracts namely DCM, MET and PET. PET extract is very effective and it showed the 'Knock down' effect within 20 min at 160 mg⁴⁹.



Figure 2: Activity exhibited by *Drynaria quercifolia*



Figure 3: Pharmacological Activities reported by *Drynaria quercifolia*

Pesticidal & pest repellent activities

Khan *et al.*, (2014)⁵⁰ have reported the pesticidal and pest repellency activities of rhizome of *Drynaria quercifolia* (J. Smith) against *Tribolium castaneum* (Herbst) which is a harmful pest of stored grain and flour-based products, using surface film method and filter paper disc method respectively. In addition, activity of the isolated compound 3, 4-dihydroxybenzoic acid was evaluated against the pest. Chloroform soluble fraction of ethanol extract of rhizome of *D. quercifolia* showed significant pesticidal activity at doses 0.88 to 1.77 mg/cm and significant pest repellency activity at doses 0.94 to 0.23 mg/cm. No pesticide and pest repellency activity was found for petroleum ether, ethyl

acetate and methanol soluble fractions of ethanol extract as well as for 3, 4-dihydroxybenzoic acid.

In vivo pharmacological activities

Anti-inflammatory activity

Anuja *et al.*, (2010)³⁰ have worked on anti-inflammatory property of the ethanolic extract of rhizome of *Drynaria quercifolia* (DQ) and its phytochemical profile. Oral administration of DQ produced significant inhibition of carrageenan-induced paw oedema and granuloma formation in rats, almost comparable to that caused by indomethacin. Anuja *et al.*, (2014)⁴⁵ have also reported the anti oedematous and anti-proliferative properties of the ethanolic extract of fertile fronds of *Drynaria quercifolia* (FF) by using standard procedures. Oral administration of FF produced significant inhibition of carrageenan and histamine induced paw oedema in Wistar rats. FF significantly reduced both wet weight and dry weight of granuloma tissue which shows the inhibitory effect on exudative and proliferative phases of inflammation. Banani Das *et al.*, (2014)⁴² have studied the anti-inflammatory activity of rhizome of *Drynaria quercifolia*. Both methanol (MEDQ) and aqueous (AEDQ) extracts showed significant inhibition of rat paw edema in dose dependent manner and the MEDQ was the most active. Different concentration of rhizome extract (100, 250, 500 mg/ kg), were analyzed for anti-inflammatory response in carrageenan-induced paw odema. Among the three concentrations, dose of 500 mg showed a maximum inhibition on carrageenan-induced rat paw oedema⁵¹.

Analgesic activity

Methanolic crude extracts of *Drynaria quercifolia* rhizome and its different solvent soluble fractions were screened for possible anti-nociceptive activities in experimental Swiss-albino mice by acetic acid induced writhing inhibition and radiant heat tail-flick methods. In peripheral method of anti-nociception, the methanolic crude extract (400 mg/kg) and carbon tetrachloride fraction (400 mg/kg) of *D. quercifolia* showed significant anti-nociceptive activity compared to standard diclofenac (51.68 % inhibition). The aqueous soluble fraction of the extract (400 mg/kg) also showed promising anti-nociceptive activity in the radiant heat tail-flick method of central anti-nociception, the methanolic crude extract (400 mg/kg) and petroleum ether fraction (400 mg/kg) of *D. quercifolia* showed significant analgesic activity. The carbon tetrachloride fraction (400 mg/ kg) also demonstrated potent analgesic activity (51.14% elongation)⁵². Analgesic activity of ethanolic extract of rhizome of *Drynaria quercifolia* (DQ) was also studied³⁰ by Anuja *et al.*, (2010). DQ significantly attenuated acute and delayed phases of formalin-induced pain and acetic acid-induced writhing episodes in mice. The analgesia was comparable to that produced by sodium salicylate and aspirin respectively. Fertile fronds of *Drynaria quercifolia* (FF) significantly attenuated acute and delayed phases of formalin induced pain, acetic acid-induced writhing, capsaicin-induced nociception, and hot plate test in mice⁴⁵. Oral administration of DQ/EDQ/HDQ of rhizomes of *D. quercifolia* produced significant inhibition of capsaicin and glutamate induced nociception

in mice, offered significant protection in tail flick and tail immersion tests in Wistar rats⁴⁵.

Antipyretic activity

Methanolic extract of *Drynaria quercifolia* rhizome (100, 250, 500 mg/ kg) was investigated for antipyretic activity on brewer's yeast-induced pyrexia in rats. The results revealed 500mg of plant extract exhibited remarkable antipyretic activity by decreasing the rectal temperature of rats in various time intervals⁵¹. Intraperitoneal (i.p.) administration of petroleum ether and ethyl acetate soluble fractions of ethanol extract of the rhizome of *D. quercifolia* at a dose of 80 mg/kg body weight were shown to significantly reduce the elevated body temperature which was induced by intraperitoneal administration of boiled milk at a dose of 0.5 mL/kg body weight of rabbit. Antipyretic activity was compared with standard aspirin and solvent used⁵³.

Hepatoprotective activity

Pradeep Kamboj and Ajudhia Nath Kalia (2013)⁵⁴ have reported the hepatoprotective effect of hydroalcoholic extract of *Drynaria quercifolia* fronds (Dq), its fractions and isolated compound (Dq-4) from ethyl acetate (EA) fraction. The toxicant CCl₄ (1ml/kg) was administered on 4th and 5th day to induce hepatotoxicity in Wistar rats (in-vivo) and the *in-vitro* hepatoprotection was evaluated against CCl₄ (1%) induced toxicity in HepG2 cellines. The pre-treatment of rats with Dq extract, EA fraction and Dq-4 for 7 days produced a significant dose dependent hepatoprotective action by decreased levels of hepatic enzymes, total bilirubin and TBARS and increased levels of total proteins, albumin, and reduced glutathione. The histological examination provided the supportive evidences. Additionally, Dq extract, EA fraction and Dq-4 significantly decreased the CCl₄-induced in-vitro toxicity in HepG2 cell lines evident by MTT reduction assay and trypan blue method.

Anti-allergic activity

In vivo anti-allergic property of the ethanol extract of rhizomes of *D. quercifolia* (DQ), ethyl acetate extract (EDQ) and hexane extract (HDQ) have been reported. Oral administration of DQ/EDQ/HDQ extracts significantly attenuated degranulation of peritoneal mast cells of Swiss albino mice⁴⁵.

Neuropharmacological activity

The neuropharmacological effect of the rhizome of *Drynaria quercifolia* J. Smith was performed by Alam Khan *et al.*, (2009)⁵⁵. 50, 100 and 200 mg/kg b wt of petroleum ether and ethyl acetate soluble fractions of ethanol extract was administered (IP) in Albino mice. The tests used were determination of effect on duration of diazepam-induced sleep, determination of effect on nikethamide-induced toxicity, light-dark test and force swimming test. The duration of diazepam-induced sleep was extended by administration of the above fractions. Nikethamide at high dose cause death of mice and time to cause death of mice was delayed by administration of these fractions. In light-dark test and force swimming test, these fractions were given diazepam type effect. The changes in doses (50-200 mg/kg) showed changes in efficiency of these effects.

Anti-ulcer activity

Anti-ulcer activity of ethanol extract of leaves of *Drynaria quercifolia* Linn (250 and 500 mg/kg body weight p.o) was evaluated against pylorus ligation and ethanol induced ulcer models in experimental rats. The Aqueous extract of *Drynaria quercifolia* showed significant ($P < 0.05$) reduction in gastric volume, free acidity and ulcer index as compared to control thus showed the anti-secretory mechanism. Ranitidine as reference standard drug to compare the antiulcer activity of plant extract. The results suggest that the extract was found to possess anti ulcerogenic as well as ulcer healing properties, which might be due to its anti-secretory activity⁵⁶.

Anti-diabetic and hypolipidemic activity

Rajimol et al (2014)⁵⁷ have studied the anti-diabetic and hypo lipidemic potential of *Drynaria quercifolia* rhizome in streptozotocin induced diabetic rats. 400mg/kg of ethanolic and chloroform extract were used for the antidiabetic and hypolipidemic studies. Glibenclamide (5mg/kg) was used as reference standard for the activity comparison. Diabetes mellitus was induced in overnight fasted adult Wistar albino rats by single intra peritoneal injection of freshly prepared STZ at a dose of 40 mg/kg. High fasting blood glucose level indicated the induction of diabetes. Both plant extracts treated groups showed extremely significant decrease in blood glucose level when compared with diabetic control rats. Also, the levels of plasma total cholesterol (TC), triglycerides (TG) and low density lipoprotein (LDL-C) were significantly increased, whereas levels of high density lipoprotein (HDL-C) were significantly decreased in diabetic rats as compared to control rats. Administration of test extracts to diabetic rats, reversed glucose and lipid profile near normal values showed that anti diabetic and hypo lipidemic activity of plant extract. Histopathological study also revealed the above findings.

Wound healing activity

Wound healing potential of *Drynaria quercifolia* Linn. rhizome (methanolic and chloroform) was investigated in normal and diabetic induced rats. Excision and incision wounds were induced in normal and diabetic rats. 5% and 10% extracts dosage form in ointment base using standard pharmaceutical treatise, were applied and examined for the efficacy. Control groups were dressed with simple ointment base and sterile distilled water while standard groups were applied with Neosporin in normal and Mupirocin/ Supirocin ointment in diabetes induced rats. Healing versus microbial infection was studied and assessed with measurement of wound size contraction, epithelization time, leukocyte counting, isolation and identification of the micro flora in the wounds etc. Both extracts (10%) were found to have significant healing potential evident from reduction in wound size, epithelization time⁵⁸.

Anti-Urolithiatic activity

Anti-Urolithiatic activity of different extracts of (pet ether, chloroform, alcoholic and water) *Drynaria quercifolia* was studied against calcium oxalate crystals in male wistar strain rats. Among the extracts, alcoholic extracts of plants

parts were effective and it significantly reduced the level of calcium and oxalate⁵⁹.

Acute toxicity study

Acute toxicity study of *Drynaria quercifolia* rhizome was studied in albino rats. Crude extracts of *Drynaria quercifolia* rhizome were administered orally. After subsequent administration of the drugs, animals were observed closely for first 2 hours for any toxic manifestations like motor activity, salivation, coma and death. Subsequent observations were made at regular intervals of 24 hours. Animals were under further observation up to a period of 4 weeks. It was found that the extracts did not show mortality at the dose of 2000 mg/kg body weight. Therefore, 2000 mg/kg dose was considered as ALD50. Common side effects such as, mild diarrhea, loss of weight and depression in treated group of animals were not recorded within 7 days of observation. In the acute skin irritation study, no sign of oedema and erythma were found during week days of observation too⁵⁸. Acute toxicity study of the isolated compound from *Drynaria quercifolia*, 3, 4-dihydroxybenzoic acid was investigated on albino mice. 300 µg of 3, 4-dihydroxybenzoic acid was administered daily for 14 consecutive days. After the experimental period, haematological, biochemical parameters were analyzed. Histopathological studies of liver, kidney, heart, lung and spleen were also performed. Insignificant adverse effects were observed from the result. In histopathological studies, no abnormalities were detected in the organs. The results of sub-acute toxicity studies indicate its safety for clinical trial³⁴.

In vitro propagation study

In vitro propagation study of *Drynaria quercifolia* was carried out in order to conserve the species in situ. The spores were found to germinate only on MS-Z4 medium (Full MS+1mg/L IAA+5mg/L Kinetin+20% CM+300mg/L CH). All other media used failed to produce prothallus. After inoculation, it took about 30 days to germinate. After development of the Prothallus and subsequent development sporophytes, the plantlets were transferred in different media but the best growth was observed in PNT-2 media (Full strength Parker and Thompson +5mg/L IAA+2mg/L Kinetin) where proliferation of vegetative fronds and rhizome were recorded⁶⁰.

CONCLUSION

Drynaria quercifolia as a multipurpose medicinal agent and it poses a remarkable activity for curing of many diseases. Several pharmacological investigations have been done both *in vitro* activities such as antimicrobial, antioxidant, mosquito repellent, pesticidal and thrombolytic activity etc. and *in vivo* on the activities such as anti-inflammatory, anti-pyretic, analgesic, hepato protective, anti-ulcer, anti-diabetic and hypolipidemic etc. In future, an attempt will make in the area of isolation and standardization of phytoconstituents and their pharmacological activities using scientific experimental animal models and clinical trials to understand exact molecular mechanism of action of isolated compounds.

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