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Dodonaea viscosa Jacq: Multi potential therapeutic agent for human health - A review

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The review's objective was to provide a comprehensive summary of the medicinal plant *Dodonaea viscosa* Jacq, which has been used for therapeutic purposes to treat various communicable and non-communicable diseases. Medicinal plants are a valuable resource in traditional medicine or cultural practices worldwide. Micro and macro bioactive compounds from medicinal plants have been employed to control various diseases. Despite the advances in treatment, the prevalence of infectious diseases is continuing to increase the mortality rate due to the emergence of antibiotic-resistant pathogens. The *D. viscosa* parts of the plant, or on the whole, have been used to treat various human ailments. In recent years, several medicinal plants, including *D. viscosa*, have been used to treat cancer due to their rich anticarcinogenic and anti-chemoprotective properties. In this review, we focused *D. viscosa* bioactive compounds' effect on various biological activities such as antimicrobial, antibiofilm, antioxidant, cytotoxicity, anticancer, antiulcer, wound healing, anti-inflammatory, antidiabetic, and anti-fertility activity. We conducted an extensive bibliographic review of peer-reviewed publications to update this review. This review provides an overview of *D. viscosa* and its bioactive compounds, which can treat various human diseases without side effects.

Keywords: Antimicrobial activity, *D. viscosa*, Diseases, Extracts, Medicinal plants, Treatment

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Introduction

Dodonaea viscosa Jacq is a shrub, flowering plant, and rarely a small tree with erect twiggy branches belonging to the Sapindaceae family (Fig. 1), which comprises 150 genera and 2000 species[1-2]. This plant is popularly known as Aliar and Vilayatimehandi in India and is available throughout India[3]. *D. viscosa* origin is believed to be Australia. Still, it exists throughout the tropics and subtropics and is widely distributed in temperate regions like Australia, Africa, Mexico, New Zealand, India, Northern Mariana Islands, Virginia Islands, South America, and parts of America[4]. The field of herbal medicine has steadily grown over the last few decades. Due to its natural origin and minimal adverse effects, it has become more prevalent in developed and developing nations[5]. Approximately 75% of the world's population uses medicinal plants for treatment and prevention[6].

Secondary metabolites found in plants are a valuable resource for therapeutic purposes[6]. The *D. viscosa*, a medicinal plant, is being utilized to treat multiple diseases in humans since it contains alkaloids, flavonoids, fixed oil, steroids, phenolics, saponins, tannins, gums, mucilages, carbohydrates, reducing sugar, glycosides and trace elements[7]. Further, *D. viscosa* is effective as an antidiabetic, antimicrobial, insecticidal, antioxidant, cytotoxic, anti-fertility, anti-inflammatory, analgesic, antiulcer, antispasmodic, antidiarrheal, detoxification agent[6], also to treat rheumatism, gout, haemorrhoids, fractures, and snakebites[8]. In recent years, there has been a rise in interest in traditional herbal remedies, their biological properties, and the use of natural ingredients in drug discovery[9].

Different *D. viscosa* bioactive compounds demonstrated various biological activities; the quercetin compound has bactericidal activity[10], flavone has antifungal[11], and clerodane diterpenoids control Human influenza A virus[12-14]. Furthermore, flavone inhibited biofilm formation in *Streptococcus* sp[15], *D. viscosa* newly isolated compounds 3,3′,4′,5,7-pentahydroxyflavane (1) and 4-methoxylstigmasterol (2) showed significant antioxidant activity[16]. Carbon

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Fig. 1 — *Dodonaea viscosa* whole plant with flowering stage.

alkylated flavonoids act as a potential antiulcer therapeutic agent[1]. Flavonoids and quercetin have wound healing activity[17], labdane type diterpenes and flavones showed anti-inflammatory activity[18], quercetin significantly reduced blood glucose, serum insulin, and lipid profiles and improved considerably glucose tolerance[19], A viscosine molecule showed antipyretic activity[20]. Our review aims to highlight the pharmacological applications and biochemical components of *D. viscosa* for treating human diseases.

Antimicrobial activity

Different *D. viscosa* extracts and metabolites were used to check against bacterial, fungal, and viral pathogens. The other pathogens are causing various infections or diseases in humans; few examples are *Staphylococcus* sp. (skin lesions, osteomyelitis, endocarditis), *Streptococcus* sp. (pharyngitis, scarlet fever, cellulitis, acute rheumatic fever, and acute glomerulonephritis), *Mycobacterium* sp. (tuberculosis, airborne respiratory disease), *Micrococcus luteus* (bacteremia, endocarditis, ventriculitis, peritonitis, pneumonia, septic arthritis), *Escherichia coli* (diarrhoea, urinary tract infections, pneumonia), *Pseudomonas* sp. (endocarditis, pneumonia, urinary tract infection, central nervous system, wounds, eyes, skin), *Corynebacterium diphtheria* (tonsils, nasal mucosa, larynx, pharynx, skin, eye conjunctiva and vagina), *Vibrio cholerae* (vibriosis, cholera).

Different fungal pathogens and diseases such as *Candida* sp. (skin, vagina, mouth, urinary tract infection), *Aspergillus* sp. (lungs, respiratory system, bronchopulmonary), *Paecilomyces varioti* (fungemia, endocarditis, peritonitis), *Microsporum gypseum* (dermatitis), and *Trichophyton rubrum* (skin, nail, jock itch, and ringworm). Human influenza A virus (fever, chills, muscle aches, cough, congestion, runny nose, headaches, and fatigue), Rotavirus SA-11 (vomiting, diarrhoea), and coxsackievirus B3 (polio and hepatitis) were described.

Plant bioactive compounds possess different levels of antimicrobial activity against other pathogens. The extracts from various plant parts showed minimal activity against various human pathogenic bacteria[21]. Antimicrobial activity of water, methanol, ethanol, and ethyl acetate of *D. viscosa* var. *angustifolia* leaf extracts exhibited enhanced action against *Staphylococcus aureus* and *Mycobacterium smegmalis* with MIC 2.5 mg/mL and 1.25 mg/mL respectively[3]. Further, crude ethanolic, n-hexane, dichloromethane, ethyl acetate, n-butanol, and water extracts of *D. viscosa* inhibited the growth of *S. aureus, Micrococcus luteus*, *Escherichia coli* and *Pseudomonas aeruginosa*[22]. The *D. viscosa* methanol leaf extract inhibited *Staphylococcus aureus, Streptococcus pyogenes*, and *Corynebacterium diphtheria*[23]. A mixture of methanol extract of *Agathosma crenulata*, *D. viscosa* and *Eucalyptus globulus* showed effective antibacterial activity[24]. All parts of *D. viscosa* methanol extract, particularly from stem extracts, effectively inhibited *Vibrio cholerae*[25].

Leaf extracts from *D. viscosa* effectively stopped the growth of human pathogenic *Streptococcus* species with an inhibition range of 4-11 mm; on the other hand, the development of different human pathogens was inhibited by 2-11 mm[26]. The ethanolic extract of *D. viscosa* and *Juniperus procera* fractions, namely JM and DC, showed good antimicrobial action[27]. However, *D. viscosa* chloroform extract also showed the highest antimicrobial activities[28]. The leaves, seed, and aerial part of *D. viscosa* were tested against resistant *Staphylococcus* isolates, and both extracts showed inhibitory zones ranging from 12.5 mm to 30.5 mm[29]. A quercetin derivative isolated from *D. angustifolia* showed broad-spectrum bactericidal activity against gram-positive and gram-negative bacteria[10]. Furthermore, common bacterial pathogens and unicellular fungi were inhibited by a flavone from *D. viscosa* var *angustifolia*[11].

The screening of *D. viscosa* methanol and chloroform extract against *S. typhi*, *S. flexneri*, *E. coli*, *V. cholerae*, *M. tuberculosis*, *P. fluorescens* showed growth inhibition zone found in 80% methanol and 20% chloroform extracts[30]. Furthermore, *D. viscosa* leaf methanol and n-hexane extracts were tested against several gram-positive and gram-negative bacterial strain[31].

The hydroalcoholic extract of *D. viscosa* leaf was tested against *Candida albicans*, and every fraction showed anticandidal activity with 10 mm inhibition[32]. In addition, *D. viscosa* leaves and shoot ethanol, methanol, ethyl acetate, chloroform, and water extracts showed activity against skin diseases causing *Aspergillus niger, A. flavus, Paecilomyces varioti, Microsporum gypseum,* and *Trichophyton rubrum,* however, chloroform extract showing overall strong inhibition[33].

Human influenza A virus (H3N2) is controlled by *D. viscosa* clerodane diterpenoids[12]. Rotavirus SA-11 (RV SA-11) and coxackievirus B3 (CVB3) were inhibited by several extracts from *D. viscosa* leaves[13]. Petroleum ether was used to make the most potent *D. viscosa* anti-HIV-1 extract; the antiviral effects could be attributed to the presence of β-sitosterol and stigmasterol[14]. In addition, *D. viscosa* leaf methanol extract demonstrated antiviral efficacy against the influenza A virus and the Coxsackievirus B325. A compound flavone-5,6,8-trihydroxy-7- methoxy-2-(4-methoxyphenyl)-4H-chromen-4-oneisolated from *Dodonaea* var. *angustifolia* demonstrated antimicrobial activity[11]. The antimicrobial activity of various extracts of *D. viscosa* demonstrated potential pathogenic suppression activity against disease-causing pathogens.

Antibiofilm activity

A biofilm is a community of bacteria colonizing a surface and acting as a multicellular organism. The biofilm matrix comprises proteins (fibrin), polysaccharides (alginate), and eDNA. The matrix and bacterial biofilms' protection help evade the host defense[34]. Biofilms act as an interactive community rather than free-living planktonic cells; thus, 65% of human bacterial infections involve biofilms. Biofilm has been linked to urinary tract infections, ear, sinuses, cystic fibrosis, indwelling catheters, chronic wounds, and periodontal disease[35]. The active chemicals in medicinal plants can prevent pathogens from forming biofilms.

Many attempts were made using plant metabolites to prevent biofilm formation. The *D. viscosa* var. *angustifolia* extract inhibits the production of germ tubes and biofilms through cell wall destruction of *Candida albicans*. In addition, the scanning electron microscopy observation showed a decrease in biofilm, hyphae development, cell wall, and membrane damage dependent on drug concentration[36]. The antibiofilm activities of *D. viscosa* leaves at different concentrations were tested against *E. coli*, and significant inhibition was recorded. The extract from *D. viscosa* leaves demonstrated broad-spectrum antibiofilm activity against *E. coli*[37]. At six-hour incubation, the growth inhibition effect of *D. viscosa* var. *angustifolia* (DVA) leaves extract was observed against *Streptococcus mutans*, killing 48% even at 0.1 mg/mL and 100% at 25 mg/mL[38]. Antibiofilm activity of a flavone (5,6,8-trihydroxy7-methoxy-2-(4-methoxyphenyl)-4H-chromen-4-one) obtained from *D. viscosa* var. *angustifolia* inhibited biofilm formation in *S. mutans*[15]. Studies on *D. viscosa* have demonstrated that extracts rich in flavonoids can prevent the production of biofilms in a variety of bacterial species.

Antioxidant activity

Radicals can react indiscriminately, damaging nearly every cellular component in the process. Antioxidants prevent free radical-induced tissue damage by preventing the formation of radicals, scavenging them, or promoting their decomposition[39]. Antioxidants can reduce oxidative stress and show promise in treating several human diseases like cancer, ageing, cardiovascular diseases, autoimmune disorders, inflammatory diseases, atherosclerosis, chronic renal failure, and diabetes mellitus[40].

Many researchers used various *in vitro* methods to assess the antioxidant activity of *D. viscosa* preparations[41]. The majority of research indicated that the methanol extract had the highest level of antioxidant activity. However, hexane and chloroform extracts also showed antioxidant activity[42]. Polyphenols are the primary plant components that exhibit antioxidant activity, as polyphenols are credited with possessing redox properties[43]; by inhibiting the acetylcholinesterase enzyme, antioxidants can slow the progression of Alzheimer's disease and limit neuronal damage[44]. Superoxide anion radical scavenging (O_2), CUPRAC, DPPH radical scavenging, ABTS cation radical scavenging, β-carotene-linoleic acid, and metal chelating techniques were used to assess the antioxidant activity of diterpenes (1, 2 and 1A) and phenolics (3-6 and 3A)

isolated from *D. viscosa*[45]. In the DPPH experiment, the methanolic extract of *D. viscosa* demonstrated a significant level of free radical scavenging and a notable antioxidant (50%) impact at low concentrations of 50 µg/mL. This suggests that it has a protective potential against various diseases, including cancer, heart disease, and arteriosclerosis[46].

The *D. viscosa* var. *angustifolia* leaf extract's antioxidant activity evaluation showed that its polysaccharide offers strong protection against hydroxyl and DPPH radicals and could be studied as a nutraceutical agent[47]. The aerial portions of *D. viscosa* were used to isolate clerodane diterpenoids (1 and 2), phenolics (3-6), and three crystals (1A, 3A, and 7A). Compound 3A was shown vigorous antioxidant activity in DPPH (IC_{50} of 27.44 µM), superoxide (28.18% inhibition at 100 µM), and CUPRAC ($A_{0.5.}$ 35.89 µM)[45]. In contrast, *D. viscosa* flower extract had the lowest IC_{50} in the hydroxyl radical scavenging experiment (19 mg/g dry weight) and hydrogen peroxide assay (11.37 mg/g dry weight), performing ascorbic and gallic acid[48]. *D. viscosa* showed highly effective free radical scavenging at 50 µg/mL. At 1000 µg/mL, the concentration-dependent increase in free radical scavenging activity reached 92.45%[46]. Teffo *et al.*,[23] studied the antioxidant activity of compounds (3,5,7-Trihydroxy-4′-methoxyflavone and kaempferol) from leaves of *D. viscosa* by DPPH (2,2-diphenyl-1-picrylhydrazyl) method which shows significant antioxidant activity. In addition, 3,3′,4′,5,7-pentahydroxyflavone and 4-methoxy stigma sterol were isolated from *D. viscosa,* showing potent antioxidant activity by the DPPH method compared to the reference gallic acid[16].

Cytotoxicity and anticancer activity

A cytotoxic compound can cause cell damage or death through necrosis or apoptosis, whereas cancer is a complex interaction involving a variety of target molecules. Cancer causes morbidity and mortality in millions of people worldwide[49]. Natural products have been studied for a long time, found to have pharmacologic activity, and proved to be safe with long-term exposure[50]. Some plant-extracted products are currently available on the pharmaceutical market as antioxidants or scavengers[49].

In an *in vitro* study, synthetic AuNPs made from *D. viscosa* leaf methanol extract reduced the proliferation of A549 NSCLC cells with IC_{50} values of 4.0 µg/mL[51]. Different fractions in the ethanol extract of *D. viscosa* leaves had a significant inhibitory effect on the growth of human colon cancer cells (HT-29). However, *D. viscosa* had a negligible cytotoxic effect on HT-29 tumour cells compared to 5 FU and no discernible cytotoxic effect on mouse epidermal cells (3T3)[52]. The *D. viscosa* aqueous leaf extract exhibited toxicological effects in albino rats; in sub-acute toxicity tests on total protein, unconjugated bilirubin, albumin, globulin, aspartate aminotransferase, and alanine aminotransferase activities[53]. Dodoneasides A and B compounds from *D. viscosa* ethanol extraction were tested for their ability to inhibit human ovarian cancer cell line A2780 growth[54]. Furthermore, *D. viscosa* purified fractions exhibited prominent anticancer activities on A549 NSCLC cells by MTT assays also provided strong evidence for this activity[55].

The MTT cytotoxicity test was used to investigate the antiproliferative impact of *D. viscosa* Dv12 and Dv20 fraction compounds on A549 human lung adenocarcinoma cells at varying drug concentrations of 5 µg to 33 µg. At 48 hours after being exposed to Dv12 and Dv20 fraction compounds, A549 cells exhibited dose-dependent reduction of cell growth[26], when *D. viscosa* extracts were tested on the MCF7 breast carcinoma cell line, the results revealed that the 80% ethanolic extract of *D. viscosa* exhibited potent cytotoxic activity, with an IC_{50} of 19.4 µg/mL, in contrast to the IC_{50} of 5.48 µg/mL for the standard drug, cisplatin[48]. The *in vivo* toxicological assessment of *D. viscosa* extracts on zebrafish revealed that they were harmful to the growth and survival of the embryo. Crude extracts of *D. viscosa* were found to be highly poisonous and have teratogenic effects on zebrafish embryos[56].

In recent decades, cancer has become a high prevalence worldwide due to genetic and food factors. Nowadays, plant-derived molecules are gaining momentum against cancer diseases. Cytotoxic and antiproliferative activity was observed in both SW480 and SW620 cancer cells after exposure to *D. viscosa* hydroethanolic extract, significant alterations in the mitochondrial membrane and an increase in apoptotic activity were seen in the metastatic derivative cell line (SW620)[57]. In mouse B16-F10 melanoma cells, Dodoviscin an isolated aerial portion of *D. viscosa* suppresses melanogenesis[58]. Additionally, the ethanolic extract fractions of *J. procera* and *D. viscosa* revealed that two fractions of DC and JM showed encouraging anticancer properties[27]. Kaempferol, a known flavonoid from *D. viscosa* was investigated for

the blockage of apoptotic cell death and thus gives its use in cancer therapy[59]. Naringenin reported from *D. viscosa* to exert anticancer effects in breast (MDA-MB-231), hepatocellular (HepG2), mammary tumour (E0771), and prostate (PC3, LNCaP) cancer cells by arresting the cell cycle and inducing apoptosis. It also causes suppression of melanoma SK-MEL-28 cells by inhibiting ERK1/2 and JNK MAPKs' phosphorylation[60]. Eriodictyol exerts antiproliferation and anti-metastasis in brain tumour cells by blocking signalling pathways (NF-kB, PI3K) and induction of apoptosis[61].

Antiulcer activity

The *D. viscosa* leaves ethanol extract has flavonoids, tannins, sterols and phenols exhibited good antiulcer activity in gastric ulcer models[62]. Similarly, ethanolic leaf extract of *D. viscosa* reduced gastric juice's ulcer index, volume, free, and total acidities[63]. The ethyl acetate extract of *D. viscosa* showed a lowering of alkaline phosphatase activity, increased serum calcium, and a greater ulcerative lesion index. The gastroprotective effect of *D. viscosa* water and ethanol extract was not as strong as hexane extract[64]. According to Al-Snafi[6], hexane extract of *D. viscosa* reduced ethanol-induced stomach lesions in a dose-dependent manner, resulting in 90% protection at 500 mg/kg, 81% protection at 250 mg/kg and 70% protection at 125 mg/kg.

Additionally, the gastroprotective activity of *D. viscosa* was investigated in Wistar rats using two distinct models (ethanol and indomethacin-induced stomach ulcer). According to Arun and Asha[62], indomethacin produced stomach lesions that resulted in 92% protection at 500 mg/kg, 77% protection at 250 mg/kg and 52% protection at 125 mg/kg. Carbon alkylated flavonoids isolated from the real parts of *D. viscosa* act as a potential antiulcer therapeutic agent[1].

Wound healing activity

A wound is characterized by losing or disrupting live tissue's cellular, anatomical, or functional continuity[65]. Medicinal plant extract and active compounds have been used to accelerate wound healing. Medicinal plants are significant sources of novel chemical substances with valuable therapeutic effects[66]. Antioxidant agents, such as flavonoids, act as reducing agents and protect against radiation[67]. These protective effects can modulate proinflammatory molecules, such as those involved in the healing process[66]. The use of plant extract liquid and cream is for treating granulomas, ruptured skin, and wound contraction, as well as to counteract the anti-healing effects of dexamethasone[68]. An ethanolic extract of *D. viscosa* leaves demonstrated wound-healing activity in rats with excised and incised wounds. Furthermore, it was determined that excision wounds treated with 10% extract had a more rapid contraction and epithelization[68]. Pawar and Mahajan[65] showed that *D. viscosa* leaf extract had wound-healing properties in diabetic wistar albino rats. The plant's highly polar extract showed significant healing effects. This could be because flavonoids are commonly found in polar extracts and promote rapid healing[69].

The *D. viscosa* formulated ointment (DVFO 2.5% and 5.0%) significantly enhanced wound healing and quicker wound contraction, epithelialization, elevated hydroxyproline levels and increased tensile strength compared to the control group. The ethyl acetate fraction of *D. viscosa* revealed flavonoids with high concentrations of quercetin (6.46%) and kaempferol (0.132%) for healing activity[17]. The effects of *D. viscosa* ethanol extract and flavonoid-rich fraction were examined in an *in vitro* wound healing experiment. The flavonoid-rich fraction of *D. viscosa* significantly impacted cell proliferation after 48 hours of exposure compared to the control group[70]. According to Habbu[69] *D. viscosa,* ethanol extract containing flavonoids and ointment significantly increased wound response and overrode the anti-healing effects of dexamethasone compound.

Anti-inflammatory activity

The *D. viscosa* leaves diterpene Hautriwaic acid (HA) exhibited a good anti-inflammatory effect on mouse ear oedema model, when *D. viscosa* dichloro-methane extract (DvDE) was evaluated at doses of 3 mg/ear on a TPA-induced oedema model, it showed considerable inhibition of 97.8% of the oedema[71]. In orally at a dose of 300 mg/kg, the hydroalcoholic extract (HAE) of *D. viscosa* leaf considerably reduced the paw oedema caused by carrageenan. This study indicates that the ethanolic extract from *D. viscosa* leaves can be utilized as an antiinflammatory[72]. Additionally, *D. viscosa* has been reported to be used to treat gastrointestinal disorders and inflammatory processes[57]. Viscosine extracted from *D. viscosa* leaves is a flavonoid glycoside significant in its lipoxygenase inhibitory activity, and its metabolites elicit inflammatory responses in the body[73]. Bioactive constituents labdane type diterpenes and flavones from *D. viscosa* showed anti-inflammatory activity[18].

A Nebrodenside A isolated from *D. viscosa* was tested as a potential anti-inflammatory compound using molecular docking simulation[74].

Antidiabetic activity

The *D. viscosa* and its plant parts demonstrated antidiabetic activity[75]. Previous research has indicated that the polar components that give maximum polar crude extract its antidiabetic properties are also present in it[21]. An *in vitro* experiment was carried out to investigate the antidiabetic activity of isolated rat hemi-diaphragm glucose uptake. The *D. viscosa* showed a glucose level of 13.80 compared to 5.34 for the control group and 15.45 mg/g/min for insulin[76].

In addition, when *D. viscosa* aqueous and butanol extracts were utilized in treating rats with alloxan-induced diabetes, aqueous ethanol extract showed a decrease in glucose percentage by 30% and by butanol by 48%[75]. Further, when alloxan diabetic albino rats were given methanol and chloroform extract of *D. viscosa,* they showed a decrease in blood glucose levels within the normal range[19]. A compound quercetin was obtained from *D. viscosa*, and it significantly reduced blood glucose, serum insulin, lipid profiles and significantly improved glucose tolerance and HDL-c levels[77]. Besides, quercetin is also reported to be active in different diabetic conditions and is also found to ameliorate oxidative stress in STZ-induced diabetic rats[78].

Anti-fertility activity

The number of medications with anti-fertility properties has increased recently due to contraceptive methods and anti-fertility effects brought on by growing population concerns in countries like China and India. The *in vivo* mice model demonstrated that the methanol extract of *D. viscosa* showed the maximum anti-fertility activity compared to the aqueous extract[79]. The acceptable range of *D. viscosa* extract doses accelerates fertility activity, but high doses can result in miscarriage[21]. Conversely, the methanolic extract of *D. viscosa* leaves significantly proved anti-fertility activity in female rats[80]. Furthermore, methanolic extract of *D. viscosa* demonstrated anti-fertility activity in house mice[81]. Different animal studies have shown that various extracts of *D. viscosa* have anti-fertility properties.

Analgesic and antipyretic activity

Antipyretic analgesics combine an analgesic action with the ability to lower pain and body temperature in a fever. Most drugs in this group combine analgesic and antipyretic with anti-inflammatory properties[82]. Synthetic or semi-synthetic medications cause significant side effects and are harmful to various human organs. Therefore, developing new compounds derived from plants that exhibit analgesic and antipyretic properties is necessary. Rat's writhes caused by 2% acetic acid were dose-dependently reduced, and additionally, an antipyretic effect was demonstrated by *Dodonaea angustifolia* water extract (50-200 mg/kg)[83]. Assessment against acetic acid writhing and hot plate tests, as well as the lipopolysaccharide (LP) induced pyrexia assay in mice and rats, demonstrated the analgesic and antipyretic properties of aqueous extracts of *Dodonaea angustifolia* and *Salvia africana-lutea*[84]. The antinociceptive effects of several *D. viscosa* leaf extracts were evaluated on several experimental pain models. In rats and mice, *D. viscosa* leaf extracts showed antinociceptive action; however, ethyl acetate extract showed the highest activity[85]. A viscousine molecule from *D. viscosa* was tested for antipyretic activity using a yeast-induced pyrexia model and molecular docking studies[20]. Analgesic and antipyretic activity has been reported for phytochemical compounds such as alkaloids, saponins, and carbohydrates found in the seeds of *D. viscosa*[85].

Discussion

Medicines are manufactured from various natural resources, including plants, and they are used to treat infections or diseases in humans, particularly in developing countries where traditional medicine is relied on for the treatment. Bioactive compounds extracted from natural resources and their stability and viability are essential for being good activity. The same plants can be extracted with different solvents (ethanol, methanol, acetone, diethyl ether, ethyl acetate, benzene, hexane, chloroform and water). Also, the same solvent can be used to extract different parts of plants (leaves, stems, flowers, bark, and root). There are many phytochemicals present in various parts of *D. viscosa,* including tannin, phenol, alkaloids, flavonoids, saponin and steroids and specific compounds like quercetin, flavone, kaempferol, viscosine, hautriwaic acid, nebrodenside A and labdane type diterpenes. Various researchers have reported different extracts on the biological activities (antimicrobial, anticancer, antidiabetic, antioxidative, antibiofilm, anti-inflammatory antiulcer, wound healing, analgesic and antipyretic activity).

Hence, phytochemicals are essential constituents, including *D. viscosa* plant, and their bioactive compounds have been used to treat various diseases.

Conclusion

The search for drugs that improve human health care without causing adverse consequences relies on creating novel therapeutic compounds from natural materials. The *D. viscosa* has been used as an herbal medicine in different countries, including India. This medicinal plant's significant biological activities have led to using either part of the plant or extracted bioactive compounds to treat various communicable and non-communicable diseases. Due to its therapeutic potential for treating many diseases, *D. viscosa* can be considered a valuable and widely used herbal medication. There are numerous possible applications for *D. viscosa*, such as traditional medicine and the development of novel drugs. The primary data and findings in the existing literature indicate that this is a field of active research for further studies. These plant bioactive compounds were evaluated *in vitro* and *in vivo* using different animal models. However, the focus might shift from plant drug to drug development to enable human clinical trials and, eventually, drug efficiency evaluation. The current comprehensive review serves as an inspiration for additional research on this potentially therapeutic medicinal plant.

Conflict of interest

The authors declare that they have no conflict of interest.

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