

REVIEW

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Phytochemical investigation and potential pharmacologically active compounds of *Rumex nepalensis*: an appraisal

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Abstract

Background: *Rumex nepalensis*, a widely known traditional medicinal plant and is used as the source of medicines and human diet in various communities. Currently, the phytochemical investigation and pharmacological studies of *R. nepalensis* are of significant research interest. Therefore, the current review is mainly focused on the phytochemical investigation and pharmacological applications of *R. nepalensis*

Main body: Various secondary metabolites like emodin, endocrocin, chrysophanol, neopodin, physcion, torachryson, aloesin, catechin, quercetin, resveratrol, and their derivatives were isolated from root and aerial parts of the plant. Both isolated compounds and extracts from *R. nepalensis* are reported to have pharmacological activities such as anti-inflammatory, antioxidant, antimicrobial, wound healing, and anti-plasmodial activities

Conclusions: Different parts of *R. nepalensis* have ethnomedicinal importance. *R. nepalensis* is one of the potential sources of pharmacologically active extracts and isolated compounds. In future *R. nepalensis* can play a vital role for the preparation of modern drugs.

Keywords: Medicinal plants, *Rumex nepalensis*, Pharmacological activities, Phytochemical

1 Background

Starting from human civilization, plants, animals, and minerals are being used by people for their rich nutritional and medicinal sources. Especially, plants have been exploited since the ancient history for their remedial purposes [1]. Several research reports showed about 270,000 plant species have been discovered, while biodiversity gives approximately around 500,000 species on earth [2]. It was reported that about 50,000 plant species were used as traditional medicines in different forms [3]. There is no synthetic substitute available for about 121 major plant-based drug molecules, which are comprising 45 from tropical and 76 from subtropical areas [4]. Several plants continue to be important sources of

many chemical compounds used in pharmacological activities and attracted the attention of scientific communities. Research activities on natural products have confirmed that there are strong efforts for the isolation, identification, and structure elucidation of secondary metabolites from plants and their uses as active components in medicinal and drug preparations [5, 6] and good source of nutraceutical products. The World Health Organization (WHO) report showed more than 80% of the population on the globe is practicing traditional medicines for primary health care due to the biological effects of present organic compounds [7].

In the world, there is traditional medicine knowledge or practices that are related to human beings and livestock's health. The natural product extraction method is the oldest human practice, and usage of plant extracts and isolated products as a diet supplement, medicine, cosmetics, and agricultural applications counts back many centuries [8, 9]. Wild plants are also reported as

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potential phytoremediation of toxic elements like heavy metals and monitoring excess metallic nutrients in agricultural soils and water [10–13]. Nowadays, the industrial applications of plant-based organic products have obtained attention due to the broad-range of their chemical compositions with minimum side effects [6]. Natural product extracts contain quite different chemical constituents that have distinct pharmacological and biological properties. These secondary metabolites comprise carbon-based compounds such as sugars, fatty acids, terpenoids, sterols, flavonoids, tannic acids, saponins, anthraquinones, vitamin C, steroids, and phenolic acids, and nitrogen-based compounds such as alkaloids, amino acids, and protein-based compounds [14]. Some valuable medicines obtained from plant-based drugs like taxol, podophyllotoxin, digitoxigenin, gitogenin, digoxigenin, vinblastine, vincristine, tubocurarine, morphine, codeine, aspirin, atropine, pilocarpine, capsaicin, allicin, curcumin, artemisinin, and ephedrine are good representative examples of pharmaceutical drugs [15]. The research interest towards phytochemical activities has been steadily growing in developing and developed countries because of the rising credit of non-narcotic plant products, lesser side effects, and affordability at low cost. Even, sometimes medicinal plants are the only way of health care accessible to the community that has no access to modern medical services [16].

The recent phytochemical and pharmacological studies revealed isolation and characterization of many novel biologically active compounds for the synthesis of drug candidates serving to manufacture advanced therapeutic drugs [17–20]. Modern drugs that are produced from natural products have a huge potential that still exists in plants for the production of many more novel organic compounds. Scientists throughout the world have identified thousands of phytochemicals that have inhibitory effects against all types of microorganisms [21]. Similarly, they were reported as potential sources of phytochemical compounds that are applied for the wide biological activities. *Rumex* species, the second largest family of polygonoaceae, have been identified as a promising source of bioactive and pharmacologically active compounds [22]. Almost all *Rumex* species are known for their ethnomedicinal values in the world [23]. Although the genus contains about 250 plant species, phytochemical and pharmacological studies have been conducted on only about 50 species as some reports on this plant species have shown the use of leaves, aerial, and roots of the plant either as treatment of several health disorders, food, coloring agent, or phytoremediation [12, 24]. Various phytochemicals and many secondary metabolites have been reported from different parts of this plant. Recently, there are significant and renewed interests in these phytochemical compounds as potential drugs or as

sources for novel drugs [5, 25]. For various medication purposes, *Rumex* plants have been processed for a long period of time in different preparation forms like decoction, crushing, chewing, making juice/paste, crude extracts, fixed oils, and essential oils [26].

Most *Rumex* species are reported to treat constipation, wound, bleeding, inflammation, ulcer, tumor, mild diabetes, diarrhea, edema, jaundice, and hypertension and have diuretic and analgesic effects [26, 27]. They are also identified to relieve diseases like oxidative stress and liver, skin, nervous, cognitive, and gallbladder disorders [28–30]. *Rumex nepalensis* spreng. has wide-spectrum therapeutic activities and was extensively used as traditional medicine for centuries [4]. A vast literature survey revealed that diverse secondary metabolites like anthraquinones, flavonoids, naphthalenes, terpenes, stilbenoids, tannins, phenols, and saponins had been reported from solvent extracts of root parts of the *R. nepalensis* [31]. Solvent extracts or isolated compounds from the plant species are reported for their constipation, bleeding, tinea, pain, and purgative activities [32–34]. Leaves and immature roots of *R. nepalensis* are also reported to be used as a food supplement and dyeing agent [35, 36]. But, if it is consumed in greater quantity, oxalic acid present in the plant needs big attention to avoid the risk factor of calcium oxalate (kidney stone) formation [24]. Similarly, the bark and leaf of the plant were reported for their cleansing purposes in bathing and washing clothes in Ethiopia [37]. *R. nepalensis* is further reported for its powerful phytoremediation effects due to its potential accumulation of metals from soils and water for monitoring the level of macro and traces of metal elements in the diet supplements [12, 38]. The plant's flower part has been found to be a good medicine to cure joint pains [39]. Looking over the current publication status, thus far no comprehensive review paper has been published on *R. nepalensis*. This review paper describes botanical description, ethnomedicinal uses, phytochemistry, and pharmacological applications of *R. nepalensis*

2 Main text

2.1 Methods

In this review, some important data on the availability, botanical description, and pharmacological activities of *R. nepalensis* was collected from PubMed, Google scholar, Royal Society of Chemistry, Scifinder, Scopus, and “Science Direct” databases. This review article aims to make a focused appraisal on the current research trends on *R. nepalensis* regarding its ethnobotanical features, ethnomedicinal uses, phytochemical investigation, and pharmacological properties.

2.2 Botanical description of *R. nepalensis*

2.2.1 Morphological features of *R. nepalensis*

Rumex genera are usually plants with erect and long tap-roots. *R. nepalensis* is a 50- to 100-cm-tall plant,

glabrous, branched, grooved, and greenish in color [40]. It is a perennial herb with large roots that grow deep into the soil and erect stems. The leaves are edible, 5- to 10-cm long, arrow- or wide-shaped at its base, with wide- and long-stalked lower, either oblong or ovate, and have a petiole. Its basal leaves have 4- to 10-cm-long petiole [41]. The plant flowers are reddish, bisexual, and spirals, forming long and nearly leafless racemes [42] (Fig. 1).

2.2.2 Taxonomy of the *R. nepalensis*

R. nepalensis is one of the 250 plant species in the *Rumex* genera. Flowering and fruiting times are in between April and September based on the altitudinal situation of the regions where it grows [40, 43]. Its meiotic chromosome ploidy count is reported as $n = 50$ (10 \times) [43]. It is a perennial, ascending herb and, in various communities, are commonly known by different vernacular names. In different communities, it is locally known by different names as a few of them are listed below in Table 1.

2.2.3 Geographical distribution of *R. nepalensis*

Rumex genera are commonly distributed in the northern part of the globe especially in Africa, America, Asia, and Europe countries, but the introduction of the plant species is possible almost everywhere. *R. nepalensis* is tolerant to wide ecological locations. It is commonly a weed plant that grows at higher altitudes between 900 and 4000 m in various weather conditions [41]. Different reports in literatures have shown that the plant grows widely in Africa, India, Turkey, China, Myanmar, Indonesia, Afghanistan, Japan, Pakistan, Tajikistan, Vietnam, and Bhutan [40, 47].



Fig. 1 Photograph of *R. nepalensis*

2.2.4 Ethnomedicinal values of *R. nepalensis*

Rumex species have a number of ethnomedicinal uses; for instance, *R. acetosa*, *R. acetosella*, *R. abyssinicus*, *R. crispus*, *R. nepalensis*, *R. sanguineus*, *R. tuberosus*, *R. thyrsiflorus*, and *R. vesicarius* are some good examples [24]. It has been reported that *R. acetosa*, *R. acetosella*, *R. nervosus*, and *R. nepalensis* leaves are also used as part of human diet [31, 48]. In some regions, *R. nepalensis* leaves are employed as food supplement mainly in the form of vegetable soups. *R. nepalensis* is a very important weed plant in the field of traditional medicines. Several experimental reports have confirmed that *R. nepalensis* has numerous medicinal benefits. The plant roots, leaves, and flower parts are often used for the remedial purposes of various health disorders through different modes of preparations. It was also reported that some communities cook leaves and young shoots of *R. nepalensis* as a vegetable diet which gives a lemon taste to dishes [18]. Further, the plant has shown the coloring nature in food [40]. Ethnomedicinal study on herbal plants has specified active importance of *R. nepalensis* to increase its capacity in drug industries [49]. Various solvent extracts of the plant parts have been reported showing promising biological activities [16, 50]. For instance, roots of *R. nepalensis* are reported to be traditionally used to treat pain, inflammation, bleeding, tinea, tumor, and constipation [51] and have diuretic, analgesic, anticancer, antimicrobial, and antioxidant activities. The leaves part of the plant are also used commonly to treat colic and headaches [52]. For example, investigation of methanolic (95%) extract of the leaves part in rat model was tested nontoxic until 4000 mg/Kg dose (i.e., LD₅₀ > 4000 mg/Kg) [53]. To the best of our knowledge, only a few reports are documented in the literature for the use of flower parts of *R. nepalensis*. The summary of ethnomedicine uses and the mode of preparation of this medicinal plant against human and livestock diseases are summarized in Table 2.

2.3 Phytochemistry of *R. nepalensis*

2.3.1 Potential bioactive compounds from *R. nepalensis*

Phytochemical investigation of *R. nepalensis* has shown a large number of organic complex and biologically active compounds. Most previous research activities that were undertaken regarding phytochemical studies have exhibited diversified secondary metabolites like flavonoids, phenols, anthraquinones, naphthalenes, saponins, cardiac glycosides, stilbenoids, terpenes, sterols, tannins, steroids, and reducing sugars [51, 67, 68]. Currently, most of the literatures related to the solvent-based isolation and characterization of *R. nepalensis* have been from the root parts of the plant species for the evidence not given clearly. For the plant species, phytochemical screening indicated the presence of alkaloid compounds

Table 1 Vernacular names of *R. nepalensis*

Local names (language)	Place/country	References
Sheep sorrel, Nepal dock, Himalayan dock (English)	Not stated	[40, 41]
Amlyā, Amlora, Jangli palak, Malori (Hindi)	India	[18]
Alphiri (Kashmir)	India	[40]
Pahari palang (Bengali)	India	[44]
Shalkhay (Pakistani)	Pakistan	[33, 45]
Kathura (Uttarakhandi)	India	[40]
Sukkankeri (Tamil)	India	[4]
Shulti (Afaan Oromo); Lut (Amharic)	Ethiopia	[37, 46, 47]

[42, 69] even though they are not confirmed by phytochemistry reports.

2.3.2 Phytochemical compounds isolated from *R. nepalensis*

Phytochemical screening activities of *R. nepalensis* have shown the plant species contain a broad spectrum of secondary metabolites. However, only a few of them have been reported by scientific communities. Studies on the solvent extracts of roots of *R. nepalensis* have confirmed [51, 67] that it contains phytochemical compounds like anthraquinones (Fig. 2), naphthalenes (Fig. 3), flavonoids (Fig. 4), terpenoids, and sterols (Fig. 5).

Table 3 shows the various terpenoid and phenolic compounds obtained from the root extracts of *R. nepalensis*. It is clear in Table 3 that mainly oxygenated compounds were identified from *R. nepalensis* plant root extracts using different solvent systems such as ethanol, methanol, n-butanol, or their mixtures. For instance, n-butanol extract of the root part of the plant has been reported to give different classes of organic compounds like endocrocin (6), nepalenside A (7), nepalenside B (8), rumexoside (9), torachryson (10), orientaloid (11), aloesin (15), catechin (17), resveratrol (21), orcinol glucoside (22), and (3,5-Dimethoxy-4-hydroxyphenol)-1-O- β -D-(6-O-galloyl) glucose (23). Of course, compounds (7) and (8) were reported for the first time from this plant species. It was stated that physcion (2), rumexoside A (12), and rumexoside B (13) were obtained from the ethanol extract of the root part of the plant by partitioning with pet ether, ethyl acetate, and water, and compounds (12) and (13) were newly reported from this plant. Isolated organic compounds like chryso-phanol (1), emodin (3), chryso-phanol-8-O- β -D-glucopyranoside (4), emodin-8-O- β -D-glucopyranoside (5), 3-O-methyl epicatechin (16), quercetin-3-O- β -D-glucuronate (18), and β -sitosterol-3-O- β -D-glucoside (20) have been also reported from the methanol/water (80/20) extract of the root part of the plant using cold percolation for 24 h.

The same report again claimed that compounds (16), (18), and (20) had been isolated for the first time from the plant species. Aloesin (15), rumexoside (9), orientaloid

Table 2 Ethnomedicinal importance of *R. nepalensis* and its mode of preparation for treatment of different ailments

Part used	Ethnomedicinal importance	Place/country	Mode of preparation	References
Root	Used as purgative, antitumor, anti-inflammatory, and treatment for dislocated bones	Nepal	Decoction	[52]
	Treat wounds, pimples, and ringworm	India	Crushing root and making paste	[54]
	Used to cure skin disorders and eczema	India	Crushing root and making paste	[55]
	Treat stomach ache, tooth ache, tonsillitis, ascariasis, rabies, and body swelling	Ethiopia	Chewing the root	[56, 57]
	Relieve stomach disorders	Ethiopia	Chewing the root	[58]
	Used as purgative	Pakistan	Chewing the root	[33]
	Leaf	Treat headaches, abdominal colic, skin diseases, wound, and allergies	Nepal/India	Decoction and making juice of the leaf powder
Treat ulcers, kwashiorkor, worms, HIV/AIDS, opportunistic diseases, and show HIV-1 activity indices		Rwanda	80% Ethanolic leaf extract	[60, 61]
Used as ethnoveterinary to treat stomachache		Ethiopia	Crushing	[58]
Used as antiseptic against wounds and skin disorders		Pakistan	Decoction	[62, 63]
Relieve irritation of sting nettle, stomachache, and snakebite		India	Crushing and making juice	[64, 65]
Treat hypertension, amoebic dysentery, and hemorrhoids		Ethiopia	Decoction	[66]
Treat swelling and joint pain		India	Crushing	[43]
Used to treat cuts		Pakistan	Decoction	[63]
Flora		Cure joint pain and body ache	India	Powder/paste application to the infected body

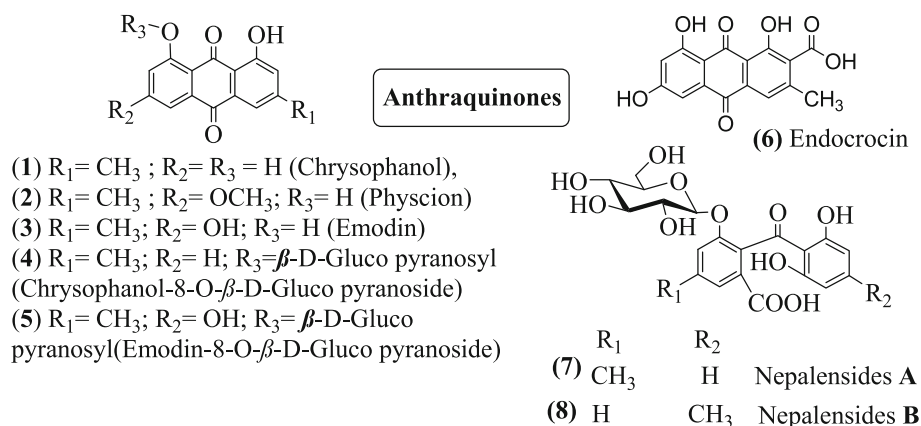


Fig. 2 Isolated anthraquinone compounds from the root extracts of *R. nepalensis*

(11), and torachysone (10) have shown an anti-inflammatory activity. Similarly, chrysophanol (1), emodin (3), and some of their derivatives (4) and (8) which were reported from Soxhlet methanol root extracts have anticancer, antifungal, antioxidant, and anti-inflammatory activities. Neopodin (14) and chrysophanol (1) which were obtained from methanol extract of the root part of the *R. nepalensis* have shown anti-inflammatory activity. Neopodin (14) was also identified for ethyl acetate extract of the root of the plant and reported to show strong anti-inflammatory activities. According to some other reports, in the methanol extract of the root part of *R. nepalensis*, secondary metabolites like torachryson (10), epicatechin gallate (19), orcinol glucoside (22), and aloesin (15) were identified for their antimicrobial, antidiabetic, anti-inflammatory, antioxidant, and antitumor activities. Nepalenside A (7) and nepalenside B (8), the two newly isolated compounds from ethanol fractions of the root part of the plant species, were also reported for their antidiabetic and cytotoxic properties. Alcoholic solvent root extractions on

R. nepalensis showed the isolation of oxygenated secondary metabolites which have wide phytotherapeutic activities (Table 3).

2.4 Pharmacological activities of *R. nepalensis*

Rumex species have shown potent pharmacological activities. Root and aerial parts of *Rumex* species are used as medicines throughout the world for a variety of human diseases such as purgative, tinea, antioxidant, cytotoxic, antipyretic, antidiarrhea, antiviral, antibacterial, antifungal, and anti-inflammatory activities [15, 29]. Leaves, roots, and few flora parts of *R. nepalensis* have been reported mostly to be used to treat skin disorders and syphilitic ulcers also. Similarly, there are many studies on this medicinal plant showing its properties as purgative, analgesic, antipyretic, antifungal, anti-inflammatory, antibacterial, and skeletal muscle relaxant activities [53, 71]. In this regard, *R. nepalensis* has been reported as potential pharmacologically active plant against various ailments. Some of these activities are discussed as follow.

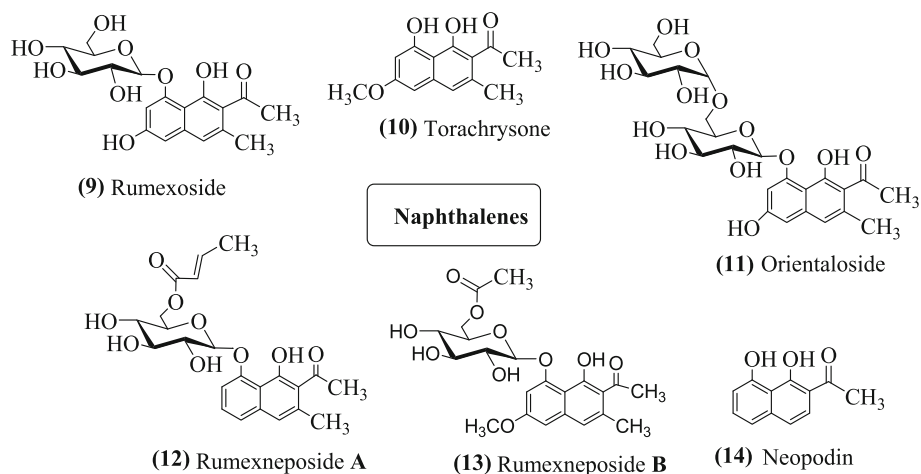


Fig. 3 Isolated naphthalene compounds from the root extracts of *R. nepalensis*

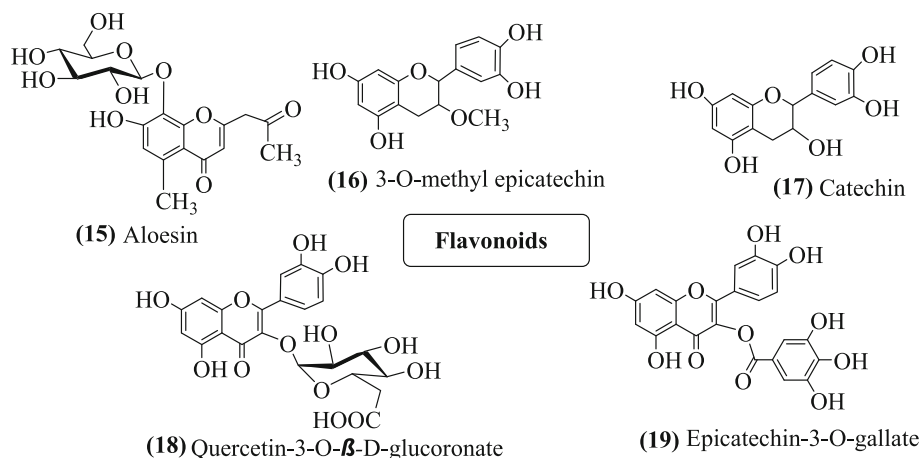


Fig. 4 Isolated flavonoids from the root extracts of *R. nepalensis*

2.4.1 Anti-inflammatory activity

Different studies have indicated that solvent extracts and isolated pure compounds of *R. nepalensis* are rich in anti-inflammatory activities. There were reports on the investigation of chloroform and ethyl acetate extracts of the root of the plant which have shown significant anti-inflammatory activity [46, 52]. For the treatment of acute inflammation of the mouse model, extracts of ethyl acetate and chloroform revealed a reduction in ear edema [40]. Another report for ethanolic extract of the root part of *R. nepalensis* demonstrated an anti-inflammatory effect that has a strong comparison with the standard diclofenac [4]. Some isolated compounds like nepodin, chrysophanol, and their derivatives from ethyl acetate fractions of the root part of the plant species have shown an improved anti-inflammatory activity than the control ibuprofen [70]. Similarly, ethyl acetate extract of the root part of *R. nepalensis* was reported to show moderate to strong inhibitory

effects against inflammatory effects on COX-1 comparing with indomethacin and COX-2 compared with celecoxib as positive controls. The presence of anthraquinones and naphthalenes in the root extract of the plant species is responsible for the inhibition effects observed [23]. From the root part of the plant, secondary metabolites such as chrysophanol, physcion, endocrocin, chrysophanol-8-O- β -D-glucopyranoside, nepodin, and nepodin-8-O- β -D-glucopyranoside were specifically reported for their anti-inflammatory activities [68].

2.4.2 Antioxidant activity

The phytochemical screening of solvent extracts of roots and leaves of *R. nepalensis* has exhibited that the plant contains potential bioactive compounds with significant antioxidant activities [24, 53]. For instance, polyphenols and flavonoids isolated from the plant species have

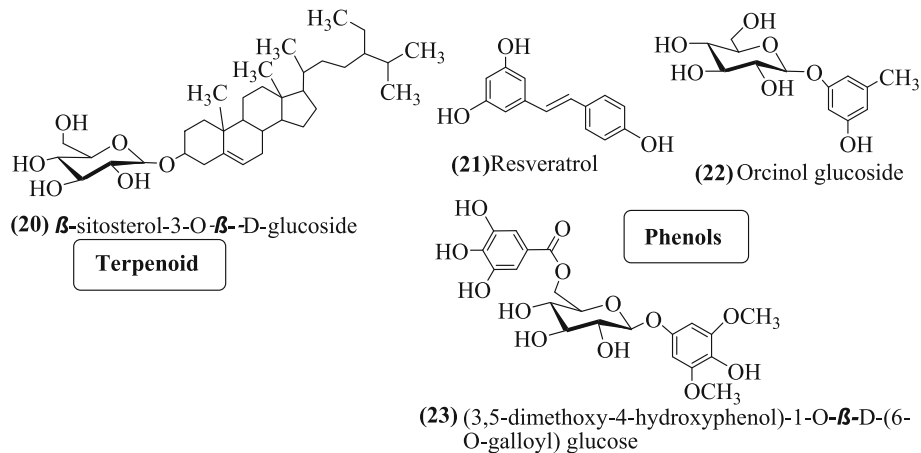


Fig. 5 Isolated terpenoid and phenol compounds from the root extracts of *R. nepalensis*

Table 3 Major compounds isolated from root extracts of *R. nepalensis* and their pharmacological activities

Isolated compounds	Method used	Pharmacological activities	References
Rumexoside (9) Torachysone (10) Orientaloside (11) Aloesin (15)	Solvent extraction (n-butanol)	Anti-inflammatory	[4, 24, 40]
Chrysophanol (1) and its derivatives (4) Emodin (3) and its derivatives (8)	Soxhlet extraction (methanol)	Antifungal Antioxidant Anticancer Anti-inflammatory	[46, 51, 67]
Neopodin (14)	Solvent extraction (ethyl acetate)	Anti-inflammatory	[40]
Nepalenside A (7) Nepalenside B (8)	Solvent extraction (ethanol)	Antidiabetic Cytotoxic	[40, 51]
Torachysone (10) Aloesin (15) Epicatechin gallate (19) Orcinol glucoside (22)	Solvent extraction (methanol)	Antimicrobial Antioxidant Antitumor Antidiabetics Anti-inflammatory	[4, 24, 67]
Chrysophanol (1) Neopodin (14)	Solvent extraction (methanol)	Anti-inflammatory	[70]

revealed important health benefits. These phytochemicals are reported as antioxidant compounds because of their single oxygen quenchers and reducing properties [72]. The leaves part of the plant are rich sources of natural antioxidants [4]. When comparing the ethanolic root extract of *R. nepalensis* with the free radical scavenging nature of the standard ascorbic acid, the extract has shown better scavenging activity [46, 73]. Antioxidant activity of extract of the root part of *R. nepalensis* by solvents such as chloroform, ethyl acetate, acetone, ethanol, methanol, and water have been also investigated and showed the marked medicinal effects. For the root part of *R. nepalensis*, for example, antioxidant effects of chloroform and ethyl acetate extracts had been studied using 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS) free radical assays, where the level of the phenolic compound in ethyl acetate was higher than in the chloroform extract and showed promising activities [24]. In vitro test showed the essential oil from roots of *R. nepalensis* has a comparable antioxidant activity to standards like ascorbic acid and vitamin E [74].

2.4.3 Antimicrobial activity

Organic solvents such as benzene, pet ether, chloroform, acetone, ethyl acetate, and methanol extracts of the root part of *R. nepalensis* have been reported showing antimicrobial activity against Gram-positive and Gram-negative microorganisms like *Staphylococcus aureus*, *Streptococcus mutans*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans*. Root extracts of the plant by ethyl acetate and benzene showed precise antifungal activity against *C. albicans* [29]. Chrysophanic acid, one of the chemical constituents obtained from *R.*

nepalensis, has been also reported to have antifungal activity [31]. The methanol extract of the root part of *R. nepalensis* has shown inhibitory activity against RNA polymerase of hepatitis C virus. Its extract has high tannin percentage which also inhibited about 80% HCV-RdRp at a concentration of 50 µg/mL [40]. The same report also showed the leaves extract of the plant has anti-HIV opportunistic diseases. For example, out of 38 tested 80% ethanolic leaves extract of the plants from 21 different families, only two plant extracts were reported to show interesting activity index towards HIV-1 in vitro virus test. One of the two plants with good anti-HIV-1 activity indices was *R. nepalensis* [60, 61]. Similarly, methanolic extracts of the plant showed to be an alternative way of medicines to prevent bacterial and fungal infections [53]. The methanol root extract of the plant was investigated on several clinical isolates and standard strains by well diffusion assay which showed moderate inhibitory effect against *Escherichia coli* (12 mm inhibition zone) for antibacterial activity and *Aspergillus niger* (11 mm inhibition zone) for antifungal activity due to the presence of anthraquinone, steroid, saponin, reducing sugar, and tannin compounds [75]. It was again reported that *R. nepalensis* methanolic root extract (29 mm inhibition zone) at 1000 µg/mL had shown similar inhibitory activity against *Staphylococcus aureus* when compared with the positive control Ciprofloxacin (29 mm inhibition zone) [76]. The leaves and root extracts of *R. nepalensis* were also reported to show significant antimicrobial and antifungal properties [77]. For the leaf aqueous extract of *R. nepalensis*, biocompatible gold nanoparticles were synthesized effectively which showed significant antibacterial activity [78].

2.4.4 Wound healing activity

The leaves extract of *R. nepalensis* was mixed with Vaseline or butter and applied to the infected body. Antibacterial and antipyretic activities of the plant products further justify *R. nepalensis* application as a traditional medicinal plant to cure wounds [40, 79]. Secondary metabolites from the plant species were also reported showing wound healing properties [18]. The powder or juice of leaves has revealed the wound healing activity of the plant species [59]. Furthermore, reports have shown methanol extracts of the root part of *R. nepalensis* were revealed promising anti-ulcer activity on pyloric ligation, cold restraint stress, and acetic acid-induced ulcer models which strengthen the claim on the plant as traditional medicinal remedy [80].

2.4.5 Anti-plasmodial activity

R. nepalensis has been practiced by traditional healers for its anti-plasmodial activity. However, there are very few reports showing anti-plasmodial properties of the plant species. For example, the ethanol fraction of the root of *R. nepalensis* showed improved plasmodium percent suppression (70.08%) compared with the water extraction (54.31%), chloroform extraction (19.61%), and methanol extraction (10.27 %) suppression [48].

2.4.6 Miscellaneous activities

The crushed root paste of *R. nepalensis* was reported to cure eczema [55]. The plant species has been reported for its application to treat swollen gums, pain, and headaches [81–83]. For instance, methanol extract of the root part of plant species was tested for its purgative activity, and the application of the extract to albino rat at 100 to 400 mg/Kg as the oral dose showed good purgative activity [44]. It is also used as ethnoveterinary medicine as the crushed leaves have shown positive effects to alleviate stomach disorders in livestock [58]. The juice of the leaves of the plant was used in the ailment of abdominal colic, skin diseases with antiallergic properties [59]. In Ethiopia, the extract of *R. nepalensis* is used for the treatment of diarrhea [84]. For example, chewing fresh root of the plant has shown marked effect in human and livestock for treatment of diarrhea [47]. Meresa et al. [66] reported the impact of boiled extract of fresh leaves to treat diseases like hypertension, amoebic dysentery, and hemorrhoids. When compared with *Ruta chalepensis*, *Clausena anisata*, *Nicotiana tabacum*, and *Zingiber officinale*, *R. nepalensis* was reported as the most preferred medicinal plant to cure the stomach ache [85]. Chrysophanol and physcion were reported as potential human pancreatic lipase inhibitory phytochemicals. Pancreatic lipase is an enzyme responsible for the reduction of abnormal fat accumulation in the body which is the cause of the risk of overweight and obesity [86].

3 Conclusions

In conclusion, this review has outlined the current research trends of *R. nepalensis* regarding its ethnomedicinal importance, phytochemistry, and pharmacological properties. *R. nepalensis* is commonly applied as traditional medicinal plants for the treatment of human diseases. Additionally, its uses are as a food supplement, coloring agent, and potential accumulation of heavy metals (i.e., phytoremediation). Various phytochemical screening on the plant extracts has revealed that it has a wide spectrum of bioactive compounds. The extracts and isolated compounds from *R. nepalensis* showed that they have wide biological applications. The potential bioactive compounds isolated from the plant using different solvent systems are classified as anthraquinones, naphthalenes, stilbenoids, flavonoids, terpenoids, phenols, and their derivatives. Most organic compounds were isolated and reported from the root parts of *R. nepalensis* using common organic solvents like ethyl acetate, pet ether, n-butanol, ethanol, methanol, and methanol/water (80/20) systems. Natural products like chrysophanol, physcion, emodin, endocrocin, torachryson, orientaloid, aloesin, catechin, and their glycoside derivatives have been reported from the solvent extracts of root, leaves, and aerial parts of the plant species. Compounds like 3-O-methylepicatechin, quercetin-3-O- β -D-glucuronate, epicatechin-3-O-gallate, orcinol glucoside, and (3,5-dimethoxy-4-hydroxyphenyl)-1-O- β -D-(6-O-galloyl) glucose were also the major bioactive compounds reported from the root extracts of the plant species. Pharmacological studies revealed that solvent extracts and secondary metabolites have antimicrobial, antioxidant, anti-inflammatory, anti-plasmodial, and wound healing activities. But, regardless of its potential sources of phytochemical compounds and potential pharmacological activities, the total number of isolated compounds from solvent extracts of plant parts especially from the leaves is too small. Authors of this review article are hoping that the review work has concisely forwarded some important information to scientific communities about the current research trends regarding the phytochemistry and pharmacological applications of *R. nepalensis* plant species. In the future, major research focus should be given toward the phytochemical investigations of the plant parts to isolate more novel bioactive compounds so that they can be used for modern drug synthesis.

Abbreviations

BW: Body weight; HCV-RdRb: Hepatitis C virus basolateral cell membrane resistances; HIV-1: Human immunodeficiency virus-1; LD50: Lethal dose, 50%; RNA: Ribonucleic acid

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Authors' contributions

YH and FB have drafted the review. MG and AB prepared different tables and figures required for the manuscript. RKB provided guidance during development of idea and wrote and revised the manuscript. The authors read and approved the final manuscript

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