

A REVIEW ON PHYTOCHEMICAL AND PHARMACOLOGICAL POTENTIAL OF WATERCRESS PLANT

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ABSTRACT

Nasturtium officinale (family: Brassicaceae) that is commonly known as watercress is a fast-growing aquatic or semi-aquatic perennial plant native to Europe, Central Asia. It is a highly significant food supplement, extensively consumed with salad, juices, or other dishes as an ingredient, flavor, or garnish. The leaves are traditionally used as stomachic, depurative, diuretic, expectorant, hypoglycemic, odontalgic, and stimulant. Meanwhile, it has been used to treat jaundice, asthma, bronchitis, scurvy, tuberculosis, urinary tract infection, and calculi. *N. officinale* is rich in glucosinolates, carotenoids, polyphenols, as well as Vitamin C, Vitamin A, and α -tocopherol. It is the main source of iron, calcium, iodine, and folic acid.

Keywords: Asthma, Carotenoids, Folic acid, Hypoglycemic, Tuberculosis, Vitamin.

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INTRODUCTION

Herbs and traditional medicines are the most reasonable source of treatment in the human health-care system that has been used for the treatment of multiple diseases since classical times [1]. The local people have enduring history of traditional plant usage for medicinal purposes [2,3]. The conclusive therapy effects are due to the presence of bioactive phytochemical constituents such as alkaloids, bitters, flavonoids, bioflavonoids, glycosides, mucilage, saponins, tannins, phenols, phenolic acids, coumarins, terpenoids, essential oils, lectins, and polypeptides [4,5]. According to the WHO reports, in many developing countries, 80% of people trust on traditional practitioners and their armamentarium of medicinal plants to meet health-care needs [6,7]. The term "traditional" does not signify conventional or allopathic; rather, it represents historical/cultural/folk system of medicine that would be assumed as "alternative" in western context [8,9]. Nowadays, medicinal plants are resources of novel drugs and many modernized medicines are originated from plants [10-12]. Nearly 12,000 compounds have been isolated from plants until now that accommodate biological efficacy [13]. About 25% of the medicinal agents prescribed around the globe originate from plants, 121 such active compounds being in the current use. Irrespective of 252 drugs considered as basic and essential by the WHO, 11% are originate from plants and various synthetic drugs obtained from natural precursors [14-16]. The current review is to provide complete latest information of the phytochemical properties of *Nasturtium officinale*, one of the plants, that is, being explored for multiple health benefits.

PLANT DESCRIPTION

N. officinale is a perennial dicotyledonous herb usually found in close proximity to water. As a member of the Brassicaceae family, it is related to several popular food and spice crops such as broccoli, cabbage, kale, radish, and mustard, as well as the model plant. In particular, watercress has been used as a medicinal and food crop for over many decades [17-22]. Morphologically (Fig. 1), *N. officinale* has small hairs, unbranched unicellular, and smooth sharp apex [23-25]. The plant is perennial, growing to 0.5–1 meter at a fast rate. The leaves are 4–12 cm long, compound with many wavy edged, oval- or lance-shaped leaflets growing from central stalk [26,27]. The stem is 10–60 cm with thin and fibrous roots at the bottom. At the top of stems and short stalks, its flowers, white in color, are 3–5 mm long and have four petals [28,29].

The fruits are 10–25 mm long and 2 mm wide and found on stalks that are 8–12 mm long. The fruits are thin, slightly curved cylinders and contain four rows of small, round seeds [30,31]. The plant begins to flower from May to October and the seeds ripen from July to October. The flowers are hermaphrodite and are pollinated by bees, flies, etc. According to the concentration of phosphorus present in water, the roots are divided into two types. When the phosphorus concentration is high, the roots are adventitious; however, when the concentration is low, the roots are mainly taproots. It has special spicy taste with food just like strong pepper [21,26,28,30,32-34].

TAXONOMICAL CLASSIFICATION

The taxonomy of *N. officinale* is in the kingdom (*Plantae*), order (*Brassicales*), family (*Brassicaceae*), genus (*Nasturtium*), division (*Magnoliophyta*), class (*Magnoliopsida*), subclass (*Dilleniidae*), order (*Capparales*), and species (*N. officinale*). The genus *Nasturtium* comprises from five species such as *N. officinale*, *Nasturtium microphyllum*, *Nasturtium gambellii*, *Nasturtium africanum*, and *Nasturtium floridanum* [35].

NOMENCLATURE

The land of origin of *N. officinale* includes Western Asia, India, Europe, and Africa, but now, it is almost present worldwide. It is considered as being introduced to North and South America, Southern Africa, Australia, and New Zealand. The plant has three synonyms, namely *Rorippa nasturtium-aquaticum* (L.), *Nasturtium nasturtium-aquaticum* (L.), and *Sisymbrium nasturtium-aquaticum* L. The vernacular name is watercress [36-39].

PHYTOCHEMICALS CONSTITUENTS

N. officinale is enriched with glucosinolates, carotenoids, polyphenols, as well as Vitamin C, Vitamin A, and α -tocopherol [40-42]. It is a main source of iron, calcium, iodine, and folic acid [43-46]. It provides a reservoir of tannins, flavonoids, terpenoids, and many other glycosides. It is a rich source of essential vitamins and minerals such as lutein and zeaxanthin [47-52].

ANTIOXIDANT ACTIVITY

Zeb [53] reported antioxidant potential, pigments, and phenolic composition of watercress leaves and roots. The study reported that

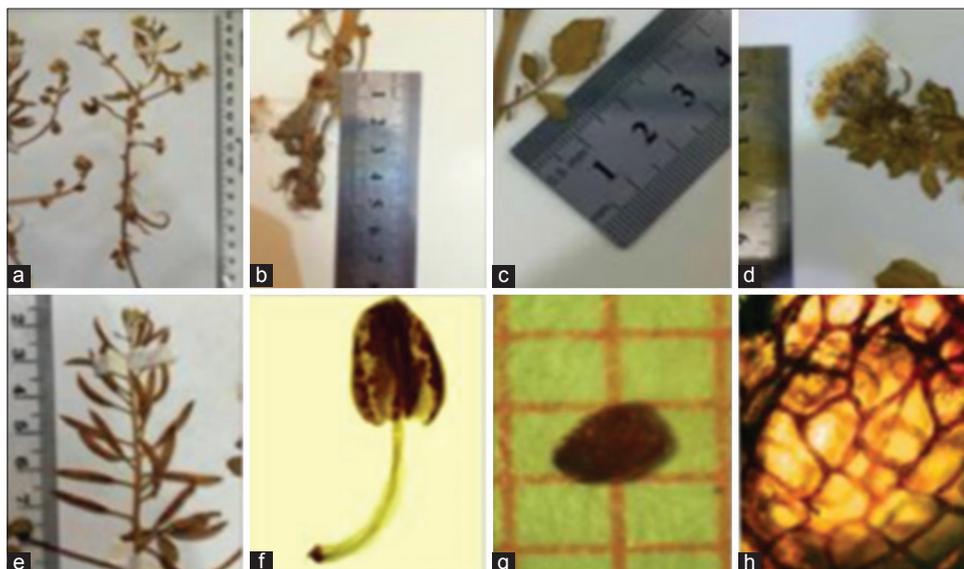


Fig. 1: Morphological characters in *Nasturtium officinale*. (a) Whole plant; (b) Roots; (c) Leaf; (d) Inflorescence system; (e) Fruits; (f) Stamen; (g) Seeds; (h) Ornamentation in seed surface

pigment chlorophyll was found in predominant concentration and total phenolic (TP) compounds were dominant in methanolic extract compared with aqueous extract. Total 14 phenolic compounds were determined in the leaves, where coumaric acid and its derivatives, caffeic acid and quercetin derivatives existed in superior amount. In roots, 20 compounds were identified, of which the above-mentioned compounds were found in higher concentration. The radical scavenging activity (RSA) of root, stem, and leaves of watercress methanolic extract were 70.0, 78.0, and 81.6%. There was a significant ($P < 0.05$) increase in percentage RSA in the methanolic extract with the order of root = stem < leaves. Mazandarani *et al.* [54] reported the relationship between secondary metabolites content and antioxidant activity in aerial parts of *N. officinale* R. Br., at various altitudes and periods of growth in northern Iran. TP and total flavonoids (TFs) contents in aerial parts of the plant were inspected spectrophotometrically and their antioxidant activities were accomplished by total antioxidant capacity (TAC) method and then compared with standards such as butylated hydroxyanisole and butylated hydroxytoluene. The results indicated that the TP content of aerial parts of *N. officinale* was 8.03–9.35 mgGA/Eg in vegetative period and 6.5–7.65 mgGA/Eg in generative period. In addition, TF contents were 26.5–31.11 mgQu/Eg in vegetative period and 36.89–42.65 mgQu/Eg in generative period. The highest secondary metabolites contents of TP were present in vegetative period. Half maximal inhibitory concentration (IC₅₀) contents in aerial parts of the plant were 932–1494 µg/mL in TAC method. The chief antioxidant activity and radical scavenging effects were observed in vegetative period with the lowest IC₅₀, 932–1227.5 µg/mL, whereas generative period with the highest amount of IC₅₀ had the weakest antioxidant activity. Tevfikozen *et al.* [55] revealed that aqueous and ethanolic extract of watercress are novel antioxidants against lipid peroxidation in linoleic acid, liver, brain, and kidney homogenate model systems. It was proved that watercress has antioxidant effects to reduce cellular lipid peroxidation, superoxide anion, and free radical scavenging activities. Intake of watercress in daily diet declined DNA damage and increased blood antioxidant status in healthy adults. Alfredo *et al.* [56] reported phytochemical and antioxidant potential of fresh baby leaves of watercress. Two major classes of healthier secondary plant metabolites phenolics and glucosinolates were identified. The major phenolics determined were chlorogenic acid, quercetin-3-O-rutinoside, dicaffeoyltartaric acid, and isorhamnetin. The glucosinolates were comprised exclusively of gluconasturtiin, the precursor of the anticarcinogenic and antimicrobial compound 2-phenylethyl isothiocyanate. The extracts of organic young baby-leaf watercress exhibited great antioxidant activity due to the presence of caffeic acid, quercetin-3-O-rutinoside, isorhamnetin, and gluconasturtiin. Bahramikia *et al.* [57] studied the antioxidant efficacy

of *N. officinale* extracts using various *in vitro* assay systems and reported that the watercress extract exhibited phenolic and flavonoid contents of 96.2 mg gallic acid equivalents/g dried extract and 63.2 mg catechin equivalents/g dried extract, respectively. The extract possessed potent antioxidant potential that was mediated through direct trapping of free radicals, reducing power, as well as through metal chelating.

ANTIHYPERLIPIDEMIC ACTIVITY

Mousa *et al.* [47] reported that hydroalcoholic extract of watercress demonstrated significant decrease in serum total cholesterol and low-density lipoprotein (LDL) cholesterol levels on repeated oral administration in streptozotocin (STZ) diabetic rats. The study claimed that treatment with watercress extract at a dose of 200 mg/kg for 4 weeks significantly declined the levels of total cholesterol and LDL cholesterol compared to diabetic animals. The mechanism by which watercress exerts lipid-lowering activity could be due to depression in cholesterol absorption from the intestine, its binding with bile acids within the intestine and increasing bile acids excretion, and a decrease of cholesterol biosynthesis also enhanced uptake of LDL by increasing LDL receptors. The study represented that the plant flavonoids, phenolic compounds, and glycosides were responsible for hypocholesterolemia and hypolipidemic activities.

ANTIDIABETIC ACTIVITY

Hoseini *et al.* [58] reported antidiabetic potential of watercress plant employing STZ-induced diabetes in rats. The author claimed that aqueous, ethyl acetate, and methanolic extract of plant exhibited antidiabetic potential. The methanolic extract of the plant at a dose of 800 and 1000 mg/kg significantly reduced the blood glucose level to 132.5 mg/dL and 125.5 mg/dL, respectively, as compared to diabetic control rats 275.7 mg/dL after 1 week of treatment. The ethyl acetate extract at a dose of 100 mg/kg significantly reduced the blood glucose level to 142.5 mg/dL as compared to control rats group 266.5 mg/dL and rats treated with standard drug glibenclamide represented blood glucose level of 255.2 mg/dL at a dose of 100 mg/kg for 2 months. The hypoglycemic potential can be due to stimulation of Langerhans islets. Consumption of watercress leaves impaired the obstacles of hyperglycemia and dyslipidemia associated with diabetes. It also upturns serum glucose levels. Engelen *et al.* [59] reported that watercress comprised glucosinolates (gluconasturtiin), which has been traditionally used for the treatment of diabetes, an endocrinal chronic disease caused by altered carbohydrate metabolism and characterized by elevated serum glucose levels.

ANTIBACTERIAL ACTIVITY

Gerard *et al.* [60] reported antibacterial activity of watercress against various bacterial strains. The results revealed that aqueous and ethanolic extract possessed significant antibacterial activity against *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa*. The phytoconstituents accountable for the antibacterial activity are tannins, flavonoids, terpenoids, and various glycosides, which aided in the treatment of numerous skin bacterial infections. Sadeghi *et al.* [61] synthesized silver nanoparticles (Ag-NPs) using leaves aqueous extract of *N. officinale* R. Br. (NO) and estimated its antibacterial activity against the growth of Gram-positive (*S. aureus*) using standard error mean (SEM). The inhibition was observed in the Ag-NPs against *S. aureus*. The results of SEM revealed that most of *S. aureus* strain was impaired and extensively diminished by the addition of Ag-NPs. The results certified that the *N. officinale* is an excellent eco-friendly and non-toxic source for the synthesis of Ag-NPs. Zafar *et al.* [32] demonstrated antibacterial potential of methanolic extract of *N. officinale* against *E. coli*, *Salmonella typhi*, *Streptococcus pneumoniae*, and *Proteus vulgaris*. Khan *et al.* [62] also reported antibacterial activity of watercress.

ANTI-INFLAMMATORY ACTIVITY

Sadeghi *et al.* [63] demonstrated the anti-inflammatory potential of the hydroalcoholic extract from the aerial parts of *N. officinale* in different animal models of inflammation, that is, carrageenan-induced paw edema in rats, formaldehyde-induced paw edema in rat, and 12-O-tetradecanoylphorbol-13 acetate-evoked ear edema in mice. The results expressed that oral administration of *N. officinale* at (250, 500, and 750 mg/kg) noticeably inhibited carrageenan-induced paw edema over a period of 4 h, and anti-inflammatory activities of the extract at 500 and 750 mg/kg were significantly compared with indomethacin (10 mg/kg). The extract at a dose of 500 mg/kg significantly reduced the development of formalin-induced paw edema in rats at 1, 2, 3, 4, and 24 h after injection of formalin as compared with indomethacin at 10 mg/kg dose. The extract at 5 mg/ear represented noticeable inhibitory effect in comparison with control group in TPA-induced rat ear edema. Molaei *et al.* [64] determined the watercress extract on red blood cells (RBC) membrane stability as an anti-inflammatory agent in female rats. The results indicated that 4 and 6 mg/kg/body weight of watercress extract has anti-inflammatory effect on RBC in female rodents.

ANTIHYPERTENSIVE ACTIVITY

Catty *et al.* [65] reported that watercress (*N. officinale* R. Br.) exhibited angiotensin-converting enzyme inhibitory activity in ethanolic extract with IC₅₀ value 19.05 µg/mL and the maximum IC₅₀ value of ethyl acetate was 2.303 µg/mL. The author reported that n-butanol fraction had the highest TP content with 15.798 mg GAE/g of extract, while maximum TF content was collected in ethyl acetate fraction with 82.847 mg QE/g of the extract.

HEPATOPROTECTIVE ACTIVITY

Ebadollahi *et al.* [66] extracted total parts of plant with alcohol-water and then sequentially fractioned using petroleum ether, n-butanol, and water, respectively. The results revealed that total extract, alcohol-water (175 mg/kg), and aqueous extract (50 mg/kg) of the whole part of *N. officinale* significantly prevented acetaminophen-induced rise in serum levels of aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase. The histopathological changes of liver induced by acetaminophen were considerably reversed following treatment by aqueous and total extract of *N. officinale*. Karami *et al.* [67] investigated the protective activity of the methanolic extract of *N. officinale* against gamma-radiation-induced hepatotoxicity along with histopathological changes. The results revealed that pre-treatment with 100 mg/kg body weight of plant extract per day for 15 days and 2 h before γ -radiation significantly lowered incidence of inflammation (portal and periportal inflammation). Furthermore, liver cells necrosis, edema, and congestion were slightly reduced. The TP and TF contents of the extract

were 11.3±0.4 mg gallic acid equivalents and 9.4±0.7 mg quercetin equivalents per gram of dried extract.

ANTIULCER ACTIVITY

Bettega *et al.* [68] reported the efficacy of ethanolic extract of *N. officinale* as an adjuvant on the healing of traumatic ulcers on rat tongue dorsum. It was observed that the solution of *N. officinale* promoted an increase in fibroblasts with a consequent lift of the deposition of collagen before the 7th day of post-ulceration, and it remained constant throughout the experimental interval. Still, the phytochemical accelerated the substitution rate of immature collagen (rich in fibers, Type III thin) to mature collagen (rich in fiber, Type I thick).

ANTITUBERCULAR ACTIVITY

Rodrigo *et al.* [69] reported that chloroform extract of *N. officinale* demonstrated antitubercular potential. The antimycobacterial properties of *N. officinale* could be attributed in part to the presence of E-phytol (minimum inhibitory concentration [MIC] = 12.5 µg/ml) and palmitic acid (MIC = 50 µg/ml) against *Mycobacterium tuberculosis* H37Rv. Corona *et al.* [22] reported *N. officinale* as most potent (MIC ≤ 100 µg/ml) against the four monoresistant variants tested against tuberculosis.

ANTICANCER ACTIVITY

Boyd *et al.* [70] demonstrated that watercress extract protects colon cancer HT29 cells from oxidative DNA damage induced by various genotoxins, 4-hydroxynonenal, hydrogen peroxide, and fecal water. Hecht *et al.* [71] reported that the consumption of watercress, 56.8 g for each 3 days inhibited the metabolic activities of a key tobacco carcinogen NNK in some smokers. Furthermore, consumption of 85 g of raw watercress once a day for 8 weeks decreased several measures of DNA damage in lymphocytes, a cancer biomarker and increased plasma levels of the antioxidant, β -carotene, and lutein. Rose *et al.* [72] demonstrated that watercress extract, although more specifically the non-volatile 7-methylsulfinyl heptyl isothiocyanate component, reduced MMP9 activity in the human breast cancer MDAMB-231 cell line. Moradi *et al.* [73] examined the antioxidant properties and the phenolic, flavonoid, and anthocyanin contents of hydroalcoholic extract of watercress extract and its effect on the growth of cancerous Hela cells and fibroblasts. The phenolic and flavonoid contents of the extract were determined through a spectrophotometric method. Antiradical activity of the extract was examined using the RSA test of 2, 2-diphenyl-1-picrylhydrazyl. The extract was applied on cancerous Hela cell line and fibroblasts at concentrations varying from 0.625 to 2 mg/mL and cell mortality rates were examined after 24, 48, and 72 h incubation using the MTT test. The survival rate of the cancerous Hela cells decreased with time and increasing concentrations of watercress extract. IC₅₀ values after 24, 48, and 72 h were 373, 349, and 333 µg/mL, respectively. Fallah and Ebrahimi [74] reported the anticancer activity of hydroalcoholic extract of watercress plant on MDA-MB-231 breast cancer cells at different concentrations (0–2 mg/mL) employing MTT assay. Bashir *et al.* [75] reported that watercress juice significantly elevated Uridine 5'-diphospho-glucuronosyltransferase (UDP-glucuronosyltransferase, UGT) enzyme activity in human-derived hepatoma cell line (HepG2) and Lhoste *et al.* [76] reported that the juice from watercress significantly elevated the activities of ethoxyresorufin-O-deethylase and NAD (P) H-quinone reductase in HepG2 cells.

ANTIFUNGAL ACTIVITY

Jafarnikan *et al.* [77] studied antifungal potential of alcoholic watercress extract on the growth of *Fusarium solani*, the causal agent of potato dry rot. The research was carried out employing the paper disc diffusion method and the assessment was done by measuring the growth inhibition zone of the fungus on potato dextrose agar medium. The different concentrations (300, 400, 500, and 600 mg/mL) of watercress extract were prepared and assessed for antifungal activity. The results represented that the highest zone of inhibition was accomplished at

600 mg/mL. The author recommended the use of watercress plant extract in manufacturing natural fungicidal compounds.

NEMATOCIDAL ACTIVITY

Zahradnikova et al. [78] evaluated the effect of watercress eluate and juice on tomato plants inoculated with the northern root-knot nematode (*Meloidogyne hapla*). It was discovered that the treatment of plants with solutions derived from watercress resulted in significant increased yield of fruit. The highest yield increment (by 96–165%) was estimated in the variant with the highest concentration of watercress extracts (macerate+200 mL of juice). While estimating the occupancy of nematodes on roots of tomato plants, the presence of pathogens was found out 0% in all treated variants. The treatment with this phytosolution corroborated not only a nematocidic effect of watercress but also its positive influence on the yield and level of Vitamin C in dependence on increasing concentrations of the effective agent.

NEPHROPROTECTIVE ACTIVITY

Karami et al. [79] inspected the potential of hydroalcoholic extract of *N. officinale* (NOE) and Vitamin E against vancomycin (VCM)-induced nephrotoxicity against adult Wistar male rats. VCM significantly escalated serum creatinine and urea levels, MDA levels, kidney weight/100 mg weight of body, as well as reduced creatinine clearance. NOE (250 and 500 mg/kg) and Vitamin E (500 mg/kg) pretreatment considerably alleviated all of these changes when compared with VCM treated alone. Histological examination of VCM-treated group showed a marked renal injury with tubular epithelial cell desquamation, swelling, and tubular dilatation. These changes were mitigated with NOE and Vitamin E.

ANTITUMOR ACTIVITY

Debora Aparecida de Souza et al. [80] investigated the effects of daily intake of an aqueous solution of watercress on the growth of the experimental Ehrlich tumor (EET). The study showed that, from the 2nd week after tumor inoculation, a reduction in tumor growth was observed in the animals receiving daily dose of aqueous watercress solution in relation to the animals of the control group. The reduction in footpad thickness was significant from the day 10 and was maintained until the end of the experiment, the histopathological examination of footpad of animals treated with aqueous solution of watercress represented reduced necrotic areas.

IMMUNOMODULATORY ACTIVITY

Asadi et al. [81] investigated the immunomodulatory effects of watercress extract on immunological and hematological parameters of rainbow trout (*Oncorhynchus mykiss*). Fish were fed for 21 days with diet supplemented with 0.1% and 1% of watercress extract per 1 kg food and with a normal diet as control. Hematological parameters such as RBC and white blood cells, hematocrit, hemoglobin (Hb), RBC index like mean corpuscular volume, mean corpuscular hemoglobin (MCH), and MCH concentration (MCHC) as well as immunological parameters such as peroxidase, lysozyme and complement activities, total protein, albumin, and globulin levels were measured after 21 days of watercress extract treatment. The results indicated that oral administration of 1% watercress extract in fish may enhance some hematological and immunological parameters including Hb and MCHC, lysozyme and complement activities, total protein, and globulin levels, compared to the controls after 21 days of experimental period. On the basis of these results, author concluded that oral administration of watercress extract may be useful to improve fish's immune system.

PSYCHOACTIVE ACTIVITY

Otsuka et al. [82] performed a literature search of the available publications on medicinal plants. The purpose of the current study was to select plants with psychoactive effects described in a Brazilian literary work written by Pio Correa in 1926. The plant species were

researched through a database search, and all the obtained information were compiled into a new database to analyze possible correlations between the chemical compounds and the psychoactive categories. Of 813 plants searched in the literary work, 104 presented chemical data in the scientific periodicals consulted. 75 of them belong to the stimulant category, in this research, it was mentioned that whole part of *N. officinale* exhibited stimulant potential due to the presence of glucosinolates and carotenoids as vital phytoconstituents.

BURN HEALING ACTIVITY

Zinadah [83] reported the healing potential of watercress oil on thermal and chemical burn injuries in rabbits. Watercress oil was applied to the experimental burns induced chemically and by direct heat, to investigate its effect on epithelization of the hair follicles, and it was observed that animals in treated groups restored the normal architecture more rapidly with significant reduction in closure time of burn.

ANTIRHEUMATIC

Panda et al. [84] reported the traditional use of *N. officinale* (watercress) seeds in the treatment of rheumatism by the residents of Odisha.

CONCLUSION

N. officinale (watercress) plant is now explored as a prominent herb that can be used in medicinal field due to its substantial usage. Conventionally, the plant has been used to cure multiple diseases that are indicated in the manuscript. The present review hence divulges the full therapeutic potential of this plant and invites further researchers to provide a platform to establish it as a standard drug in the pharmaceutical industry.

AUTHORS' CONTRIBUTION

Hazar Hisham and Doha Mohamed were responsible for downloading the relevant publications from SciFinder, PubMed, ScienceDirect, and Google Scholar database and preparing notes for the manuscript. Sachin Chaudhary was responsible for designing the manuscript and assisted in drafting the notes for the manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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