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Research Article

GC-MS PROFILING, ANTIBACTERIAL AND ANTIOXIDANT ACTIVITIES OF *NARDOSTACHYS JATAMANSI* (D. DON) DC. RHIZOMES COLLECTED FROM TAPLEJUNG, GORKHA AND JUMLA DISTRICTS OF NEPAL

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ABSTRACT

Nardostachys jatamansi (D. Don) DC. is a highly traded and critically endangered medicinal plant distributed in the high altitudes of Nepal. This study aims to investigate the chemical profile of essential oil from *N. jatamansi* collected from three different geographical regions of Nepal; Taplejung (NT), Gorkha (NG) and Jumla (NJ) and evaluate their antimicrobial and antioxidant activities. Greater amount of essential oil was obtained with NT and lesser amount was obtained with NJ. GC-MS analysis of NT revealed the identification of total of 35 compounds. In NG and NJ, 28 compounds in each were identified. Altogether 66 compounds were identified in NT, NG and NJ oil samples. Sesquiterpenes were the major compounds present in all three samples. Seven compounds like calarene, seychellene, α-patchoulene, valencene, 7-epi-α-selinene and patchouli alcohol were common in all three samples. Valeranone (37.42%), cadin-4-en-10-ol (28.07%), and patchouli alcohol (6.09%) were identified as the major components in NT. Similarly, valeranone (40.24%), cadin-4-en-10-ol (29.99%), patchouli alcohol (6.71%) with different composition were the major components in NG. In contrast, dihydrotagetone (21.30%), valencene (16.58%), β-pinene (12.56%), guaia-6,9-diene (10.93%) were the major components in NJ. In antimicrobial assay, only NJ showed activity with inhibition zone of 19.0 mm against *Bacillus subtilis, Escherichia coli* and *Candida albicans*. NT and NG oils were inactive. Because of the variation in chemical constituents, the oil samples showed different antibacterial activities. In antioxidant assay (DPPH), all the oil samples showed moderate activity.

Keywords: Antimicrobial, Antioxidant, GC-MS, *Nardostachys jatamansi*

INTRODUCTION

Nardostachys jatamansi is a perennial herb distributed in the alpine and sub-alpine Himalayan regions from Eastern to Western Nepal. It occurs at elevations ranging from 3000-5000 m above sea level (Amatya & Sthapit, 1994) and is among the most commercially important medicinal plant. About 160 tonnes of rhizomes and 2.30 tonnes of oil were exported from Nepal between 2008 and 2018, mainly to India (Chauhan, 2021). About 3.28 tons of Jatamansi oil was exported in 2023 (DPR, 2024). It is a significant source of livelihood of local people in the remote districts of Nepal for generating revenue.

The rhizomes of *N. jatamansi* have a pleasant aroma and it holds great value in Nepalese culture. It is one of the important components of many Ayurvedic formulations. It offers powerful healing effects on mental and physical well-being and is used in the treatment of epilepsy, hysteria, convulsions, heart palpitation, intestinal colic and anti-arrhythmic activities in different systems of traditional medicines (Purohit et al., 2012).

The plant is rich in volatile essential oil called Jatamansi or Spikenard oil which has wide applications in medicine, cosmetics and food industries. It is mainly composed of monoterpenes, sesquiterpenes, aliphatic and aromatic compounds like ester, aldehydes, ketones and alcohols (Chatterjee et al., 2000; Chatterjee et al., 2005, Rawat et al., 2025). The extract and essential oil of *N. jatamansi* displayed a wide range of pharmacological activities such as antidepressant (Khan et al., 2012), anticonvulsant (Rao et al., 2005), antiparkinson (Ahmad et al., 2006), hepatoprotective (Dandagi et al., 2008), antibacterial (Kumar et al., 2006) cardioprotective (Subashini et al., 2006), antialzheimer (Joshi and Parle, 2006; Anupama et al., 2023) and antioxidant (Razack et al., 2015).

There is always a great variation in the yield and chemical profile of Jatamansi oil of different origins. Such variations may arise due to different chemotypes, climatic conditions, soil composition and age of the plant. In addition, harvesting season, post-harvest drying and storage condition also play a significant role. Therefore, it is challenging to obtain oil of similar compositions. The change in chemical constituents and composition affect the quality and consequently, the therapeutic efficacy that alters the overall commercial value (Masotti et al., 2003; Angioni et al., 2006; Rawat et al., 2025). Hence, the aim of the present study is to determine the chemical profile of essential oils collected from the three different geographical locations of Nepal and evaluate their antibacterial and antioxidant activities. There is no comparative data available to date on the chemical profile of *N. jatamansi* collected from Taplejung, Gorkha and Jumal districts of Nepal. Further, research on *N. jatamansi* is highly prioritized by Nepalese government for the economic prosperity of the country (DPR, 2024).

MATERIAL AND METHODS

Plant materials and extraction of essential oil

The rhizomes of *N. jatamansi* (D. Don) DC. were collected from Taplejung (3,770 m, 27.6398° N 87.5812° E), Gorkha (4,000 m, 28.2340° N 84.9038° E) and Jumla (4,214 m, 29.3180° N 82.4185° E) districts in September 2024. The plant material was identified by Prof. R. P. Chaudhary and the voucher specimens were deposited at Research Center for Applied Science and Technology (RECAST) Tribhuvan University (Voucher no. NT-24, NG-24 and NJ-24). The three rhizome samples were allowed to dry under shade separately and crushed to fine pieces. Each plant sample (30 g) was hydro-distilled in a Clevenger apparatus for 7-8 hours. The volatile oil was collected in a sample vial, dried over anhydrous sodium sulphate and stored in a refrigerator for further use.

GC-MS analysis of essential oil

The essential oil samples were analyzed by GC-MS using Shimadzu GC-2010 gas chromatograph, coupled with a mass spectrometer, QP2010 with headspace sampler, auto GC injector and an RTX-5MS capillary column (length 60 m, internal diameter 0.32 mm, 0.25 µm film thickness). The stationary phase consists of 5% diphenyl-95% dimethylpolysiloxane, that separates the sample components based on their chemical properties. The mass selective detector with an ion source was set at temperature of 230 °C and interface temperature was set at 270 °C. The temperature of the injector was adjusted to 250 °C. Sample was diluted with DCM in 1:20 ratio and 1 µL diluted sample was injected in the split less mode. Helium was used as carrier gas with a flow rate of 112 mL/min with a column flow rate of 2 mL/min. The initial oven temperature was maintained at 50 °C for 1 min. The temperature was increased to 300 °C at a rate of 12 °C/min and kept at the final temperature for 5 minutes. MS was operated in electron impact mode with ionization energy of 70 eV. Full scan mass spectra were acquired from 45-350 amu. The total run time was 25 minutes. The detected compounds were identified by processing the raw GC-MS data with Lab-solution software and compared with Flavors and Fragrances of Natural and Synthetic compound (FFNSC 4.0) library. The percentage of each constituent present in essential oil was evaluated from peak area.

Determination of antimicrobial activity

The antimicrobial activities of the extracts were evaluated by the agar well diffusion method as described before (Sapkota et al., 2024) against one Gram-positive bacterium *B. subtilis* (ATCC 6051), one Gram negative bacterium, *E. coli* (ATCC 8739) and one yeast, *C. albicans* (ATCC 2091). The microorganisms were provided by Himalayan Research Institute of Biotechnology, Bhaktapur. The essential oil solutions were prepared at a concentration of 50 mg/mL in 10% DMSO. Then, 50 µL of the oil sample was introduced into the agar well of 6 mm diameter seeded with the respective microorganisms. Negative control experiments were performed using an equivalent volume of 10% DMSO, and positive control experiments were performed using a standard antibiotic, kanamycin (3 mg/mL, 10 µL) for bacteria and itraconazol (25 mg/mL, 10 µL) for fungus. The plates were kept in the refrigerator at 4 °C for 4 hours, then turned over and incubated overnight at 37 °C in an inverted position. At the end of incubation period, clear inhibition zone of bacterial and fungal growth was observed around each well in the presence of different oil samples/standards that were measured.

Determination of antioxidant activity

The antioxidant activity of the essential oils was determined using DPPH free radical as previously described (Sapkota et al., 2024). DPPH solution (2.5 mL, 0.10 mM) was mixed with 0.5 mL catechin or essential oil solutions of different concentrations and incubated in dark for about 30 minutes. Then, the absorbance of control (A_c) and absorbance of essential oil solutions (A_s) were measured at 517 nm

against blank. The percentage of DPPH radical scavenging activity was calculated using formula (1).

Radical scavenging percentage

$$= \frac{A_c - A_s}{A_c} \times 100 \quad \ldots (1)$$

The IC_{50} values were calculated from the plotted graph of radical scavenging percentage against the concentration of catechin or essential oils. All the measurements were carried out in duplicate.

RESULTS AND DISCUSSION

Yield of essential oil

Among the three rhizome samples form Taplejung (NT), Gorkha (NG) and Jumla (NJ), higher oil yield (4.03% v/w) was obtained with NT followed by NG (3.27% v/w). The lesser yield was obtained with NJ (1.37% w/v). So, in terms of oil content, NT and NG can be considered as superior materials than NJ. The content of essential oil in plant materials depends on genetic, environmental, geographic variations as well as collection time and drying methods (Rahimmalek et al., 2013; Fattahi et al., 2016). The three oil samples showed different organoleptic properties like color and odor which varies with chemical constituents and composition (Paudyal et al., 2012). The results are presented in Table 1. The rhizomes of *N. jatamansi* generally contains about 0.5-2% essential oil (Jadhav et al., 2009). In our previous study, 1.5% essential oil was obtained from the sample purchased from Kathmandu market (Paudyal et al., 2012). In another study, it has been reported that the higher yield was obtained with the Jumla sample (1.17%) and lower in Dharan sample (0.53%) (Sharma et al., 2016). Generally, the yield of oil varies depending on the growing condition, collection season and post-harvest drying condition (Rawat et al., 2017; Rawat et al., 2025).

Table 1. Percentage yield and organoleptic properties

Samples	Percentage yield	Organoleptic properties
NT	4.03	Brownish yellow with musk odor
NG	3.27	Straw yellow with musk odor
NJ	1.37	Greenish yellow with pine odor

GC-MS profiling of essential oil samples from Taplejung, Gorkha and Jumla

Environmental as well as genetic factors play a significant role in the production and accumulation of secondary metabolites in plants. Therefore, essential oil of each type showed different GC-MS fingerprint (Hu et al., 2006). Altogether sixty six compounds were identified from Taplejung (NT), Gorkha (NG) and Jumla (NJ) essential oil samples by GC-MS based profiling. Seven compounds like calarene, seychellene, *α*-patchoulene, valencene, 7-epi-*α*-selinene and patchouli alcohol were common in all three essential oils. Sixteen compounds were common in NT and NG. However, their contents were different. Similarly, ten compounds were common in NJ and NT. Only seven compounds were common in NG and NJ.

In Taplejung sample, thirty five compounds were identified constituting 99.99% of the essential oil. Among them, twenty nine were sesquiterpenes (82.85%), three were monoterpenes (8.57%), one ketone (2.85%), one aldehyde (2.85%) and one unsaturated macrocyclic epoxide. Valeranone or jatamanson (37.42%), cadin-4-en-10-ol (28.07%), and patchouli alcohol (6.09%) were identified as the major components. In addition, calarene (2.08%), seychellene (2.01%), valencene (2.34%), methyl isopropenyl ketone dimer (2.47%) and viridiflorol (2.73%) were some other components. Terpenoids are one of the major class of phytochemicals present in volatile oils and they achieve great structural and functional diversity. When plant materials are allowed to dry, they are partially released into the environment. In Gorkha sample, twenty eight compounds were identified constituting 99.27% of the essential oil. Among them, twenty three were sesquiterpenes (82.14%) two were monoterpenes (7.14%), two were ketones (7.14%) and one fatty acid (3.57%). Valeranone (40.24%), cadin-4-en-10-ol (29.99%), patchouli alcohol (6.71%) were the major components. Calarene (1.35%), seychellene (1.16%), valencene (1.67%), Epi-*α*-selinene (2.41%), methyl isopropenyl ketone dimer (2.23%), bicyclogermacrene (2.25%) were some other noticeable components. Ledol, a poisonous sesquiterpene alcohol in very low concentration (0.22%) was detected only in NG. It has been reported that jatamanson has tranquilizing, hypotensive, anticonvulsant and antipyretic activities (Arora et al., 1962; Gunther, 1968; Arora & Arora 2016). As NT and NG have higher percentage of

jatamanson (37.42-40.24%), these oils can be used to manage symptoms related to central nervous system disorders such as anxiety, insomnia and seizures. It may produce significant cooling effect to lower the body temperature and have great potential in aroma therapy, cosmetics and pharmaceutical field. Patchouli alcohol is also the major components of many Jatamansi oil. Its content varies from 40-52% depending on habitat as well as the post-harvest drying method (Chauhan et al., 2017). It's cytotoxic, antibacterial, antiplaque and fungicidal activities have been reported (Singh et al., 2008; Agnihotri et al., 2011). The presence of reasonable amounts of patchouli alcohol in NT and NG (6.09–6.71%) indicated that these oils have great commercial values in the formulation of personal care products.

In Jumla sample also, twenty eight compounds were identified constituting 96.44% of the essential oil. Among them, nineteen were sesquiterpenes (67.85%), seven were monoterpenes (25.00%), one ketone (3.57%) and one ester (3.57%). Dihydrotagetone (21.30%), valencene (16.58%), *β*-pinene (12.56%), guaia-6,9-diene (10.93%) were the major components. A moderate amount of bornyl 2-methylbutanoate (5.12%), dauca-5,8-diene (4.76%), furopelargone A (3.87%), bornyl isovalerate (3.34%) were also present. Although sesquiterpenes were the most abundant compounds, somewhat greater percentage of monoterpenes were detected in NJ. Previous work reported that *β*-pinene (19.26%), valeranone (8.2%), myrtenol (7.22%) were the major constituents of Jumla sample (Sharma et al., 2016). Dihydrotagetone is an acyclic monoterpene ketone common in *Tagetes* (marigold) species (Rezaei et al., 2018) but it has not been reported from *N. jatamansi*. This indicated that *N. jatamansi* growing in Jumla could be of different chemotype. The genetic, climatic and edaphic conditions may determine such differences (Senatore et al., 2004). Valencene is a sweet sesquiterpene common in citrus fruits, mainly in the valencia orange peel. It has great industrial value and widely used as a flavouring agent in food and beverage industries (Schempp *et al*., 2018). Valencene is identified from some plants like *Myrica rubra*, *Cyperus rotundus*, *Alpinia oxyphylla* (Tsoyi et al., 2011; Ambroz et al., 2017, Deng et al., 2024). *β*-pinene is a common metabolite of coniferous plants and it is rich in jatamansi oils from western Nepal like Jumla, Nepalgunj and Surkhet (Sharma et al., 2016). It exerts potential antifungal, antibacterials and antiviral activities due to their toxic effects on membranes (Alma et al., 2004; da Silva et al., 2012). Because of the different constituents present in NJ, it could have great commercial value.

The chemical profile of *N. jatamansi* oil collected from Taplejung, Gorkha and Jumla districts were different. The results are presented in Table 2. The structures of some major compounds are given in Figure 1. These differences are common in plants growing in different geographical locations with diverse climatic and ecological conditions. In the Chinese Pharmacopoeia, nardosinone is considered as a marker compound for the quality evaluation of *N. jatamansi* (Wen et al., 2021). However, it is absent in Taplejung, Gorkha and Jumla oils. The profile of secondary metabolites in *N. jatamansi* is greatly influenced by changing climate that shift the natural habitats. Again, the microclimate of the sites as well as the availability of plants in North or South facing slopes have notable role (Wen et al., 2022). The investigation of chemical diversity in plants growing in different habitat could be helpful to determine the optimum growing condition of such plants for domestication in future.

Table 2. Phytochemicals present in NT, NG, NJ, retention time and relative concentration

SN	Compounds	RT	Relative concentration %		
			NT	NG	NJ
1	Methyl myrtenate	27.865	-	-	0.66
2	*β*-pinene	28.013	-	-	12.56
3	Myrtenyl acetate	29.154	-	-	1.01
4	*β*-maaliene	33.170	0.20	-	-
5	Calarene	34.149	2.08	1.35	1.14
6	Dauca-5,8-diene	34.212	-	-	1.60
7	Epi-*β*-santalene	34.245	-	0.19	-
8	Guaia-6,9-diene	34.538	0.28	-	10.93
9	Seychellene	34.653	2.01	1.16	1.66
10	*cis*-calamenene	34.997	-	-	1.18
11	*α*-patchoulene	35.235	0.30	0.30	0.69
12	Germacrene D	35.320	-	-	0.99

13	9-*epi*-(*E*)-caryophyllene	35.398	0.41	0.38	-
14	Dauca- 5, 8-diene	35.739	-	-	3.11
15	*E*-*β*-ionone	36.422	-	-	0.67
16	*β*-selinene	36.514	0.73	0.27	-
17	Valencene	36.798	2.34	1.67	16.58
18	*α*-selinene	36.865	-	1.11	-
19	Germacrene A	37.045	0.44	-	-
20	Z-8-hydroxylinalool	37.154	-	-	1.06
21	*E*-caryophyllene	37.289	-	-	0.7
22	7-*epi*-*α*-selinene	37.878	1.24	2.41	1.49
23	Methyl isopropenyl ketone	39.311	2.47	2.23	-
24	Dihydroisocaryophyllene epoxide	39.778	1.44	-	-
25	Epi-longipinanol	39.989	0.51	-	-
26	Cadin-4-en-10-ol	40.599	28.07	29.99	-
27	Furopelargone A	40.700	-	-	3.87
28	Viridiflorol	41.056	2.73	0.33	-
29	Globulol	41.061	-	2.65	-
30	Copaborneol	41.175	-	-	1.33
31	Carvenone	41.245	0.94	0.44	-
32	Ledol	41.503	-	0.22	-
33	Javanol	41.868	0.30	-	-
34	Spathulenol	42.423			0.55
35	Bicyclogermacrene	42.535	0.46	2.25	-
36	trans-isolongifolanone	42.976	0.37	-	-
37	Longipinanol	43.199	-	0.31	-
38	2-methyl Bornyl butanoate	43.295	-	-	5.12
39	Pogostol	43.549	0.50	-	-
40	Neo-intermedeol	43.559	-	0.74	-
41	Patchouli alcohol	43.851	6.09	6.71	0.56
42	4(15),5,10(14)-germacratrien-1-ol	44.115	0.51	0.39	-
43	*Z*-jasmone	44.413	-	-	0.68
44	Valeranone	44.479	37.42	40.24	-
45	*E*-14-methylhexadec-8-enal	44.787	-	0.27	-
46	Tetradec-7(*E*)-enal	44.789	0.58	-	-
47	*cis*-cadinene ether	45.126	0.46	-	-
48	Sesquicineol-2- one	45.475	0.22	-	-
49	*β*-atlantol	45.697	0.48	-	-
50	*E*-isovalencenol	45.702	-	0.49	-
51	Cyclocolorenone	45.992	-	0.93	1.26
52	*E*-4-cyclopentadecenone	46.994	-	0.05	-
53	Cedroxyde	46.998	0.95	-	-
54	Caryophylla-4(12),8(13)-dien-5-alpha-ol	47.582	0.39	-	-
55	Eudesma-4(15),7-dien-1- *β*-ol	47.596	-	-	-
56	Eremophilone	47.707	-	0.20	-
57	14-hydroxy-4,5-dihydro-*β*-caryophyllene	48.586	0.55	-	-
58	Nootkatone	49.309	0.23	-	1.10
59	9,11,-epoxy-guaia-3,10(14)-diene	50.354	0.33	-	-
60	5-hydroxy-isobornyl isobutanoate	51.213	3.04	1.99	-
61	15-oxy-α-muurolene	51.408	0.27	-	0.75

62	Sesquicineole	51.683	0.43	-	-
63	Oplopanone	52.327	0.22	-	-
64	3-Hexenyl-methyl butanoate |	53.296	-	-	0.55
65	Bornyl isovalerate	55.544	-	-	3.34
66	Dihydrotagetone	62.622	-	-	21.30
	Total	-	99.99	99.27	96.44

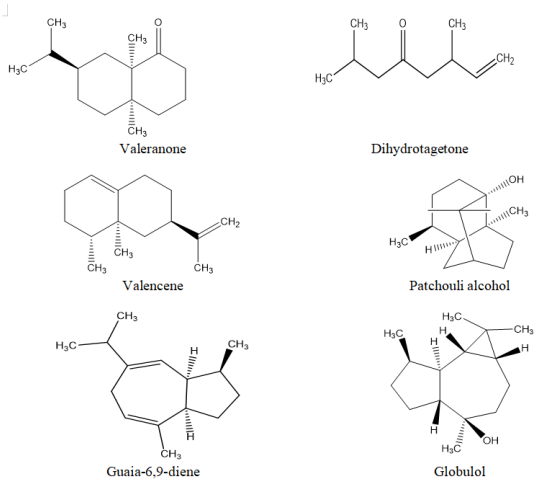

Figure 1. Structure of some major compounds present in *N. jatamansi* essential oil

Antimicrobial activity

In the antimicrobial assay, variation in activities were observed among three essential oil samples from Taplejung, Gorkha and Jumla districts. Only Jumla oil sample, NJ, showed activities against all three tested microorganisms with equal zones of inhibition of 19.0 mm including 6 mm well. Both Taplejung, NT and Gorkha, NJ samples did not show any activities. It could be due to somewhat similar constituents with different compositions present in NT and NG oil samples. The results are presented in Table 3 and Figure 2. Several studies have shown that essential oils have antibacterial properties (Thielmann et al., 2019). However, the chemical constituents and compositions of particular oil determine the antimicrobial activities (Burt, 2004). The antimicrobial activities of NJ could be due to the presence of major amounts of specific compounds like dihydrotagetone, valencene, *β*-pinene and other terpenoids. Dihydrotagetone, which is the major component of *Tagetes minuta* essential oil, showed antibacterial activity against Gram positive bacteria (Senatore et al., 2004). Both antibacterial and antifungal properties of valencene have been reported (Liu et al., 2012; Carneiro et al., 2025). The potent activity of *β*-pinene against both Gram positive and negative bacteria as well as fungus have been reported (de Macêdo Andrade et al., 2018). In addition to the dominant effects of some major components, in some cases, minor components are also critical for such activities. Therefore, in general, whole essential oils have a greater antibacterial activity than the major components due to synergistic effect (Gill et al., 2002). Essential oils that display antimicrobial properties have great potential in the formulation of antiseptics and food preservatives. Again, the antibacterial activity depends on the terpene content. The hydrophobic nature of terpene in essential oil partitioned the lipids present in the cell membrane of bacteria. This results in the leakage and finally death of bacterial cell structure occurred (Devi et al., 2010).

Table 3. Antibacterial activities of *N. jatamansi* essential oils

Oil samples	**Inhibition zone in mm including well**		
	B. subtilis	***E.coli***	***C. albicans***
NT	-	-	-
NG	-	-	-
NJ	19.0	19.0	19.0
Kanamycin	22.0	24.0	-
Itraconazole	-	-	20.0
Negative control	-	-	-

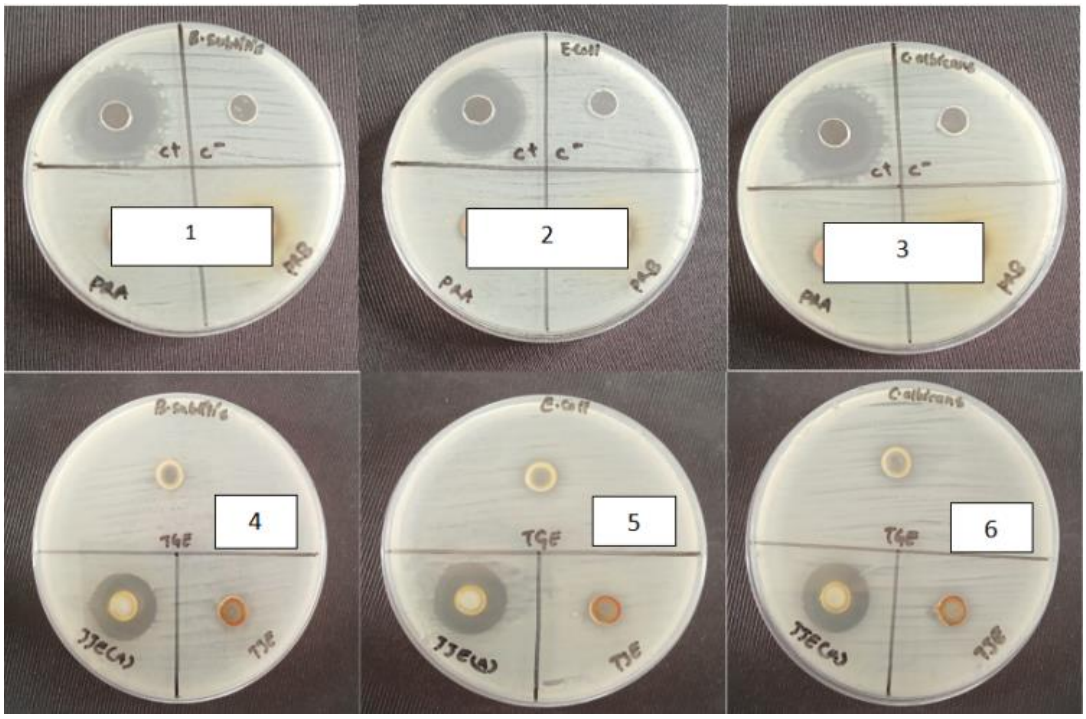

Figure 2. Plate 1, 2, 3-positive and negative controls. Plate 4-antibacterial activity against *B. subtilis*, Jatamansi Gorkha essential oil (JGE), Jatamansi Taplejung essential oil (JTE) and Jatamansi Jumla essential oil (JJE), Plate 5-against *E. coli*, Plate 6-against *C. albicans*

Antioxidant activity

Essential oils derived from plants contain a high diversity of volatile, aromatic, and low-molecular weight compounds. Some common volatile compounds with antioxidant properties are thymol, carvacrol, methyl chavicol, geraniol, *p*-cymene, menthol, eucalyptol (Santos et al., 2018; Gursul et al., 2019). Antioxidant activity of essential oil samples of Taplejung, Gorkha and Jumla was examined by DPPH free radical scavenging assay. The results showed that all the tested oil samples showed moderate radical scavenging activities (IC_{50} values: NT- 711.11±24.89 µg/mL, NG-713.96±33.76 µg/mL and NJ-970.25±37.91 µg/mL) whereas the standard antioxidant compound, catechin showed IC_{50} value of 10.62±1.06 µg/mL. The IC_{50} values were expressed as the mean of two values accompanied by standard deviation. The results are present in Figure 3.

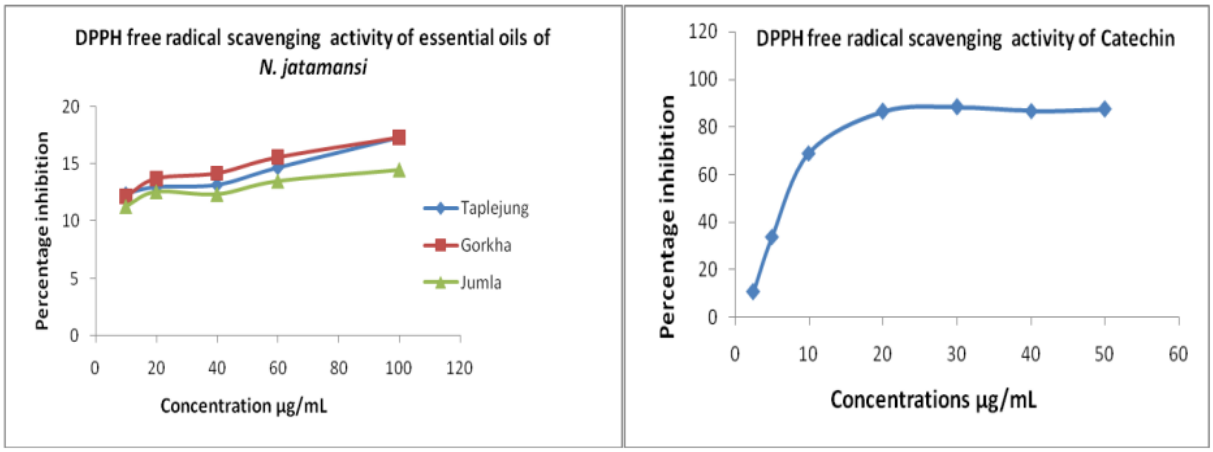

Figure 3. Plots of concentration against percentage radical scavenging of three essential oil samples and catechin

Antioxidants have the ability to inhibit oxidative stress which is simply the disturbance in oxidant-antioxidant balance that cause several human diseases. Antioxidants stabilize and deactivate free radicals before they damage cells (Poprac et al., 2017). It has been reported that the essential oil from *N. chinensis* showed moderate DPPH free radical scavenging activity (IC_{50} 637.47 µg/mL). The major constituents identified were calarene, aristolone, α-selinene and β-maaliene (Wang et al., 2010). Similarly, the moderate DPPH radical scavenging activity of *N. jatamansi* essential oil has been reported (IC_{50} of 0.95±0.008 mg/mL). The major constituents were guaia-6,9-diene, calarene, jatamansone, *α*-gurjunene, valencene, *α*-maaliene, sprojatamol, and caratol (Majeed et al., 2023). Therefore, the overall constituents and compositions of essential oils are responsible for such activities. Generally, the primary components play a major role, but the minor constituents have also significant role (Karakoti et al, 2022). The constituents of our samples, NT, NG and NJ are different so they showed different DPPH free radical scavenging activities.

CONCLUSION

The present study highlights the variation in oil content, phytochemical profile and antibacterial activities of *N. jatamansi* essential oil collected from Taplejung, Gorkha and Jumla districts of Nepal. Altogether 66 compounds were identified from three essential oil samples. In NT, 35 compounds were identified and in NG and NJ, 28 compounds in each were identified. Sesquiterpenes were the major compounds present in all three samples. Valeranone, cadin-4-en-10-ol, and patchouli alcohol were identified as the major components in NT and NG. However, their contents were different. In contrast, dihydrotagetone, valencene, *β*-pinene, guaia-6,9-diene were the major components in NJ. Only seven compounds like calarene, seychellene, *α*-patchoulene, valencene, 7-*epi*-*α*-selinene and patchouli alcohol were common in all three essential oils. The content of monoterpenes was higher in NJ than in NT and NG. The variation in chemical constituents could be due to ecological and genetic factors. In antimicrobial assay, only NJ showed activity with inhibition zone of 19.0 mm against all tested microorganisms, *B. subtilis*, *E. coli* and *C. albicans*. NT and NG were inactive. In antioxidant assay, NT, NG and NJ showed moderate DPPH radical scavenging activities. The chemotypic variation of essential oils across three different geographical regions of Nepal presents both a challenge for quality standardization and an opportunity for the selective, value-added use of regional resources. For instance, NJ oil may be prioritized for antimicrobial products formulations, while NT and NG oils may be better suited for sedative, hypnotic and anxiolytic drugs formulation. Therefore, routine analysis of jatamansi oil samples obtained from different sources is necessary to evaluate and monitor their quality for commercial applications.

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AUTHORS CONTRIBUTION

Conceptualization: MR, CKS, BRP; Methodology: RP, JS; Validation: MR; Investigation: MR, CKS and BRP; Data analysis: MR, RP and JS; Writing-original draft: MR, RP and JS; Writing-review & editing: MR, RP, CKS, JS, BRP; Supervision: MR; Funding acquisition: MR

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

DATA AVAILABILITY STATEMENT

The GCMS data are available from the corresponding author.

SUPPLEMENTARY INFORMATION

None

REFERENCES

Agnihotri, S., Wakode, S., & Ali, M. (2011). Chemical composition, antimicrobial and topical anti-inflammatory activity of *Valeriana jatamansi* Jones. essential oil. Journal of Essential Oil Bearing Plants, *14*(4), 417–422. https://doi.org/10.1080/0972060X.2011.10643596.

Ahmad, M., Yousuf, S., Khan, M. B., Hoda, M. N., Ahmad, A. S., Ansari, M. A., ... & Islam, F. (2006). Attenuation by *Nardostachys jatamansi* of 6-hydroxydopamine-induced parkinsonism in rats: behavioral, neurochemical, and immunohistochemical studies. Pharmacology Biochemistry and Behavior, *83*(1), 150–160. https://doi.org/10.1016/j.pbb.2006.01.005.

Alma, M. H., Nitz, S., Kollmannsberger, H., Digrak, M., Efe, F. T., & Yilmaz, N. (2004). Chemical composition and antimicrobial activity of the essential oils from the gum of Turkish pistachio (*Pistacia vera* L.). *Journal of Agriculture and Food Chemistry*, *52*, 3911–3914. https://doi.org/10.1021/jf040014e.

Amatya, G. & V. Sthapit (1994): A Note on *Nardostachys jatamansi*. *Journal of Herbs, Spices & Medicinal Plants 2*(2): 39–47. https://doi.org/10.1300/J044v02n02_06.

Ambroz, M., Matouskova, P., Skarka, A., Zajdlova, M., Zakova, K., and Skalova, L. (2017). The effects of selected Sesquiterpenes from *Myrica rubra* essential oil on the efficacy of doxorubicin in sensitive and resistant cancer cell lines. *Molecules* *22*:1021. doi: 10.3390/molecules22061021.

Angioni, A., Barra, A., Coroneo, V., Dessi, S., Cabras, P. (2006). Chemical composition, seasonal variability, and antifungal activity of *Lavandula stoechas* L. ssp. stoechas essential oils from stem/leaves and flowers. *Journal of Agriculture and Food Chemistry*, *54*, 4364–4370. https://doi.org/10.1021/jf0603329.

Anupama, K. P., Shilpa, O., Antony, A., & Gurushankara, H. P. (2023). Jatamansinol from *Nardostachys jatamansi*: A multi-targeted neuroprotective agent for Alzheimer's disease. *Journal of Biomolecular Structure and Dynamics*, *41*(1), 200–220. https://doi.org/10.1080/07391102.2021.2005681.

Arora, R. B., Singh, M., & Kanta, C. (1962). Tranquilizing activity of jatamansone-A sesquiterpene from *Nardostachys jatamansi*. *Life Sciences*, *1*(6), 225–228. https://doi.org/10.1016/0024-3205(62)90001-2.

Arora, R. B., & Arora, C. K. (2016). Hypotensive and tranquillizing activity of jatamansone (valeranone) a sesquiterpene from *Nardostachys jatamansi* DC. In *Pharmacology of Oriental Plants: Proceedings of the First International Pharmacological Meeting, Stockholm, 22–25 August, 1961* (p. 51).

Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods-A review. *International Journal of Food Microbiology*, *94*, 223–253. https://doi.org/10.1016/j.ijfoodmicro.2004.03.022

Chatterjee, A., Basak, B., Saha, M., Dutta, U., Mukhopadhyay, C., Banerji, J., ... & Harigaya, Y. (2000). Structure and stereochemistry of nardostachysin, a new terpenoid ester constituent of the rhizomes of *Nardostachys jatamansi*. *Journal of Natural Products*, *63*(11), 1531-1533. https://doi.org/10.1021/np990503m

Chatterjee, A., Basak, B., Datta, U., Banerji, J., Neuman, A., & Prange, T. (2005). Studies on the chemical constituents of *Nardostachys jatamansi* DC (Valerianaceae). *Indian Journal of Chemistry*, *36*, 430–433.

Carneiro, J. N. P., Dos Santos, A. T. L., Fonseca, V. J. A., de Freitas, M. A., dos Santos Silva, F., de Souza, L. A. L., ... & Morais-Braga, M. F. B. (2025). Antifungal action of valencene and nootkatone compounds in association with fluconazole and their mechanism of action against *Candida* spp. and *Pichia kudriavzevii* strains. *Current Microbiology*, *82*(4), 1-11. https://doi.org/10.1007/s00284-025-04133-0.

Chauhan, R. S., Nautiyal, M. C., Figueredo, G., & Rana, V. S. (2017). Effect of post harvest drying methods on the essential oil composition of *Nardostachys jatamansi* DC. *Journal of Essential Oil Bearing Plants*, *20*(4), 1090-1096. https://doi.org/10.1080/0972060X.2017.1363001.

Chauhan, H. K. (2021). *Nardostachys jatamansi*. The IUCN Red List of Threatened Species 2021: e.T50126627A88304158.

Dandagi, P. M., Patil, M. B., Mastiholimath, V. S., Gadad, A. P., & Dhumansure, R. H. (2008). Development and evaluation of hepatoprotective polyherbal formulation containing some indigenous medicinal plants. Indian Journal of Pharmaceutical Sciences, *70*(2), 265. doi: 10.4103/0250-474X.41474.

da Silva, A. C.; Lopes, P. M.; de Azevedo, M. M.; Costa, D. C.; Alviano, C. S.; Alviano, D. S (2012). Biological activities of alpha-pinene and

beta-pinene enantiomers. *Molecules*, *17*, 6305–6316. https://doi.org/10.3390/molecules17066305

Deng, X., Ye, Z., Duan, J., Chen, F., Zhi, Y., & Huang, M. (2024). Complete pathway elucidation and heterologous reconstitution of (+)-nootkatone biosynthesis from *Alpinia oxyphylla*. *New Phytologist*, *241*, 779–792. doi: 10.1111/nph.19375.

de Macêdo Andrade, A. C., Rosalen, P. L., Freires, I. A., Scotti, L., Scotti, M. T., Aquino, S. G., & de Castro, R. D. (2018). Antifungal activity, mode of action, docking prediction and anti-biofilm effects of (+)-β-pinene enantiomers against *Candida* spp. *Current Topics in Medicinal Chemistry*, *18*(29), 2481–2490. https://doi.org/10.2174/1568026618666181115103104.

Devi, K. P., Nisha, S. A., Sakthivel, R., & Pandian, S. K. (2010). Eugenol (an essential oil of clove) acts as an antibacterial agent against *Salmonella typhi* by disrupting the cellular membrane. *Journal of Ethnopharmacology*, *130*, 107–115. https://doi.org/10.1016/j.jep.2010.04.025.

DPR (2024). Jatamansi Conservation Action Plan (2081-2090). Department of Plant Resource. Ministry of forest and environment. Thapathali, Kathmandu.

Fattahi, B., Nazeri, V., Kalantari, S., Bonfill, M., & Fattahi, M. (2016). Essential oil variation in wild-growing populations of *Salvia reuterana* Boiss. collected from Iran: Using GC–MS and multivariate analysis. *Industrial Crops and Products*, *81*, 180–190. https://doi.org/10.1016/j.indcrop.2015.11.061

Gill, A. O., Delaquis, P., Russo, P., & Holley, R. A. (2002). Evaluation of antilisterial action of cilantro oil on vacuum packed ham. *International Journal of Food Microbiology*, *73*, 83-92. https://doi.org/10.1016/S0168-1605(01)00712-7.

Gunther, R.T. (1968). The Greek herbal of Discorides. Hafner, London, pp. 10.

Gursul, S., Karabulut, I., & Durmaz, G. (2019). Antioxidant efficacy of thymol and carvacrol in microencapsulated walnut oil triacylglycerols. *Food Chemistry*, *278*, 805–810. https://doi.org/10.1016/j.foodchem.2018.11.134.

Hu, L. F., Li, S. P., Cao, H., Liu, J. J., Gao, J. L., Yang, F. Q., & Wang, Y. T. (2006). GC-MS fingerprint of Pogostemon cablin in China. *Journal of Pharmaceutical and Biomedical Analysis*, *42*, 200–206. https://doi.org/10.1016/j.jpba.2005.09.015.

Jadhav, V. M., Thorat, R. M., Kadam, V. J., & Kamble, S. S. (2009). Herbal anxiolyte: *Nardostachys Jatamansi*. *Journal of Pharmacy Research*, *2*(8), 1208–1211.

Joshi, H., & Parle, M. (2006). *Nardostachys jatamansi* improves learning and memory in mice. *Journal of medicinal food*, *9*(1), 113-118.https://doi.org/10.1089/jmf.2006.9.113.

Karakoti, H., Mahawer, S.K., Tewari, M., Kumar, R., Prakash, O., de Oliveira, M.S., & Rawat, D.S. (2022). Phytochemical profile, in vitro bioactivity evaluation, *in silico* molecular docking and ADMET study of essential oils of three *Vitex* species grown in Tarai region of Uttarakhand. *Antioxidants*, *11*, 1911.https://doi.org/10.3390/antiox11101911.

Khan, M. B., Hoda, M. N., Ishrat, T., Ahmad, S., Moshahid Khan, M., Ahmad, A., Ahmad, A., Yusuf, S. & Islam, F. (2012). Neuroprotective efficacy of *Nardostachys jatamansi* and crocetin in conjunction with selenium in cognitive impairment. *Neurological Sciences*, *33*(5), 1011-1020. https://doi.org/10.1007/s10072-011-0880-1

Kumar, V. P., Chauhan, N. S., Padh, H., & Rajani, M. (2006). Search for antibacterial and antifungal agents from selected Indian medicinal plants. *Journal of Ethnopharmacology*, *107*(2), 182–188. https://doi.org/10.1016/j.jep.2006.03.013.

Liu, K., Chen, Q., Liu, Y., Zhou, X., & Wang, X. (2012). Isolation and biological activities of decanal, linalool, valencene, and octanal from sweet orange oil. *Journal of Food Science*, *77*, C1156–C1161. https://doi.org/10.1111/J.1750-3841.2012.02924.X.

Majeed, A., Guleria, S., Sharma, N., Salaria, K. H., Aiman, F., Singh, B., & Gupta, V. K. (2023). Antioxidant capacity and combinatorial antimicrobial effects of *Nardostachys jatamansi* essential oil with conventional antibiotics against some drug resistant bacteria. *Current Research in Biotechnology*, *5*, 100118. https://doi.org/10.1016/j.crbiot.2022.100118.

Masotti, V., Juteau, F., Bessie`re, J.M., & Viano, J., (2003). Seasonal and phenological variations of the essential oil from the narrow endemic species *Artemisia molinieri* and its biological activities. *Journal of Agriculture and Food Chemistry*, *51*, 7115–7121. https://doi.org/10.1021/jf034621y.

Paudyal, M. P., Rajbhandari, M., Basnet, P., Yahara, S., & Gewali, M. B. (2012). Quality assessment of the essential oils from *Nardostachys jatamansi* (D. Don) DC and *Nardostachys*

chinensis batal obtained from Kathmandu valley market. *Scientific World*, *10*(10), 13–16.

Poprac, P., Jomova, K., Simunkova, M., Kollar, V., Rhodes, C. J., & Valko, M. (2017). Targeting free radicals in oxidative stress-related human diseases. *Trends in Pharmacological Sciences*, *38*(7), 592–607. doi: 10.1016/j.tips.2017.04.005.

Purohit, V., Chauhan, R., Andola, H., Pratti, P., Nautiyal, M.C., & Nautiyal, A. (2012). *Nardostachys jatamansi* DC. Is at risk in the Himalayan region. *Current Science*. *103*, 251–252.

Rahimmalek, M., & Goli, S. A. H. (2013). Evaluation of six drying treatments with respect to essential oil yield, composition and color characteristics of *Thymys daenensis* subsp. daenensis. Celak leaves. *Industrial Crops and Products*, *42*, 613–619. https://doi.org/10.1016/j.indcrop.2012.06.012.

Rao, V. S., Rao, A., & Karanth, K. S. (2005). Anticonvulsant and neurotoxicity profile of *Nardostachys jatamansi* in rats. *Journal of Ethnopharmacology*, *102*(3), 351–356. https://doi.org/10.1016/j.jep.2005.06.031.

Rawat S, Jugran AK, Bhatt ID, Rawal RS, Andola HC, & Dhar U. (2017). Essential oil composition and antioxidant activity in *Valeriana jatamansi* Jones: influence of seasons and growing sources. *Journal of Essential Oil Research*, *29*(1), 101–107. https://doi.org/10.1080/10412905.2016.1189856

Rawat, V., Rawat, S., Kewlani, P., Bahukhandi, A., Bhatt, I. D., Nandi, S. K., & Pande, V. (2025). Essential oil and polyphenolic composition in *Nardostachys jatamansi* influenced by different plant parts and drying conditions. *Discover Plants*, *2*(1), 280. https://doi.org/10.1007/s44372-025-00360-8.

Razack, S., Hemanth Kumar, K., Nallamuthu, I., Naika, M., & Khanum, F. (2015). Antioxidant, biomolecule oxidation protective activities of *Nardostachys jatamansi* DC and its phytochemical analysis by RP-HPLC and GC-MS. *Antioxidants*, *4*(1), 185–203. https://doi.org/10.3390/antiox4010185.

Rezaei, F., Jamei, R., & Heidari, R. (2018). Evaluation of volatile profile, fatty acids composition and in vitro bioactivity of *Tagetes minuta* growing wild in Northern Iran. *Advanced Pharmaceutical Bulletin*, *8*(1), 115. doi: 10.15171/apb.2018.014.

Santos, B. C. S., Pires, A. S., Yamamoto, C. H., Couri, M. R. C., Taranto, A. G., Alves, M. S., ... & de Sousa, O. V. (2018). Methyl chavicol and its synthetic analogue as possible antioxidant and antilipase agents based on the in vitro and *in silico* assays. *Oxidative Medicine and Cellular Longevity*, *2018*(1), 2189348. https://doi.org/10.1155/2018/2189348.

Sapkota, S., Maharjan, A., Tiwari, S., & Rajbhandari, M. (2024). Phytochemical analysis, antioxidant potential and antibacterial activities of different anatomical parts of *Hypericum cordifolium* choisy. *The Scientific World Journal*, 2024(1), 8128813. https://doi.org/10.1155/2024/8128813.

Schempp, F. M., Drummond, L., Buchhaupt, M., & Schrader, J. (2018). Microbial cell factories for the production of Terpenoid flavor and fragrance compounds. J. Agric. Food Chem. *66*, 2247–2258. doi: 10.1021/acs.jafc.7b00473.

Senatore, F., Napolitano, F., Mohamed, M. A. H., Harris, P. J. C., Mnkeni, P. N. S., & Henderson, J. (2004). Antibacterial activity of *Tagetes minuta* L.(Asteraceae) essential oil with different chemical composition. *Flavour and fragrance journal*, *19*(6), 574–578. https://doi.org/10.1002/ffj.1358.

Sharma, N., Sharma, A. R., Patel, B. D., & Shrestha, K. (2016). Investigation on phytochemical, antimicrobial activity and essential oil constituents of *Nardostachys jatamansi* DC. in different regions of Nepal. *Journal of Coastal Life Medicine*, *4*(1), 56–60. https://doi.org/10.12980/jclm.4.2016j5-188.

Singh, A., Rahman, L., Kukreja, A. K., Yadav, A., Naqvi, A.A., Khanuja, S.P.S. (2008). Seasonal effect on essential oil content and quality of *Valerian wallichii* DC. cultivated in Uttarakhand hills (India). *Indian Perfumer*, *52*, 49–52.

Subashini, R., Yogeeta, S., Gnanapragasam, A., & Devaki, T. (2006). Protective effect of *Nardostachys jatamansi* on oxidative injury and cellular abnormalities during doxorubicin-induced cardiac damage in rats. *Journal of Pharmacy and Pharmacology*, *58*(2), 257–262. https://doi.org/10.1211/jpp.58.2.0014.

Thielmann, J., Muranyi, P., & Kazman, P. (2019). Screening essential oils for their antimicrobial activities against the foodborne pathogenic bacteria *Escherichia coli* and *Staphylococcus aureus*. *Heliyon*, *5*(6). https://doi.org/10.3390/foods10071596

Tsoyi, K., Jang, H. J., Lee, Y. S., Kim, Y. M., Kim, H. J., Seo, H. G., Lee, J. H., Kwak, J. H., Lee, D. U., & Chang, K. C. (2011). Nootkatone and valencene from rhizomes of *Cyperus rotundus* increase survival rates in septic mice due to heme oxygenase-1 induction. *Journal of*

Ethnopharmacolohy, *137*, 1311–1317. https://doi.org/10.1016/j.jep.2011.07.062.

Wang, J., Zhao, J., Liu, H., Zhou, L., Liu, Z., Wang, J., Han, J., Yu, Z., & Yang, F. (2010). Chemical analysis and biological activity of the essential oils of two valerianaceous species from China: *Nardostachys chinensis* and *Valeriana officinalis*. *Molecules*, *15*(9), 6411–6422.

Wen, J., Liu, L., Li, J., & He, Y. (2021). A review of nardosinone for pharmacological activities. *European Journal of Pharmacology*, *908*, 174343. https://doi.org/10.1016/j.ejphar.2021.174343G.

Wen, J., Zhou, L., Liu, L., & He, Y. (2022). Analysis of the impact of climate change on the distribution and active compound content of the plateau medicinal plant *Nardostachys jatamansi* (D. Don) DC. *Industrial Crops and Products*, *187*, 115438. https://doi.org/10.1016/j.indcrop.2022.115438.