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Comprehensive review on *Saussurea costus*: Exploring Antimicrobial potentials

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ABSTRACT

Saussurea costus (Falc.) Lipsch., commonly known as Kuth or Costus, is a high-value medicinal plant from the Himalayan region and used traditionally in all forms of traditional medicines like Ayurveda, Siddha, and Unani. This comprehensive review explores the antimicrobial potential of *S.costus* emphasizing its ethnomedicinal use in traditional practices, its intrinsic phytochemistry, and its pharmacological interpretation. The roots of *S. costus* contain numerous bioactive compounds, especially sesquiterpenes (costunolide and dehydrocostus lactone), and they have been known to have anti-inflammatory, analgesic, and antimicrobial properties. A total of thirteen antimicrobial studies is reviewed, covering various extracts of methanol, ethanol, chloroform, aqueous, and essential oils tested against a wide spectrum of bacterial and fungal strains, including *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Candida albicans*, and *Aspergillus niger*. The results of the review reveal significant antimicrobial activity, especially in methanol and chloroform extracts, particularly against multidrug-resistant strains. Thus, the traditional use of Kuth against respiratory, gastrointestinal, and skin ailments complies with the scientifically validated antimicrobial effects. This review emphasizes the therapeutic value of *S. costus* as a potential natural antibiotic and advocates for further clinical validation and pharmacological developments to support its integration into modern therapeutic applications.

INTRODUCTION

Saussurea costus, often called Kuth root or Costus in English, is a genus of the Compositae (Asteraceae) family. It is commonly known as Gostham in Tamil, Kustha in Sanskrit, Kust in Arabic and Persian, Kut, Kur, Pachak in Hindi and Bengali, Kostum, Putchuk, Upaleta, Kur in Gujarati, Kot, Kust in Punjabi, Changala in Telugu, Sepuddy in Malayalam, Kostha in Kannada, and Kuth, Postkhai in Kashmiri [1].

The genus *Saussurea* is primarily sourced from the Himalayan region and is recognized for its medicinal properties. It possesses 410 species throughout the temperate and arctic regions of Asia, North America, and Europe, with the majority of species found in the Himalayas and in the alpine regions of Central Asia. India contains about 61 species of this genus. *Saussurea costus* (Falc.) Lipsch. is now taxonomically synonymous with *Dolomiaea costus* (Falc.) however, the constancy of use of the earlier name occurs in scientific and traditional practice because people are more accustomed to its usage [2]. It is mostly distributed on moist rocky slopes and in damp ravines of forests, from Kashmir to Uttaranchal, at heights of 2600 to 4000 meters. The plant can be grown with root cuttings or seeds [3].

Saussurea costus has a diverse history of action and pharmacological effects, such as hepatoprotective, anticancer, anti-inflammatory, anti-ulcer, and antimicrobial properties. It is recognized for its therapeutic use as a carminative, aphrodisiac, anthelmintic, and general tonic. It was traditionally believed to enhance brain function and was used in disorders related to the liver, kidneys, and blood. It has also been used for deafness, headache, paralysis, asthma, cough and chronic febrile conditions, inflammation, and many other eye disorders [4-7].

The medicinal uses of *Saussurea costus* can be generally related to a variety of biological activities, of which antibacterial activity is noted. A long history of uses and a wide range of phytoconstituents have been identified; nevertheless, specific studies of uses are limited. Accordingly, this study aimed to investigate the antimicrobial effects of *Saussurea costus* and to further explore its potential therapeutic benefits based on traditional knowledge.

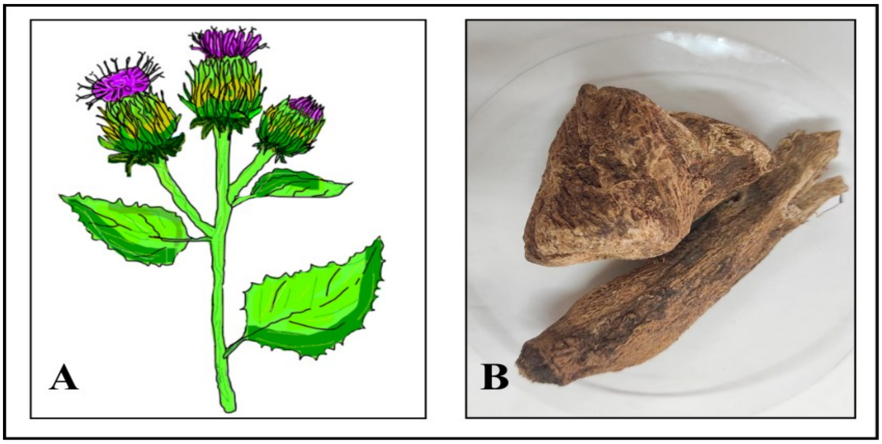

Fig 1. Saussurea costus Lipsch Plant (A); Root (B)

Taxonomical classification

Taxonomical classification is the system scientists use to organize and group plants and animals based on their similarities and differences. It helps us understand the relationships between different living organisms. In this review, we present the taxonomical classification of *Saussurea costus* [8].

Botanical name: *Saussurea costus* (Falc.) Lipsch.
Family: Asteraceae
Kingdom: Plantae
Infra division: Angiospermae
Division: Tracheophyta
Subdivision: Spermatophytina
Class: Eudicots
Superorder: Asteranae
Order: Asterales
Genus: *Saussurea*
Species: Costus

Distribution

This species usually grows on damp, rocky slopes and in ravines within forested areas from Kashmir to Uttarakhand, at elevations between 2,600 and 4,000 meters. It is a tall, perennial herb with an overall height of approximately 2 meters. The lower (basal) leaves are broad and attached to winged stalks (petioles), whereas the upper (cauline) leaves are smaller and often basely lobed or clasping the stem. It flowers from June to August, and the flowers are about 2 cm long and bluish-purple to nearly black in color, found in rounded clusters. It is principally propagated via root cuttings and seeds. Historically, the dried root is the main part of the plant used in traditional systems of medicine [9].

Ethnobotanical uses

The Indian systems of medicine, like Siddha, Ayurveda, and Unani, have acknowledged the therapeutic qualities of *Saussurea costus* and its variety of pharmacological effects. *S. costus* roots have long been used as an antispasmodic for various conditions, including rheumatism, asthma, chronic cough, cholera, and chronic skin problems [10]. It is also used to combat health issues like colds, malaria, leprosy, hiccups, rheumatic pain, and stomach and toothaches. The plant is reputed to help the treatment of gout and erysipelas and aid in spermatogenesis [11]. It has extensive use in various indigenous medical traditions for conditions like rheumatism, the common cold, headaches, abdominal pain, and throat infections [12].

Saussurea costus has a variety of biological activities beyond its uses. It has noteworthy antimicrobial, cytotoxic, and photocatalytic activities [13]. Its anti-inflammatory activity reinforces its use to treat rheumatic diseases [11]. The plant has hepatoprotective, antioxidant, and anti-urolithiatic actions [14]. In addition, it has been displayed to have anti-hepatotoxic, anti-hypercholesterolemic, hypercholesterolemic, and antithyroidal effects [15]. Studies also show its relative effectiveness in preventing damage to reproductive, renal, pulmonary, and splenic tissues as well as reproductive toxicity [16]. Furthermore, *S. costus* has shown antifungal activities, particularly with regard to species of *Candida* [17]. The therapeutic usefulness of *Saussurea costus* is attributed to its phytochemical discrepancies, antimicrobial abilities, and antifeedant characteristics, with all of these features being included in modern scientific reports.

Phytochemistry of Saussurea *costus*

The antimicrobial and cancer-fighting benefits of *Saussurea costus*, a valuable medicinal plant, mainly come from the many beneficial natural compounds in its roots, like flavonoids, sesquiterpenoids, and essential oils [17,18]. The plant has various pharmacological properties, including anti-cancer and anti-diabetic effects. Its wide range of secondary metabolites is responsible for these actions [19].

Table 1: Parts used and bioactive constituents of *Saussurea costus*

Plant part	Usage frequency	Active compounds
Root	Most harvested	Flavonoids, Dehydrocostus lactone, Sesquiterpenes, and Costunolide
Flower	Moderate	Essential oils
Rhizomes	Moderate	Lignans, triterpenes
Whole plant	Least	Volatile oils, phytosterols

The Active Constituents Identified in roots are Sesquiterpenes that have an open chain structure include Nemophila-1(10)-7(11)-die. Examples of sesquiterpenes and monoterpenes include α-pinene, α-caryophyllene, and p-cymene. Two important sesquiterpene lactones with anticancer effects are costunolide and dehydrocostus lactone [19]. The phytochemicals found in *Saussurea costus* roots include 79.80% sesquiterpenoids and 13.25% monoterpenoids [19].

The classification of sesquiterpenes is based on their carbocyclic skeletons. With 56 known compounds, guaiane-type sesquiterpenes have a unique ring structure made up of 5, 7, and 5 carbon atoms along with a γ-lactone. They also frequently have exocyclic double bonds at locations C(4)=C(15), C(10)=C(14), and C(11)=C(13). The 38 compounds in the eudesmane-type sesquiterpenes are recognized by their decalin ring structure, where the γ-lactone forms through a link between C(12) and either C(6) or C(8). Germacrane-type sesquiterpenes, of which there are only six known compounds, are typically unstable and less prevalent; notable examples include dihydrocostunolide, saussureamine A, and eleganin [19].

One of *the Saussurea costus* representative germacrane sesquiterpenes is dihydrocostunolide, a stable form of costunolide. While 12-methoxydihydrocostunolide is a methoxylated derivative of dihydrocostunolide, saussureamine A has shown cytotoxic action. There have been claims that eleganin possesses anti-inflammatory qualities. Costunolide 15-O-β-D-glucopyranoside is the glycosylated derivative of costunolide, which itself has antimicrobial and anticancer properties [17]. In addition, around 19 O-glycoside flavonoids, made up of sugars connected to aromatic molecules, have been found in *Saussurea* species. Additionally, 15 phytosterols have been found, mainly differing in where the double bonds are located and the groups attached at positions C(3), C(7), and C(17). In addition, 26 triterpenes have been divided into four groups: ursane, lupane, lanostane, and oleanane, with ursane being the most prevalent [18]. There are 26 lignans, mainly O-glycosides that have hydroxyl (-OH) or methoxy (-OMe) groups, and 14 phenolic O-glycosides that have been discovered. Additionally, nine derivatives of chlorophyll have been identified in *Saussurea* species [20].

Pharmacological activity:

The root of *Saussurea costus* is often used in traditional medicine like Ayurveda, Siddha, and Unani to treat different health issues, such as inflammation, liver problems, ulcers, cancer, and infections. A multitude of papers detailing its spectrum of biological activities have been recorded in both in vitro and in vivo experimental models. This review examines a total of thirteen antibacterial activities.

Antimicrobial activity:

A total of thirteen investigations has been conducted to assess the antibacterial properties of *Saussurea costus* extracts against various highly pathogenic reference strains, including both Gram-positive and Gram-negative bacteria, along with several fungal species [21].

The bacterial strains included in the study comprised gram-positive strains such as *Staphylococcus aureus (S. aureus)*, *Staphylococcus epidermidis (S. epidermidis)*, *Staphylococcus saprophyticus (S. saprophyticus)*, *Streptococcus pyogenes (S. pyogenes)*, *Bacillus subtilis (B. subtilis)*, *Bacillus cereus (B. cereus)*, *Enterococcus faecalis (E. faecalis)*, and *Micrococcus luteus (M. luteus)*, as well as gram-negative strains including *Escherichia coli (E. coli)*, *Pseudomonas aeruginosa (P. aeruginosa)*, *Klebsiella pneumoniae (K. pneumoniae)*, *Salmonella typhi (S. typhi)*, *Salmonella sp.*, *Enterobacter cloacae (E. cloacae)*, *Citrobacter freundii (C. freundii)*, *Proteus vulgaris (P. vulgaris)*, *Acinetobacter baumannii (A. baumannii)*, and *Aeromonas hydrophila (A. hydrophila)* [22 – 34].

The antifungal strains that were included in this study are *Candida albicans* (*C. albicans*), *Aspergillus niger* (*A. niger*), *Penicillium verrucosum* (*P. verrucosum*), *Aspergillus ochraceus* (*A. ochraceus*) and *Saccharomyces candidus* (*S. candidus*) [25], [27], [29], [32].

The existing research has thoroughly documented the antibacterial properties of various *Saussurea costus* extracts, detailing the methodologies used, the microbial strains tested, key findings, and observed therapeutic effects, all of which are summarized in the accompanying Table 2.

A wide array of extraction techniques has been utilized to evaluate the antibacterial activity of *Saussurea costus* root, including ethanol and aqueous extracts, essential oil extraction, methanolic, hexane-chloroform, ethyl acetate, petroleum ether, n-butanol, n-hexane, chloroform, and dichloromethane extracts, as well as hot ethanol and root oil preparations. These diverse solvent systems reflect the effort to isolate a broad spectrum of bioactive compounds from the root for antimicrobial screening.

The different studies used various methods to test the antimicrobial effects of the root extracts, including well diffusion, disc diffusion, microdilution susceptibility assay, and cup plate diffusion techniques, as well as measuring minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), and minimum fungicidal concentration (MFC), giving a thorough evaluation of how effective the extracts are against microbes.

Table 2: Antimicrobial activity

S. NO.	Study	Therapeutic effect	Extract (Plant part)	Method	Tested strain	Result	Reference
1.	Duraipandiyan et al., 2012	Antibacterial	n-hexane, Chloroform, Ethyl acetate and Methanol (Root)	Disc-diffusion method MIC	*S. aureus* *S. epidermidis* *B. subtilis*	When everything was considered, chloroform extract had the highest activity, particularly against *S. epidermidis* (MIC=0.312 mg/ml). Methanol extracts consistently defeated all three of the examined Gram-positive bacteria. The aqueous extract (MIC > 5 mg/mL) did not significantly impact any of the tested strains. The extract of ethyl acetate had just a slight effect on *S. aureus*.	22
2.	Negi et al., 2014	Antibacterial	Methanol extract (Root)	Well diffusion method MIC	*E. coli* *C. freundii* *E. faecalis* *S. aureus* *S. typhimurium* *P. vulgaris*	*Saussurea lappa* methanolic extracts have shown dose-dependent antibacterial activity, specifically against *E. coli*, *C. freundii*, and *E. faecalis*, *S. aureus*. *E. coli* had the lowest MIC (3.12 µg/µL) and the largest inhibition zone (8 mm), whereas *S. aureus* had the greatest MIC (50 µg/µL). *P. vulgaris* and *S. typhimurium* exhibited resistance. The extract with the highest activity was *S. lappa*, which was taken from Ramni (SL II, 2800 m).	23
3.	Alaagib & Ayoub, 2015	Antibacterial	Petroleum ether, chloroform, methanolic extract and aqueous extract. (Root)	Cup plate agar diffusion method	*E. coli* *B. subtilis* *S. aureus* P. aeruginosa K. pneumonia	The *Saussurea lappa* chloroform extract had the strongest antibacterial activity when tested using the cup-plate agar diffusion technique, with a mean inhibition zone of 23 mm against *Staphylococcus aureus, Bacillus subtilis and Escherichia coli*,	24
4.	Abdallah et al., 2017	Antibacterial and antifungal	Methanol and ethanol extracts (Root)	Disc diffusion method	*B. cereus* *S. saprophyticus* *S. epidermidis* *S. aureus* *A. niger*	The roots of *Saussurea costus* demonstrated strong antibacterial effects in both methanol and ethanol extracts, particularly against Gram-positive bacteria like *Bacillus cereus*, *Staphylococcus saprophyticus*, *Staphylococcus epidermidis*, and *Staphylococcus aureus*. The biggest area where bacteria were inhibited was found with *Bacillus cereus*, measuring 16.0 ± 0.0 mm for methanol and 15.5 ± 0.5 mm for ethanol. *Bacillus cereus* exhibited the largest zone of inhibition. Methanol weighs 16.0 ± 0.0 mm, while ethanol weighs 15.5 ± 0.5 mm. Against these bacteria, both extracts showed the lowest MIC (50 mg/ml), while MBC values ranged from 100 to 200 mg/ml, indicating largely bactericidal actions (MBC/MIC ≤ 4). On *Aspergillus niger*, the extracts likewise showed fungicidal action (MIC = MFC = 50 mg/ml, MFC/MIC = 1).	25

5.	Omer et al., 2019	Antibacterial	Ethanol extract and Aqueous extract (Root)	Well diffusion method	*S. aureus* *Salmonella sp.*	The ethanol extract of *Saussurea lappa* root demonstrated strong antibacterial activity against the Gram-positive bacterium *Staphylococcus aureus*, producing a clear inhibition zone measuring 18–20 mm. In contrast, the water extract showed no effect against the Gram-negative *Salmonella* and only a mild inhibitory effect on *S. aureus*, which was noticeably weaker than that of the ethanol extract, although the exact inhibition zone was not specified.	26
6.	Deabes et al., 2021	Antibacterial Antifungal	Ethanolic extract, ethyl acetate, n-butanol, and n-hexane (Root)	Well diffusion method	*S. aureus* *Salmonella typhi* *P. verruscum* *A. ochraceus*	Chloroform worked best to kill bacteria and fungi when tested with the ethanol extract of *Saussurea costus*. The area where fungi were stopped measured 22.5 mm, and for bacteria, it was 23 mm. The microorganisms that were most affected by the extract were *P. aeruginosa* and *E. coli*, needing only 0.08 to 0.3 mg/mL to be inhibited. Depending on concentration, the zone of inhibition for fungi was 22.5 mm, while for bacteria it was 23 mm. The microorganisms that were most susceptible to the extract were *P. aeruginosa* and *E. coli*, with a minimum inhibitory concentration (MIC) of 0.08 to 0.3 mg/mL. *A. flavus* had the highest sensitivity, with an MIC of 0.25 to 1.17 mg/mL for fungal extraction. These findings suggest that the extract of S. costus may be useful as a natural antibacterial and may potentially be a means of treating illnesses that are resistant to drugs.	27
7.	Abdelwahab et al., 2021	Antimicrobial	Oil extraction (Root)	Disc-diffusion method	*E. coli* *P. aeruginosa* *S. aureus* *B. subtilis* *C. albicans*	Saussurea lappa essential oil (SLEO) has been found to effectively kill bacteria like *B. subtilis*, *S. aureus P. aeruginosa*, *E. coli*, and *Candida albicans*, with its effectiveness increasing with higher doses. The strongest overall effect was seen at 100 µg/mL, where it completely stopped the growth of *S. aureus* with a 29 mm area and *B. subtilis* with a 25 mm area. Additionally, the essential oil demonstrated a modest level of antifungal activity against *Candida albicans* (15 mm at 100 µg/mL).	28
8.	Ahmed et al., 2023	Antibacterial Antifungal	Essential oil extraction, Aqueous extraction, methanolic and Hexane-Chloroform extractions (Root)	Disc diffusion method Microdilution susceptibility assay	*S. epidermidis* *S. aureus* *E. faecalis* *E. cloacae* *E. coli* *P. aeruginosa* *K. pneumoniae* *A. baumannii* *C. albicans*	Against the tested pathogens, hexane-chloroform extracts, methanol, essential oil, and aqueous extracts showed the following antimicrobial profile: the hexane-chloroform extract exhibited strong activity against *S. epidermidis* (15.3 mm inhibition zone) and *S. aureus* (13.3 mm), while *Candida albicans* measured 14.6 mm; the essential oil had moderate zones (12.5 mm for *S. epidermidis* and 12 mm for *S. aureus*); methanol performed similarly (13 mm for *S. epidermidis*, 11 mm for *S. aureus*); the aqueous extract showed only modest inhibition (11.6 mm for *S. aureus*) and no effect on *S. epidermidis*; *P. aeruginosa* remained resistant to all extracts and among minimum inhibitory concentrations, the essential oil was most potent (3.12 µl/ml against *S. epidermidis* and *C. albicans*, 6.25 µl/ml against *S. aureus*), followed by the methanol extract (3.12 mg/ml for *S. aureus*; 6.25 mg/ml for *S. epidermidis* and *C. albicans*), hexane-chloroform extract (6.25 mg/ml for *S. aureus*, 12.5 mg/ml for *C. albicans*), and aqueous extract (6.25 mg/ml for *S. aureus*, 12.5 mg/ml for *S. epidermidis*).	29
9.	Al-Zayadi et al., 2023	Antibacterial	Ethanolic extract (Root)	Disc diffusion method	*S. pyogenes* *E. coli* *B. subtilis* *P. aeruginosa*	The methanolic and ethanolic extracts of *Saussurea costus* roots showed strong antibacterial activity against both Gram-positive and Gram-negative bacteria. *Streptococcus pyogenes* (17 mm at 100 mg/L) and *E. coli* (17 mm at 50 mg/L) showed the largest zones of inhibition. Both bacteria also had the lowest minimum inhibitory concentration (MIC) at 50 mg/L, with overall MIC values ranging from 50 to 100 mg/L. The minimum bactericidal concentration (MBC) ranged from 100 to 200 mg/L. While *E. coli* and *S. pyogenes* had MBC values of 100 mg/L, *Bacillus subtilis* and *Pseudomonas aeruginosa* required 200 mg/L for complete bacterial killing.	30
10.	Mammate et al., 2023	Antibacterial	Aqueous extract and ethanolic extract (Root)	Disc-diffusion method MIC MBC	*P. aeruginosa* *E. colic* *K. pneumoniae* *S. aureus*	The ethanolic extract of *Saussurea costus* was somewhat effective against *Klebsiella pneumoniae* and very effective against *Staphylococcus aureus*. The corresponding minimal inhibitory concentrations (MICs) for the ethanolic extract were 50 mg/mL and 200 mg/mL, respectively. *K. pneumoniae* was only slowed down from growing, while *S. aureus* was killed, as shown by its minimum bactericidal concentration (MBC) of 100 mg/mL. The aqueous extract had MICs of 400 mg/mL for *S. aureus* and 200 mg/mL for *K. pneumoniae*, meaning it only stopped the bacteria from growing instead of killing them. Importantly, the ethanolic extract affected multi-drug-resistant strains of *K. pneumoniae* and *S. aureus*, indicating that it could be useful for other antibiotic treatments.	31

11.	Rahman et al., 2023	Antibacterial and Antifuungal	Root oil n-hexane and dichloromethane (root)	Well- diffusion method MIC	*A. hydrophila P. aeruginosa E. coli M. luteus B. subtilis C. albicans S. candidus*	The strongest inhibition against *B. subtilis*, *A. hydrophila*, and *E. coli* was demonstrated by *S. lappa* root oil and hexane extract (MIC = 5 µL/mL). Additionally, ether extract worked well, especially against *B. subtilis* and *E. coli* (MIC = 8 µL/mL). Moderate sensitivity was also demonstrated by fungus strains such as *S. candidus* and *C. albicans*. The least susceptible bacteria were gram-negative ones, such as *P. aeruginosa*.	32
12.	Binobead et al., 2024	Antibacterial	Methanol extract (Root)	Disc-diffusion method MBC MIC	*S. aureus S. epidermidis B. subtilis E. coli K. pneumoniae P. aeruginosa*	The extract of *Saussurea costus* root in methanol has shown potent antibacterial, antioxidant, and anticancer properties. The extract from *Saussurea costus* root in methanol effectively killed bacteria, showing strong effects against *S. aureus*, *S. epidermidis*, and *B. subtilis*, with minimum inhibitory concentrations (MICs) as low as 7.81 µg/mL and minimum bactericidal concentrations (MBCs) up to 31.3 µg/mL.	33
13.	Aween et al., 2025	Antibacterial	Aquous extract, ethanol, hot ethanol (Root)	Disc-diffusion method Well- diffusion method MIC MBC	*S. pyogenes E. coli K. pneumonia S. aureus*	The hot ethanolic extract C of Indian *Costus* demonstrated strong antibacterial activity against *S. pyogenes* and *K. pneumoniae*, with a MIC of 6.25 mg/ml and an MBC of 100 mg/ml, indicating its potent inhibitory effect on these bacteria.	34

DISCUSSION

Saussurea costus is a medicinal plant known for its rich array of bioactive compounds, which have played vital roles in traditional medicine. It has shown considerable impact on human health and the economy, owing to its extensive use in treating bacterial and fungal infections, as well as a variety of other ailments. Numerous studies have investigated its potential as a natural antibiotic, particularly against drug-resistant pathogens. This comprehensive review highlights its ethnobotanical relevance, geographical distribution, phytochemical profile, and documented biological activities, with a special focus on its antibacterial and antifungal properties. Key phytoconstituents such as sesquiterpenes and flavonoids contribute significantly to its pharmacological potential. Building on its traditional use in treating respiratory illnesses and skin disorders, further research is necessary to thoroughly assess the clinical potential of *Saussurea costus* and validate its integration into modern medical practice.

CONCLUSION

Saussurea costus is an important medicinal plant known for its natural compounds that help fight bacterial and fungal infections. Its traditional use in treating respiratory and skin problems shows its health benefits. While studies support its potential as a natural antibiotic, more research is needed to confirm its safety and effectiveness in modern medicine. With further study, *Saussurea costus* could become a valuable part of healthcare in the future.

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