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Ethnobotanical, phytochemical and pharmacological aspects of Bengal Pogostemon (*Pogostemon benghalensis*)

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ABSTRACT

Pogostemon benghalensis (Burm.f.) Kuntze (Lamiaceae) is an important aromatic plant. Multiple classes of phytochemicals such as flavonoids, phenols, phytosteroids, carbohydrates, fatty acids, glycosides, sterols, terpenoids, tannins, essential oil, and alkaloids have been isolated from the title species. Different plant parts have been used as traditional remedies for various ailments. The present review aims to update and coherent the fragmented information on botanical aspects, phytochemistry, traditional uses, and pharmacological activities. An extensive review of the literature was carried out by using various search engines like PubMed, Scopus, Science Direct, Google Scholar, Google, Scifinder for information. The articles were searched using the keywords "Pogostemon", "Parviflorus', "benghalensis". Chemical structures of the chemical compounds were drawn using software Chem Draw ultra 8.0. Most of the plant parts have been used for the treatment of various ailments. Phytochemistry reveals that the plant is a rich source of various biologically active compounds. *Pogostemon* extracts exhibited numerous pharmacological effects like anticancer, anti-inflammatory, antimicrobial and antioxidant activities. In sum, *P. benghalensis* is a promising aromatic and medicinal plant as depicted by its various traditional uses and pharmacological studies. Bioactive compounds, responsible for its various pharmacological activities at the molecular level, need further detailed investigations. Future clinical studies are also required to validate the various traditional uses of *P. benghalensis*.

Implication for health policy/practice/research/medical education:
This review represented the various useful pharmacological activities like anticancer, anti-inflammatory, antimicrobial and antioxidant activities of *Pogostemon benghalensis*. Further, the results of the present review revealed that essential oil and various extracts of *P. benghalensis* possess good pharmacological potential and have broad spectrum activities on various ailments such as cold, cough, pneumonia, diarrhoea, dysentery, skin diseases, and digestive problems as evident from the traditional knowledge and reported bioassays. It also provided basic information for further studies.

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Introduction

Plants produce a diverse assortment of secondary metabolites that do not participate directly in the growth and development of the plant (1). Due to their complex chemical structure and biosynthetic pathways, these myriad natural products have received little attention from the biological scientists. However, humans have been using the herbs and their products as medicines to cure various ailments and diseases like cough, cold, fever, digestive disorders, food poisoning, etc. since time immemorial (2,3). Owing to their various traditional uses, researchers are showing more and more interest in re-evaluating and recognising various biological properties of natural plant products. Some of these natural plant products are essential oils, dyes, colouring agents, and pharmaceutical compounds. Now a day, essential oils are one of the most important secondary metabolites that are receiving considerable attention of the researchers. Because of various aromatic and therapeutic properties, these are widely used in food, flavour and fragrance, cosmetic, and other pharmaceutical industries (4).

Pogostemon benghalensis (Burm.f.) Kuntze is an aromatic undershrub that grows in open riverine forest areas of tropical climates (5) and generally found in attitudes

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between 150-1300 m. It is native to South Asia and is widely distributed in India, Nepal, Bangladesh, Myanmar, Sri Lanka, China, Thailand, Vietnam and Bhutan (6, 7). The floral buds and leaves are rich in essential oil, which in turn is rich in sesquiterpenes. Various researchers have studied the chemical profile of the essential oil of *P. benghalensis*. The essential oil and the leaf extracts of *P. benghalensis* have been studied for their antioxidant (10), antibacterial (11-13), antifungal (11,13), antiviral (14), larvicidal (9) and anticancerous activities (15). Traditionally, its leaves and roots have been used to cure cold, cough, pneumonia, diarrhoea, dysentery, skin diseases, and digestive problems (16,17). The present review compiles the incomplete information on the phytochemistry, traditional uses, and other pharmacological properties of *P. benghalensis* and highlights that the plants are a rich source of phytochemical worth exploiting for human benefits.

Taxonomy and vernacular names

The plant *P. benghalensis* (=*P. fructescens* J. Garham, *P. indicus* (Roth) Kuntze and *P. purpuricaulis* Dalzell., *Origanum benghalense* Burm.f., *O. indicum* Roth, *Mentha integra* Buch.-Ham. Ex Benth,) belong to Lamiaceae family of lamiales order (18). It is commonly known as Bengal Pogostemon, cockspur patchouli and has various vernacular names like Kala basing, Lujrya, raudera and Ishwar jata in Hindi, Jui-lata in Bengali, Sukloti in Assamese, Lamgi thoiding and Liriiwo in Manipuri, Pangli in Marathi, Dumobadotoko and Poksunga in Oriya, Bhoothachedayan in Malyalam, Arissikaai in Tamil, Naati pachhe thene in Kannada, Pedda tulasi, Gondripula and Kasurijang in Telugu, Niam nguang chaang in Thailand, Rudhilo and Rasangan, Basdam, Nampani (Chepang), Utajara (Danuwar), Rutili (Tamang), Kali-bant (Tharu) in Nepalese, and Kali suhali in Pakistan.

Botanical description

Pogostemon benghalensis is an undershrub to shrub with a strong, solid, angular and tomentose stem. The leaves are ovate with double dentate margin and acuminate apex, pubescent and bear epidermal hairs and secretary structures, arranged in opposite phyllotaxy (19). It bears purple or pinkish-white bilipped flowers with strong aroma in verticillaster inflorescence; stamens are exerted with long violet purple hairs on filaments; the ovary is glabrous with slenderical style and bilobed stigma (20, 21). Fruits are trigonous, reddish brown and composed of four nutlets.

Phytochemistry

A little work has been done on the photochemistry of *P. benghalensis*. As per studies done using GC-MS (gas chromatography- mass spectrometer), the plant has a rich profile of phytochemicals like phenolics, steroids, tannins, flavonoids, terpenoids, and essential oils. The crude extracts and essential oils are mainly composed of sesquiterpenes, but also have terpene derivatives, aromatic alcohols and other organic compounds (5,6,8,9).

In a study performed by Chanotiya et al, Elemol (11.6-20.5%), β-caryophyllene (8.1-12.5%), β-bisabolene (3.6%-18%), α-humulene (4.0-8.7%), β-ocimene (3.6-3.7%), germacrene B (2.5-4.8%), were reported as the major components in *Pogostemon* oil extracted from leaves and inflorescence of the plant (8). Moreover, the presence of these components was also confirmed by Bhuiyan et al (6). In a similar study of the phytochemistry of *Pogostemon*, Anjana and Thoppil (9) reported dehydranone (26.66%) as major component followed by δ-cadinol (23.06%) whereas, in contrast, Dhakal et al (5) reported 7-Isopropyl-1,4-dimethyl-azulen-2-ol (41.72%) as the major component followed by α-gurjunene isomer (9.23%). The variations observed in the chemical profile of *P. benghalensis* could have been possibly due to differences in geographical location, climatic conditions, harvesting methods, the growth stage of the target plant at the time of harvesting, plant parts used for oil extraction, soil profile *etc*. Some of the important components detected in the essential oil of *P. benghalensis,* along with their known pharmacological properties are given in Table 1 (22-63).

Nutritive value

Nutrient analysis of the leaves of *P. benghalensis* by Unni et al revealed the presence of approximately 0.25 ± 0.1% carbohydrates, 6.175 ± 0.2% fatty acids, 4.59 ± 0.1% proteins, 7.10 ± 0.1% fibre, 1.6 ± 0.2% tannin, 84.77 ± 2.4% moisture, and 75.01 ± 1.6% nutritive value. The investigators also determined the fatty acid composition through GC analysis after converting lipids into methyl esters which ensured the presence of methyl ester of palmitic acid (0.75%) and a mixture of oleic, linoleic and linolenic acids (3.75%), of which linoleic and linolenic are the essential fatty acids for human beings (64).

Ethnobotanical uses

Different parts of *P. benghalensis* have been traditionally used by different ethnic groups in India and other countries for domestic and therapeutic purposes. Generally, genus *Pogostemon* was used by tribal people for its roots and leaves (65). Different plant parts were used in formulations like decoction, fresh extract, poultice, and infusion *etc*. to get rid of health ailments. The plant is used as an antidepressant, antiseptic, aphrodisiac and to cure skin problems in aromatherapy (64). It has been widely used in folk medicine for the treatment of intestinal disorder and intermittent fever (66). Tribal people also used the plant as an antidote to snakebite. The paste of soft leaves and fresh roots was applied to the snake bites. Boiled root extract was orally given to the patient (67). Traditionally, leaf and root juice have been given to cure cough and cold (11,68), haemorrhage (69), malaria,

Table 1. List of chemical components of essential oil of *Pogostemon benghalensis* with their known pharmacological activities

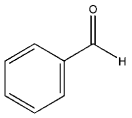
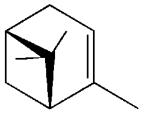
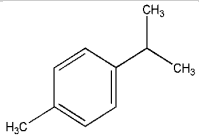
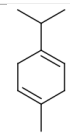
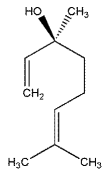
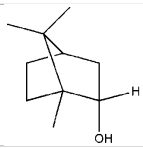
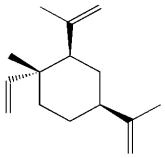
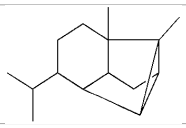
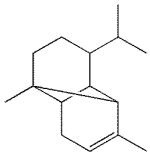
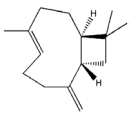
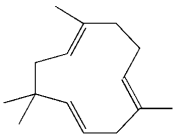
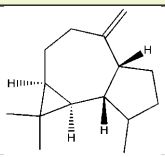
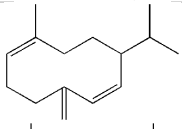
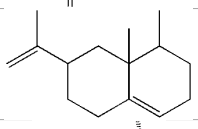
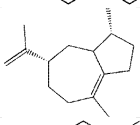
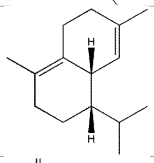
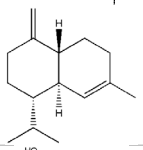
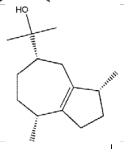
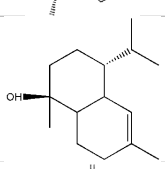
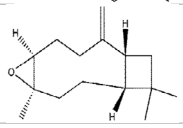
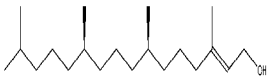
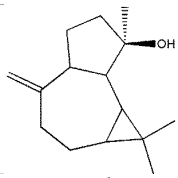
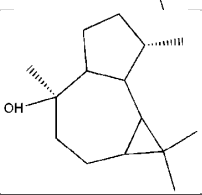
Compound, Molecular formula, M. weight, nature	Chemical structure	Structure ID	Pharmacological properties
Benzaldehyde C_7H_6O 106.124 g/mol Aromatic aldehyde		PubChem CID 240	Larvicidal (22)
α-Pinene $C_{10}H_{16}$ 136.238 g/mol Monoterpene		PubChem CID 6654	Anti-inflammatory (23), antibacterial, antitumor (24), antioxidant (25), fumigant (26), analgesic (27)
p-Cymene $C_{10}H_{14}$ 134.222 g/mol Monoterpene		PubChem CID 7463	Anti-inflammatory (28), antioxidant (25), antitumor (28), analgesic (29)
β-Ocimene $C_{10}H_{16}$ 136.238 g/mol Monoterpene		PubChem CID 5281553	Antioxidant (25), nematicidal (30)
γ-Terpinene $C_{10}H_{16}$ 136.238 g/mol Monoterpene		PubChem CID 7461	Anti-inflammatory (28), antioxidant (25), insecticidal (31)
Linalool $C_{10}H_{18}O$ 154.253 g/mol Monoterpene alcohol		PubChem CID 6549	Antitumor (32), anti-inflammatory (33), fumigant (34), anesthetic and sedative agents (35), analgesic (36)
Borneol $C_{10}H_{18}O$ 154.253 g/mol Monoterpene alcohol		PubChem CID 439569	Antitumor (37, 38), analgesic (39), antioxidant (25), fumigant (40), trypanocidal (41)
β-Elemene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 6918391	Anti-inflammatory (42), apoptotic (43)
Cyclosativene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 519960	Antioxidant (44)
α-Copaene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 25245021	Analgesic and anti-inflammatory (45), antigenotoxic (46)
β-Caryophyllene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 5281515	Leishmanicidal (47), Anti-endemic, Anti-tumor, Anti-oxidant, Anti-microbial and Anti-inflammatory (48), Antioxidant46
α-Humulene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 23204	Anti-inflammatory (49), Antioxidant (25)

Table 1. Continued

Compound, Molecular formula, M. weight, nature	Chemical structure	Structure ID	Pharmacological properties
Alloaromadendrene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 91746537	Antiproliferative (50)
Germacrene D $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 5373727	Aphid repellent (51), Mosquitocidal (52)
Valencene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 9855795	Antioxidant (25)
α-Bulnesene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 94275	Antiplatelet aggregation agent (53)
δ-Cadinene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 12306054	Antimicrobial (54), Mutagenic and Carcinogenic (55)
γ-Cadinene $C_{15}H_{24}$ 204.357 Sesquiterpene		PubChem CID 92313	Mutagenic and Carcinogenic (56)
Guaiol $C_{15}H_{26}O$ 222.372 Sesquiterpene alcohol		PubChem CID 227829	Antioxidant (25); Insecticidal (57)
α-Cadinol $C_{15}H_{26}O$ 222.372 Sesquiterpene alcohol		PubChem CID 519662	Anti-mite activity (57)
Caryophyllene oxide $C_{15}H_{24}O$ 220.356 Sesquiterpene		PubChem CID 1742210	Analgesic, Anti-inflammatory (58), Antifungal (59), Anaesthetic (60)
Phytol $C_{20}H_{40}O$ 296.539 g/mol Diterpene alcohol		PubChem CID 296.539	Antioxidant (25), Anticancerous (61)
Spathulenol $C_{15}H_{24}O$ 220.356 g/mol Sesquiterpene alcohol		PubChem CID 92231	Antifungal (62)
Viridiflorol $C_{15}H_{26}O$ 222.372 Sesquiterpene alcohol		PubChem CID 11996452	Anti-inflammatory, Antimycobacterial, Antioxidant (63)

pneumonia, tuberculosis (70), fever (71,72), vomiting, food poisoning, stomach problems (17) and respiratory tract infections (68). Leaves are used to cure scabies and ringworms (73) and burning (74). Its leaves are also used as vegetable (75). A decoction of fresh leaves is given orally to cure dyspepsia (76). Bhattarai et al reported that the decoction of roots of *Pogostemon* plant along with the root of the plant of *Ageratum conyzoides* was used to cure typhoid by the local people of Nawalparasi district, Nepal (77). Fresh leaves of *P. benghalensis* are used in Southern Assam for the herbal preparation known as "Shuktani", which is used for the treatment of diarrhoea, dysentery, and indigestion, and also used by women for lactation and body strength after parturition (16). The young leaves are also used as a vegetable, and used to prepare pancake with powdered rice (78). The essential oil of *P. benghalensis* is used in the perfumery industry, and its dried leaves are used to scent cloth (79). Leaves and shoots of this plant are also used to extract natural colour and dyes (80), which are further used to decorate the wall of the houses (81). Various traditional uses of *P. benghalensis* are summarized in Table 2.

Pharmacological activities

Various pharmacological properties have been studied in plant *P. benghalensis*. Some of such activities like antibacterial, antiviral, antioxidant, antifungal, anti-inflammatory of the plant are given in Table 3 and discussed below.

Antibacterial activity

Taylor et al reported that methanolic extracts of the aerial parts of *P. benghalensis* possessed antibacterial activity and inhibited the growth of bacteria *Bacillus subtilis* and *Staphylococcus aureus* at 2 g/mL (11). Later on, Bhattarai et al reported that the methanolic extract of *P. benghalensis* from Nepal inhibited the growth of two gram-positive (*Bacillus subtilis, Staphylococcus aureus*) and two gram-negative bacteria (*Escherichia coli, Pseudomonas aeruginosa*), but was found inactive against bacteria *Bacillus subtilis* and *Staphylococcus aureus* (12). Thoppil et al studied the antibacterial activity of leaf essential oil of three species of genus *Pogostemon* (*P. benghalensis, P. purpurascens, P. vestitus*) against seven strains of bacteria. All three species of *Pogostemon* showed promising antibacterial activities against all the tested seven bacterial strains. However, the essential leaf oil of *P. benghalensis* was found to be the most effective in inhibiting bacterial growth. It inhibited the growth of *Staphylococcus aureus* with the highest inhibition zone (39.33±1.53 mm) as compared to the standard drug gentamycin sulphate with inhibition zone of diameter 35±1.0 mm (13). The methanolic extracts have been demonstrated to inhibit the growth of pathogenic bacteria, *Bacillus subtilis* and *Salmonella typhi* (66) thus, validating the traditional use of *P. benghalensis* as an antibacterial agent in the treatment of various ailments like typhoid, tuberculosis, dysentery, and wounds.

Antiviral activity

The traditional application of *P. benghalensis* for treatment of cold, cough, dysentery implies an antiviral activity of the plant. Taylor et al screened 21 species of medicinal plants including *P. benghalensis* for their antiviral activities against three mammalian viruses (Polio virus, Sindbis virus, *Herpes simplex* virus) and reported that methanolic extracts of the aerial parts of *P. benghalensis* had considerable antiviral activity. At 200 µg/ml, it effectively inhibited the growth of Sindbis virus (14).

Antifungal activity

Traditionally, leaves of *P. benghalensis* have been used by local people of Panchthar district (Nepal) to cure scabies, ringworms, thus, implicating the antifungal property of the plant. Various extracts of *P. benghalensis* were reported to possess antifungal activity. The methanolic extracts of the aerial parts of this aromatic plant showed antifungal activity against *Microsporum gypseum* and *Trichophyton mentagrophytes* (11). Similarly, Thoppil et al (13) revealed the antifungal potential of crude essential oil of three species of genus *Pogostemon* including *P. benghalensis* against eight fungal strains, and reported that *P. benghalensis* inhibited the growth of *Fusarium solani* and *Candida albicans* with maximum inhibition zone of 32.33±2.08 mm and 32.33±2.52 mm, respectively over the standard antibiotic nystatin (inhibition zone; 30.33±1.53).

Antioxidant activity

In a study conducted by Singh et al, the antioxidant activity of crude essential oil of ten species of family Lamiaceae including *P. benghalensis* was evaluated through 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) scavenging activity and total antioxidant activity (TAA). The essential oil of *P. benghalensis* exhibited DPPH scavenging activity and TAA with an EC50 (Half-maximal Effective Concentration) value of 171.3±5.74 µg/mL, 89.5±2.33 µg/mL, respectively whereas, the EC50 value of standard butylated hydroxytoluene (BHT) for DPPH scavenging activity and standard ascorbic acid for TAA were 156.4 and 165.7 µg/mL. The EC50 value of *Pogostemon* oil was nearly close to the standard value for DPPH scavenging activity, and the EC50 for TAA was lower than the standard value (10).

Larvicidal activity

Anjana and Thoppil evaluated the larvicidal potential of essential oil of four species of genus *Pogostemon* including *P. benghalensis* against the fourth instar larvae of *Aedes albopictus* Skuse. *P. benghalensis* essential oil showed 100% larval mortality at 100 and 200 ppm concentrations and the activity was attributed to sesquiterpene rich essential oil (9). Several reports have confirmed the larvicidal

Table 2. Traditional uses of *Pogostemon benghalensis*

Place	Local name	Part used	Administration	Traditional uses	References
Uttra Pradesh, India	Maspindi	Leaves	Juice	It is applied on the cut and injuries to stop bleeding.	82
Assam, India	Rujanto	Leaves	Leaf	As leafy vegetable to cure stomach problems	83
Nawalparasi District, Central Nepal	Bhati	Whole plant	Decoction	To cure cold, cough and typhoid	12
Udhampur district, Jammu and Kashmir, India	Kali suaali	Leaves	Decoction	To cure cold, cough and dyspepsia	76
Kumaun, Uttrakhand, India	Pacholi	Leaves	-	Used to scent linen, shawls *etc.*	79
Assam, India	Rujanto	Leaves	Paste	To make *Shuktani* (ethno-medico recipe) along with other 34 angiosperms.	16
Panchthar district, Nepal	-	Leaves		To cure scabies and ringworms	73
Western Chitwan, Nepal	Rudhilo	Leaves and young shoot	Dye	Used for decoration of house wall	81
Una, Himachal Pradesh, India	Kalibausti	Leaves	Chewing	as anti-diabetic remedy	84
Ahmednagar (Western Ghat), Maharashtra, India	Phangala	Root	Juice and paste	Boiled root juice is given orally and paste is applied on snake bite site	67
Chepang community, Chitwan District, Nepal	Rudilo	Leaves, root	-	To cure fever, malaria, pneumonia, tuberculosis	70
Bhilla tribe, Maharshtra, India	Phangala	Leaves	Juice	Leaf juice along with the dried gums of *Sturculia urens* fried in til oil, is taken orally to cure piles.	85
Bagata tribe, Visakhapatnam district, Andhra Pradesh, India	Gondri poolu	Leaves, roots	-	To cure fever, digestive disorders,	72
Tehrathum district, Eastern Nepal	Rudilo	Roots, leaves	-	To cure haemorrhage	69
Assam, India	Sukloti	Leaves	Juice	To stop bleeding	86
Salem district, Tamil Nadu	Arissikaai	Fruits	-	Edible	87
Chitwan, Nepal	Rudhilo	Leaves	-	To cure typhoid, sinusitis	80
Nawarangpur district, Odisha, India	Gonda-dulia, Ishwarjata, Puka-sunga	Leaves	Paste	To cure spondylitis	88
Maharashtra, India	-	Leaves	Fumigation	To repel insect	89
Uttarakhand, India	Lojad	Leaves	Paste	To cure boils and blisters	90
Rangamati District, Bangladesh	Lomboi Shak	Laeves	-	As leafy vegetable	91

Table 3. Pharmacological activity of *Pogostemon benghalensis*

Activity	Plant part	Extract	Dose-range	Action	Sources
Antioxidant	Leaves	EO	50-400 µg/mL	Scavenging of free radicals	10
Antibacterial	Aerial part	ME	2g dried plant material/mL	Growth inhibition of *Bacillus subtilis* and *Staphylococcus aureus* bacteria	11
	Aerial part	ME	1g dried plant material/mL	Inhibited the growth of *E. coli* and *Pseudomonas aeruginosa*	12
	Leaf	EO	Dilution 1:0,1:1,1:2 in diethyl ether	Inhibited bacterial growth	13
Antiviral	Aerial part	ME	400 µg crude plant extract/mL	Inhibited growth of SINV	14
Antifungal	Aerial part	ME	2 g dried plant material/mL	Showed antifungal activity	11
	Leaf	EO	Dilution 1:0,1:1,1:2 in diethyl ether	Showed antifungal activity against 8 strains of fungi	13
Larvicidal	Leaf	EO	5-200 ppm	Showed 100% larvicidal activity at conc. 100 and 200 ppm	9
Anticancerous	Leaf	HEAE	5-2000 mg/kg body weight	Showed anticancerous activity	15

Abbreviations: EO, essential oil; ME, methanolic extract; HEAE, Hydroethanolic and aqueous extract; SINV, Sindbis virus

activity of sesquiterpenes (92-94).

Anticancerous activity

Patel et al reported the anti-tumour activity of *P. benghalensis* and reported that MST (Median Survival Time) of tumor-bearing mice significantly increased when treated with HEEPB (hydroethanolic extracts), AEPB (aqueous extracts) and 5-FU (5-Fluorouracil) over tumor control. After one month, reported tumor volume was ~1.90 ml ~1.67 and 1.62 ml for the mice groups treated with 5-FU (20 mg/kg), HEEPB (500 mg/kg) and AEPB (500 mg/kg), respectively, over the tumor control mice with ~3 ml of tumor volume (15).

Conclusions

The present review congregated information about the botanical aspects, ethnobotanical uses and recent studies on phytochemistry, and biological activities of different extracts of *P. benghalensis*. Essential oil is highly rich in sesquiterpenes. Various studies have evaluated the anticancerous, antibacterial, antifungal, antiviral, antioxidant and larvicidal properties of the essential oil and different extracts of *P. benghalensis*. It has been found that essential oil and various extracts of *P. benghalensis* possess good pharmacological potential and have broad spectrum activities on various ailments as evident from the traditional knowledge and reported bioassays. Despite ample traditional uses of *P. benghalensis*, only limited *in vivo* model studies have been conducted to evaluate its pharmacological properties. Therefore, there is an utmost need for *in vivo* clinical trials to confirm these pharmacological activities. To further strengthen the pharmacological profile of *P. benghalensis* for drug development, more rigorous research should be conducted on the extraction, identification and the mode of action of the bioactive components at the molecular level. Further, more investigations are required to elucidate the correlation between traditional uses and its pharmacological activities.

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Authors' contributions

SD wrote the first draft of the paper. DRB and HPS did critical revision. All authors read and approved final version of the manuscript.

Conflict of interest

None to declare

Ethical considerations

Ethical issues have been observed by the authors.

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