



Review Article

**MARICHA (PIPER NIGRUM LINN.): AN INTEGRATIVE REVIEW OF AYURVEDIC PERSPECTIVES
AND MODERN PHARMACOLOGICAL INSIGHTS**

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ABSTRACT

Background: Piper nigrum Linn. (*Maricha*), commonly known as black pepper, is a prominent spice in Ayurvedic pharmacopeia known for its *Deepana* (appetizing), *Pachana* (digestive), and *Krimighna* (anthelmintic) properties. Scientific research increasingly supports its traditional use in treating metabolic, respiratory, and gastrointestinal disorders. **Objective:** This study presents a comprehensive review of the Ayurvedic significance, classical references, phytochemical composition, and pharmacological activities of *Maricha*, aiming to bridge traditional wisdom with modern scientific validation. **Methods:** Extensive literature was reviewed from classical Ayurvedic texts, including *Charaka Samhita*, *Sushruta Samhita*, *Bhavaprakasha Nighantu*, and modern pharmacological research indexed in PubMed, Scopus, and Google Scholar. The phytoconstituents and pharmacological activities were analyzed and summarized based on experimental and clinical findings. **Results:** Piper nigrum contains alkaloids (notably piperine), essential oils (sabinene, limonene), flavonoids (quercetin, catechin), and minerals. It exhibits antioxidant, anti-inflammatory, anticancer, antimicrobial, lipid-lowering, immunomodulatory, and insecticidal properties. These findings support its use in managing lifestyle disorders and microbial infections. Its classical indications correlate well with its modern pharmacological activities. **Conclusion:** The integration of classical Ayurvedic understanding with recent pharmacological evidence highlights the therapeutic versatility of *Maricha*. It holds potential for development into multi-target phytopharmaceutical agents, especially in metabolic and inflammatory diseases.

INTRODUCTION

Piper nigrum Linn., commonly known as *Maricha* in Ayurveda and black pepper in English, belongs to the Piperaceae family. It is highly regarded as both a culinary spice and a medicinal herb, having been recognized in classical Ayurvedic texts for its various properties, including *Deepana* (appetizer), *Pachana* (digestive stimulant), *Krimighna* (anthelmintic), and *Shwasahara* (respiratory relief). [1] Ayurvedic lexicons such as *Bhavaprakasha Nighantu* and *Raja Nighantu* are classified under *Shatpushpadi Varga* or *Pipplayadi Varga*, highlighting their

significant therapeutic importance.[1,2] *Maricha* is commonly used in formulations detailed in the *Charaka Samhita* and *Ashtanga Hridaya*, including *Trayushnadi Churna*, *Vyoshadi Saktu*, and *Hingvadi Churna*. These formulations primarily target metabolic syndromes, respiratory conditions, and digestive disorders.[3,4] Its inclusion in the *Lekhaniya Mahakashaya* group highlights its use in treating obesity, hyperlipidemia, and other disorders arising from over-nutrition. [4] Phytochemical analysis of Piper nigrum reveals a variety of bioactive compounds, with piperine, a piperidine alkaloid, being the most pharmacologically significant. Piperine is responsible for the herb's distinct pungency and exhibits bioenhancing activity by inhibiting hepatic and intestinal metabolizing enzymes. This action improves the bioavailability of various drugs and nutrients. [5] Additionally, Piper nigrum contains essential oils (such as sabinene, β -pinene, and limonene), flavonoids

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(including quercetin and catechin), carotenoids (like β -carotene and lutein), and essential minerals such as magnesium, calcium, and potassium, all of which contribute to its pharmacological potential. [6] Scientific studies have confirmed this compound's antioxidant, anti-inflammatory, antimicrobial, anticancer, insecticidal, and lipid-lowering properties [6,7]. For example, piperine has been shown to inhibit tumor growth and induce apoptosis in cancer cells[7]. Additionally, its ability to modulate lipids has been demonstrated in preclinical models of diet-induced obesity[8]. The connection between traditional Ayurvedic uses and modern scientific evidence highlights the importance of Piper nigrum as a multi-target therapeutic agent. It shows considerable potential in developing phytopharmaceuticals, especially for chronic conditions related to metabolic dysfunction and microbial infections.

Botanical description [9, 10]

- **Latin Name:** Piper nigrum L.
- **Family:** Piperaceae
- **Regional Names:** In various regions, Piper nigrum is known by several vernacular names, such as *Kali Mirch*, *Gol Mirch*, and *Maricha* in Hindi; *Golmaricha* in Bengali; *Kare Manesu* in Kannada; *Nallamuluku* in Malayalam; *Philphil Asvad* in Arabic; *Philphil Syah* in Persian, and Black Pepper in English.

- *Maricha (Piper nigrum)* is a vigorous, woody climbing vine that typically grows between 4 to 9 meters in height, often requiring support from nearby trees.
- Its leaves are simple, entire, elliptical in shape, measuring around 10–15cm in length and 5–9 cm in width. The texture is leathery, and the surface is generally smooth and hairless (glabrous).
- The flowers are usually bisexual, though some display vestigial male or female parts. They are white and are arranged in drooping spikes containing 20 to 30 small flowers.
- The fruits are small drupes, approximately 8mm in diameter, commonly known as peppercorns. These dried immature fruits form the commercial black pepper. When dried, they appear dark brown to black, with a wrinkled surface.
- **Flowering & Fruiting Season:** The plant generally flowers during June–July, and fruiting occurs from December to March.
- **Habitat & Distribution:** Black pepper is cultivated in tropical regions such as Malaysia, Indonesia, Sri Lanka, and India. Within India, it predominantly grows in the hot and humid climates of Kerala, Karnataka, Tamil Nadu, and to a smaller extent, Assam.

Table 1: Properties and Actions of Maricha in Ayurveda^[11]

S.N.	Properties	Ardra Maricha	Sushka Maricha
1.	Rasa	Katu	Katu
2.	Guna	Tikshna, Guru	Tikshna, Laghu
3.	Vipaka	Madhur	Katu
4.	Virya	Natyauishna	Ushna
5.	Dosha karma	Pittavardhak	Vatakapshanashak, Pittavardhak
6.	Roghagna karma	Kaphanisarak	Ruchikar, Krimihar, Swas, Shool Vaman, Sotha, Avrishya

MATERIAL AND METHODS

This study utilized a qualitative literature review methodology. Ayurvedic references were gathered from authoritative texts, including the *Charaka Samhita*, *Sushruta Samhita*, *Ashtanga Hridaya*, and classical Nighantus such as *Bhavaprakasha*, *Raja Nighantu*, and *Dhanvantari Nighantu*. These texts were critically analyzed to extract information on the synonyms of Maricha and its Rasa, Guna, Virya, Vipaka, therapeutic indications, and formulations. In addition, modern scientific data was collected from peer-reviewed journals indexed in databases such as PubMed, Scopus, Science Direct, and Google Scholar. The keywords used in the search included “Piper nigrum,” “black pepper phytochemistry,” “piperine pharmacology,” and “Ayurveda Piper nigrum.” Articles from the past two decades were prioritized to ensure current findings. Studies that discussed pharmacological effects, phytochemical analysis, and clinical or preclinical evaluations were selected.

Charaka Samhita (1000 B.C. - 4th Cent. A.D)^[12]**Table 2: The names of Formulations, indications, and references of *Maricha* are mentioned below**

S.No.	Formulation	Indications	References
1.	<i>Kusthadi churna, Triyushnadi mantha, Vyoshadhya saktu</i>	<i>Santarpanjanya roga</i>	Ch. Su. 23/15,18, 19-24
2.	<i>Lekhaniya Mahakasaya</i>	<i>Lekhan</i>	Ch. Su. 4/3
3.	<i>Prameha nashak yoga</i>	<i>Prameha</i>	Ch. Chi. 6/26
4.	<i>Kaphaj Prameha nashak Das Yoga</i>	<i>Kaphaj Prameha</i>	Ch. Chi. 6/27-29
5.	<i>Haridrachurnadi Pralepa</i>	<i>Arsh</i>	Ch. Chi. 14/52
6.	<i>Haridradi kshara</i>	<i>Agnivardhan</i>	Ch. Chi. 15/182
7.	<i>Lodhrasav/madhvasav</i>	<i>Prameh</i>	Ch. Chi. 6/41-44
8.	<i>Nasya yoga, Mustadi churna, Madhvasav, Kanakbinduristha, Manshyadi lepa, Tiktaikshvadi taila, Kanakksheeree taila, Sidhmahar lepa</i>	<i>Kustha</i>	Ch. Chi. 7/48, 65-67, 73-75, 76-79, 87, 108-110, 111-116, 117-118
9.	<i>Yavanishadav churna, Talishadi churna</i>	<i>Rajyakshama</i>	Ch. Chi. 8/141-147
10.	<i>Hingvadhyah ghrita, Lashunadhya ghrita, Apamargadhya Anjan, Siddharthakadi agad</i>	<i>Unmada</i>	Ch. Chi. 9/34, 66-68, 69-72
11.	<i>Mahapanchgavya ghrita, Triphlaladi talia, Kayasthadi varti, Mustadi varti</i>	<i>Apasmara</i>	Ch. Chi. 10/18-24, 43-44, 46-47, 48-49
12.	<i>Saindhavadi churna</i>	<i>Kshatkshina</i>	Ch. Chi. 11/85-87
13.	<i>Saindhavadi churna, Gandiradhyaristha, Ashtasataristha, Krishnadi churna, Kshara gutika, Kansh haritaki, Chitrakadi ghrita</i>	<i>Sotha</i>	Ch. Chi. 12/27, 32-33, 41-46, 50-52, 55-56
14.	<i>Narayan churna, Neelinyadi churna Vidangadi yoga, Triphaladi kwatha</i>	<i>Udarroga</i>	C.Chi. 13/125-132, 137, 148, 149
15.	Method of using <i>Takra</i> in <i>Udarroga</i>		
16.	<i>Kaphaj Udarroga, Sannipataj Udaeroga, Jalodar</i>	<i>Takra with Maricha</i>	Ch. Chi. 13/104-106
17.	<i>Triyushnadhya churna, Chavyadi ghrita Pipalyadi ghrita, Abhyaristha, Kankaristha</i>	<i>Arsh</i>	Ch. Chi. 14/62-64 107-109, 113-118, 138-143, 158
18.	<i>Triyushnadhya ghrita, Panchmuladhya ghrita. Chitrakadi vati, Marichadi churna, Takraristha, Bhunimbadhya churna, Kiratiktadi churna, Pippalimuladi churna, Bhallatak kshara, Pancham Triphladi kshara.</i>	<i>Grahani</i>	C.Chi. 15/87, 88, 96-97 109-110, 120, 132-133 137-140, 168-169, 177-178, 188-193
19.	<i>Navayasa loha, Mandura vatak Swarnamakshika yoga, Yograaj, Punarnava mandura, Darvyadhya leha, Beejakaristha</i>	<i>Pandu</i>	Ch. Chi. 16/70-71, 73-77, 78-86, 93-97, 106-110
20.	<i>Vyoshadhya ghrita</i>	<i>Mritikabhakshan janya Pandu</i>	Ch. Chi. 16/119-120
21.	<i>Mudgayush, Bharanginagaradi yoga</i>	<i>Hikka-swasa</i>	Ch. Chi. 17/98, 110
22.	<i>Triyushnadhya ghrita, Vidangadi leha Chitrakadi leha, Prapaundrikadi dhum Tvagadi leha, Dashmooladi ghrita Kantkari ghrita, Chitrakadi leha Padmakadi leha, Jeevantyadi leha</i>	<i>Kasa</i>	Ch. Chi. 18/39-42, 52-56, 71-72, 92-93, 123-124, 125-127, 173-179

23.	<i>Chavyadi ghrita</i>	<i>Gudabhransh</i>	Ch. Chi. 19/44
24.	<i>Kapitthadi churna</i>	<i>Atisara</i>	Ch. Chi. 19/112
25.	<i>Gandhhasti agad, Maha gandhhasti agad Kshara agad, Shirishpushpadi yoga, Amrit ghrita</i>	<i>Vish</i>	Ch. Chi. 23/70-76, 77-94, 101-104, 193-198, 242-248
26.	<i>Ashtanga lavana</i>	<i>Kaphaj madatya</i>	Ch. Chi. 24/177-179
27.	<i>Udumbaradi leha</i>	<i>Kaphaj hridrog</i>	Ch. Chi. 26
28.	<i>Kshara gutika, Kalak churna, Mridvikadi churna</i>	<i>Mukhroga</i>	Ch. Chi. 26/192, 194, 198
29.	<i>Sukhavati varti</i>	<i>Netra roga</i>	Ch. Chi. 26/252-253
30.	<i>Pippalyadi varti, Pushyanug churna</i>	<i>Yonivyapad, Pradar</i>	Ch. Chi. 30/72, 90-94
31.	<i>Kalyanak guda, Vyoshadi modaka Pandu, Mutrakriksha</i>	<i>Mandagni/Arsh Pandu, Mutrakriksha</i>	Ch. Kalp 7/40-44
32.	<i>Gomutra bhavita churna yoga</i>	<i>Kosthagat vyadhi</i>	Ch. Kalp 12/23
33.	<i>Aptantrak nashak ghrita</i>	<i>Aptantrak</i>	Ch. Si. 9/20

Sushruta Samhita (1000 B.C.-5th Cent. A.D)^[13]

Table 3: The Names of Formulations, Indications, and References of *Maricha* are mentioned below

S.No.	Formulation	Indications	References
1.	<i>Hingwadi churna</i>	<i>Kasa, Swasa, Gulma, Udarroga</i>	Su. Chi. 5/28
2.	<i>Vajraka taila</i>	<i>Kustha</i>	Su. Chi. 9/55
3.	<i>Navayasa loha</i>	<i>Sthaulya, Pandu, Sotha</i>	Su. Chi. 13/11
4.	<i>Bhadrodaya anjan</i>	<i>Netra roga</i>	Su. U.T. 18/96
5.	<i>Gutika anjan</i>	<i>Netra roga</i>	Su. U.T. 18/100
6.	<i>Pathyadi varti</i>	<i>All Netra roga</i>	Su. U.T. 18/105
7.	<i>Panchgavya ghrita</i>	<i>Vishama jvara</i>	Su. U.T. 39/241
8.	<i>Vidangadi avaleha</i>	<i>Pandu, kamala</i>	Su. U.T. 44/31
9.	<i>Bharangyadi leha</i>	<i>Shwasa roga</i>	Su. U.T. 51/44
10.	<i>Maricha churna</i>	<i>Kasa</i>	Su. U.T. 52/22
11.	<i>Phalatrikadi churna</i>	<i>Vataj & Pittaj kasa</i>	Su. U.T. 52/22

Astanga Hridaya (7th Cent. A.D)^[14]

Table 4: The names of Formulations, indications, and references of *Maricha* are mentioned below

S.No.	Formulation	Indications	References
1.	<i>Amritaprasha ghrita</i>	<i>Nashta shukra, Kshata kshina, Brihmaniya, kasa, Hikka, etc.</i>	A.H.Chi. 3/94-101
2.	<i>Kushmandaka rasayana</i>	<i>Kasa, Hikka, Jwara, Shwasa</i>	A.H.Chi. 3/114-117
3.	<i>Saindhavdi churna</i>	<i>Aruchi, dipana, Balya, parshav shula</i>	A.H.Chi. 3/141-143
4.	<i>Eladi Sharpi guda</i>	<i>Rajyakshama</i>	A.H.Chi. 5/28-32
5.	<i>Yavanishadav churna</i>	<i>Rajyakshama, Aruchi, Hridroga</i>	A.H.Chi. 5/55-57
6.	<i>Talishpatra churna</i>	<i>Rajyakshama, Kasa, Shwasa, Aruchi</i>	A.H.Chi. 5/58-60
7.	<i>Ashtanga lavana</i>	<i>Kaphaj madatya</i>	A.H.Chi. 7/40-41
8.	<i>Abhyaristha</i>	<i>Arsh, Grahani, Panduroga</i>	A.H.Chi. 8/64-67
9.	<i>Kalyanak Khsara</i>	<i>Arsh, Gulma, Pandu, Udarroga</i>	A.H.Chi. 8/140-143
10.	<i>Putikaranj Chukra</i>	<i>Arsh, Gulma, Pleeharoga</i>	A.H.Chi. 8/145-148

11.	<i>Piluphala Shukta</i>	<i>Arsh, Gulma</i>	A.H.Chi. 8/149-150
12.	<i>Dashmoola guda</i>	<i>Arsh, Gulma, Pleeharoga</i>	A.H.Chi. 8/151-152
13.	<i>Chitraka avleha</i>	<i>Arsh, Kustha, Pleeharoga</i>	A.H.Chi. 8/153-154
14.	<i>Gudadi gutika</i>	<i>Arsh, Tvakvikara</i>	A.H.Chi. 8/155
15.	<i>Suranmodaka</i>	<i>Arsh</i>	A.H.Chi. 8/157
16.	<i>Yavanyadi churna</i>	<i>Atisara, Grahani, Kshaya</i>	A.H.Chi. 9/110-112
17.	<i>Talishadi Vataka</i>	<i>Grahani, Parsvashula, Kshardi</i>	A.H.Chi. 10/16-21
18.	<i>Panchmuladi ghruta</i>	<i>Shula, Gulma, Udarroga, Swasa, Kasa</i>	A.H.Chi. 10/27-29
19.	<i>Patoladi churna</i>	<i>Grahani, Hridroga, Pandu, Kamla</i>	A.H.Chi. 10/34-36
20.	<i>Bhunimbadi churna</i>	<i>Grahani, Gulma, Kamla</i>	A.H.Chi. 10/37-38
21.	<i>Hingwastak churna</i>	<i>Vataj Gulma</i>	A.H.Chi. 14/35
22.	<i>Narayan churna</i>	<i>Udarroga</i>	A.H.Chi. 15/14-21
23.	<i>Nilinyadi churna</i>	<i>Udarroga, Gulma</i>	A.H.Chi. 15/26
24.	<i>Navayas churna</i>	<i>Pandu, Kamla, Hridroga</i>	A.H.Chi. 16/14
25.	<i>Mandur vataka</i>	<i>Panduroga, Kustha, Kamla</i>	A.H.Chi. 16/16-19
26.	<i>Tapyadi churna</i>	<i>Pandu, Visha, Kasa, Rajyakshama, Visamjvara</i>	A.H.Chi. 16/20-22
27.	<i>Vrikshak kwatha</i>	<i>Tvaka Vikar</i>	A.H.Chi. 19/36
28.	<i>Lakshadi churna</i>	<i>Kustha</i>	A.H.Chi. 19/41
29.	<i>Saptsama gutika</i>	<i>Kustha</i>	A.H.Chi. 19/43
30.	<i>Mustadi churna</i>	<i>Kustha, Sotha, Panduroga</i>	A.H.Chi. 19/59-60
31.	<i>Marichadi lepa</i>	<i>Sidhma kustha, Naveen Sweta kustha</i>	A.H.Chi. 19/73-74
32.	<i>Vajraka taila</i>	<i>Kustha, Nadivrana</i>	A.H.Chi. 19/79-80
33.	<i>Bhallatakadi lepa</i>	<i>Switra, Twakvikara</i>	A.H.Chi. 20/16-17
34.	<i>Nimbadi ghruta</i>	<i>Kustha, Nadivrana, Arbuda, Bhagandara, Gandmala</i>	A.H.Chi. 21/58-61
35.	<i>Chandanadi taila</i>	<i>Used as Pana, Nasya, Abyanga in Kustha, Dushta vrana, and Apache.</i>	A.H.Ut. 30/22

Description of Synonyms and Ayurvedic Properties (Guna-Karma) of Maricha in Classical Nighantus

Dhanvantari Nighantu (10th–13th Century A.D.) [15]

Maricha is categorized under the *Shatpushpadi Varga*. This text mentions ten synonyms for *Maricha*, including *Maricha*, *Palita*, *Shyama*, *Vallija*, *Krishna*, *Ushna*, *Yavaneshta*, *Shirovrtta*, *Kolaka*, and *Dharmapattana*. It is described as possessing *Katu* and *Tikta Rasa* with *Ushna Virya*. The drug is beneficial in eliminating aggravated *Kapha dosha* and has a vermifuge action (destroys intestinal worms).

Sodhala Nighantu (12th Century A.D.) [16]

Under *Shatpushpadi Varga*, *Sodhala Nighantu* lists nine synonyms such as *Maricha*, *Palita*, *Vellaja*, *Krishnabhushana*, *Yavaneshta*, *Shirovrittama*, *Kolaka*, and *Varmapattaka*. The classification and description highlight its pungent and penetrating nature.

Madanapala Nighantu (14th Century A.D.) [17]

Maricha has been placed under the *Shunthyadi Varga* in this treatise. Five synonyms are provided: *Maricha*, *Vallija*, *Tikshna*, *Malina*, and *Shyamabhushana*. It is characterized by a predominance of *Katu Rasa*, *Tikshna* and *Ruksha Guna*, and *Ushna Virya*. Therapeutically, it is beneficial in conditions such as *Shwasa*, *Shoola*, and *Krimi Roga*.

Kaiyadeva Nighantu (15th Century A.D.) [18]

In this work, *Maricha* is described under *Aushadhi Varga*. Ten synonyms are noted: *Maricha*, *Malina*, *Shyama*, *Vellaja*, *Tikshna*, *Ushna*, *Yavaneshta*, *Shirovrinta*, *Suvrija*, and *Charmabandha*. The attributes denote its intense, sharp, and heating properties.

Bhavaprakasha Nighantu (16th Century A.D.) [19]

Located in the *Haritakyadi Varga*, this text enlists synonyms like *Maricha*, *Vellaja*, *Krishna*, *Ushna*, and *Dharmapattana*. It is rich in *Katu Rasa*, *Tikshna-Ruksha Guna*, and carries *Ushna Virya*. It pacifies *Vata*

and *Kapha* while aggravating *Pitta*. *Maricha* is a *Dipana* (digestive stimulant) and useful in managing *Shwasa* and *Krimi*. The fresh (*Ardra*) *Maricha* is described as *Madhura Vipaka*, slightly less heating, having *Guru* and *Tikshna* qualities. The dried form has *Katu Rasa*, *Laghu Guna*, and stronger *Ushna* potency, and can aggravate *Pitta*.

Raja Nighantu (17th Century A.D) [20]

Maricha appears under the *Pipplayadi Varga* with fifteen synonyms, including *Maricha*, *Palita*, *Shyama*, *Kola*, *Vallija*, *Ushna*, *Yuvanesta*, *Shakanga*, *Dharmapattana*, *Katuka*, *Shirovritta*, *Vira*, *Kaphavirodhi*, *Sarvahita*, and *Krishna*. It possesses *Tikta* and *Katu Rasa*, with *Ushna* and *Laghu Guna*. *Maricha* is indicated in *Krimi*, *Hridroga*, and *Aruchi* due to its *Agni Deepana* properties and its effectiveness in balancing *Vata* and *Kapha*.

Phytochemical Constituents of Maricha (Black Pepper)

Piper nigrum (black pepper) is a nutritionally dense spice containing numerous bioactive components. In 100 grams of its seeds, the proximate composition includes approximately 66.5 grams of carbohydrates, 10 grams of protein, and 10.2 grams of fat [21]. Additionally, it contains essential minerals in substantial quantities, including calcium (400mg), potassium (1200mg), magnesium (235.8–249.8mg), and phosphorus (160mg), whereas elements like sodium, zinc, and iron are present in smaller proportions [21,22]. These micronutrients are vital for various physiological and metabolic functions in the human body. Black pepper also provides notable amounts of vitamins, especially vitamin C and B-complex group vitamins such as B1, B2, and B3.

Studies carried out on black pepper accessions cultivated in Nigeria indicated a tannin concentration varying between 2.11mg and 2.80mg per 100 grams of dried sample [22]. Moreover, investigations by Ashok Kumar et al. [10] have reported the existence of antioxidant flavonoids like catechin, quercetin, and myricetin, along with carotenoids including lutein and β -carotene in appreciable quantities. [23]

Volatile Oil Composition

Black pepper seeds produce around 3% essential oil, which consists mainly of monoterpene hydrocarbons (about 80%). Compounds such as sabinene, β -pinene, limonene, α -pinene, terpinene, Δ^3 -carene, and myrcene dominate its aromatic profile. Several oxygenated monoterpenes, including linalool, 1,8-cineole, borneol, carvone, and carvacrol, are also present. Sesquiterpenes make up nearly 20% of the oil, with major components being β -caryophyllene, humulene, β -bisabolone, caryophyllene oxide, and ketonic compounds. Trace elements of phenyl ethers like eugenol, safrole, and myristicin are observed as well. Sensory-active compounds such as linalool, α -phellandrene, α -pinene, limonene, and myrcene are largely responsible for the spice's characteristic aroma. Furthermore, branched aldehydes like 3-methylbutanal and methylpropanal are also reported. The musty scent noticed in aged pepper is due to the emergence of heterocyclic substances like 2-isopropyl-3-methoxypyrazine and 2,3-dimethyl-5-methylpyrazine, typically found at concentrations of about 1 ppb. [24,25]

Alkaloidal Principles

The characteristic pungency of black pepper is chiefly attributed to piperine, a bioactive alkaloid-like amide formed from piperine acid and piperidine. The pungent quality is predominantly due to the trans-trans isomer of this compound. In addition to piperine, related analogs such as piperanine (a partially saturated derivative), piperettine (with an extended carbon skeleton), piperyline (amide of piperic acid with pyrrolidine), and piperamine have been isolated. Collectively, these piperine-related compounds constitute roughly 5% of the total alkaloidal content. These phytoconstituents have been shown to possess a wide array of pharmacological properties. [24,25]

Exploring the Pharmacological Activity of BPEO and Piperine

Piperine, BPEO, and their active constituents show various potential biological activities, such as antioxidant, antimicrobial, antitumor, and cytotoxic effects. The potential biological activities of BPEO and piperine are illustrated in Fig. 3. [23]

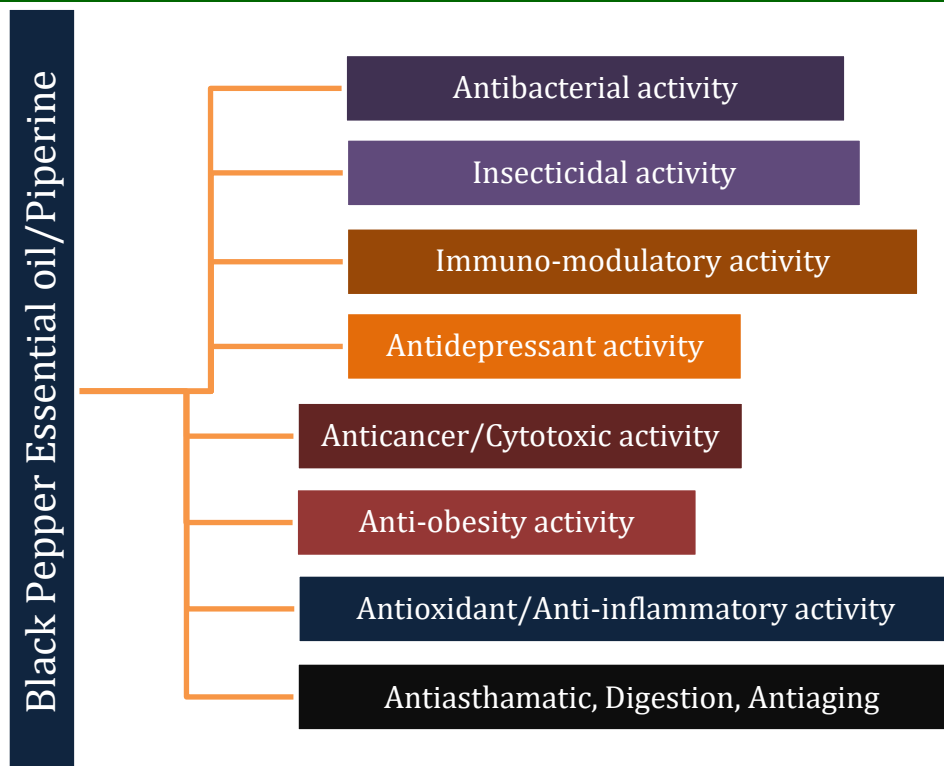


Fig. 3: A diagrammatic representation of the potential Pharmacological activities of black pepper essential oil and piperine

Antioxidant Activity

Oxidative stress plays a pivotal role in the pathogenesis of numerous chronic and degenerative disorders such as cancer, diabetes, Parkinson's disease, and immunodeficiency conditions.^[26] Antioxidants, whether naturally derived or synthetically produced, can counteract oxidative stress by neutralizing free radicals and thereby help prevent or slow the progression of such diseases.^[27]

Anti-bacterial and Anti-microbial Activity

Although the exact antimicrobial mechanism of black pepper remains to be fully elucidated, studies have shown promising effects. According to Rani et al.^[28] Piperine exhibited notable antimicrobial and antifungal activity against strains including *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Aspergillus niger*, *A. flavus*, *Alternaria alternata*, and *Fusarium oxysporum*. Additionally, phenolic constituents from fresh black pepper seed extracts demonstrated inhibitory effects on bacterial growth, including *Bacillus*, *E. coli*, *S. aureus*, *S. faecalis*, and *B. cereus*.^[29, 30] One study also found that a concentration of 1.0 µl/mL of BPEO (Black Pepper Essential Oil) was effective in inhibiting meat-borne *E. coli*, highlighting its potential utility as a natural antibacterial agent in the food industry. Similar antimicrobial activity was observed against *E. coli*, *B. subtilis*, and *S. aureus*.^[31]

Anti-cancer Properties

Piperine has shown significant inhibitory effects on the proliferation of prostate cancer cells, including both androgen-sensitive and androgen-

insensitive types.^[32] When administered in combination with docetaxel, piperine enhanced the anticancer efficacy in human prostate cancer models. Furthermore, it was reported to induce apoptosis and cause DNA damage in tumor cells, pointing to its potential application in osteosarcoma treatment.^[33,34] It also exhibited protective effects against lung cancer through the activation of antioxidant defense enzymes and suppression of lipid peroxidation processes.^[35]

Cytotoxic Effects

Both piperine and BPEO have been reported to enhance the cytotoxic potential of tumor necrosis factor (TNF)-induced apoptosis in breast cancer cell lines.^[36]

Insecticidal Activity

Black pepper has demonstrated insect-repellent and insecticidal properties. It was found to be effective against the European chafer (*Amphimallon majale*), a significant agricultural pest.^[37] A 0.2% v/v concentration of black pepper essential oil displayed repellent action against *Tribolium castaneum*, a major pest in wheat storage. Naseem and Khan^[38] noted that higher concentrations and longer exposure times maximized their repellent efficacy. However, given the limited number of studies conducted in this area, further research is warranted to explore its full insecticidal potential.

Anti-Obesity Effects

Among various botanicals studied for anti-obesity effects, *Piper nigrum* holds considerable

promise. Investigations using 3T3-L1 preadipocytes revealed that both the black pepper extract and its major bioactive compound, piperine, effectively inhibited adipocyte differentiation without showing cytotoxicity. Gene expression analysis supported its modulatory role in lipid metabolism-related pathways. In vivo studies also demonstrated that piperine supplementation (40mg/kg) with a high-fat diet led to a reduction in body weight, total cholesterol, triglycerides, LDL, VLDL, and fat mass, while HDL levels increased without affecting food intake. These findings suggest that piperine could serve as a lipid-lowering and fat-reducing agent without impacting appetite.^[39]

Anti-inflammatory activity

Piperine has been assessed for its anti-inflammatory, analgesic, and anti-arthritic potential. In vitro studies were conducted on interleukin-1 β -stimulated fibroblast-like synoviocytes derived from rheumatoid arthritis patients to determine anti-inflammatory activity. The analgesic and anti-arthritic properties were evaluated using the carrageenan-induced paw edema model in rats. Markers such as prostaglandin E2 (PGE2), cyclooxygenase-2 (COX-2), interleukin-6 (IL-6), and matrix metalloproteinases (MMPs) were measured using ELISA and RT-PCR techniques. The results indicated that piperine, at concentrations ranging from 10–100 μ g/mL, inhibited PGE2 synthesis in a dose-dependent manner, with significant inhibition observed even at 10 μ g/mL. Further, piperine suppressed the expression of IL-6 and MMP-13, and it also blocked the nuclear translocation of activator protein-1 (AP-1) in IL-1 β -treated synoviocytes. However, nuclear factor kappa B (NF- κ B) migration remained unaffected. In vivo, piperine administration significantly reduced pain and arthritic symptoms in the experimental rats. These findings support the anti-inflammatory, analgesic, and anti-arthritic effects of piperine in arthritis models.^[40,41]

Immuno-modulatory activity

Piperine has demonstrated promising immunomodulatory and antitumor potential. In experimental models, it exhibited cytotoxicity against Ehrlich ascites carcinoma (EAC) cells and Dalton's lymphoma ascites (DLA) at a concentration of 250 μ g/mL. Additionally, L929 cells in culture showed a significant cytotoxic response to piperine at a lower dose of 50 μ g/mL. In vivo studies conducted on Balb/c mice revealed that piperine treatment led to a marked increase in total white blood cell (WBC) count, along with enhanced bone marrow cellularity and a higher percentage of alpha-esterase positive cells, suggesting stimulation of hematopoietic activity and immune modulation.^[40,42]

DISCUSSION

Maricha (*Piper nigrum*) has been revered in Ayurveda for its *Agni-deepana* (digestive fire-stimulating) and *Krimighna* (anthelmintic) roles. Classical texts like *Charaka Samhita* classify it under formulations targeting *Santarpanajanya Vyadhi*, such as *Prameha*, *Arsha*, and *Grahani*. The main active compound, piperine, has emerged as a bioenhancer, significantly improving the bioavailability of other herbs and drugs by inhibiting hepatic and intestinal enzymes. Its pharmacodynamic effects align with its traditional applications: antioxidant action justifies its use in *Rasayana* formulations, while its lipid-lowering and anti-obesity effects support *Lekhaniya Mahakashaya* classification. Modern studies also validate its antimicrobial, anti-inflammatory, and anticancer actions. For example, piperine's ability to induce apoptosis in cancer cells, inhibit adipogenesis, and modulate inflammatory mediators like COX-2 and IL-6 echoes its classical indications in *Kasa*, *Swasa*, and *Shotha*. Its immunomodulatory action also complements its *Rasayana* role in Ayurveda. These scientific findings affirm that *Maricha* is a potent multi-dimensional herb with systemic benefits. It demonstrates the importance of exploring classical Ayurvedic herbs through a modern biomedical lens.

CONCLUSION

Maricha (*Piper nigrum*) stands as a unique example of an Ayurvedic herb with both deep classical roots and strong scientific validation. The synergy of its phytoconstituents- especially piperine- gives it a broad pharmacological profile useful in addressing metabolic disorders, infections, inflammation, and oxidative stress. Modern studies increasingly corroborate its traditional indications for *Prameha*, *Shwasa*, and *Grahani*. Future research and standardization may lead to its development as a lead compound in phytopharmaceutical formulations. Thus, *Maricha* holds immense potential as a bridge between ancient wisdom and contemporary medicine.

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