

Chemical aspects of black pepper - *Piper nigrum*

A. D. Theeshya Dulmini and K. Sarath D. Perera

Department of Chemistry, The Open University of Sri Lanka

Black pepper is known all over the world as “King of Spices”, since it is not only an ingredient to make mouthwatering food, but also rich in immense medicinal value [1,2]. The pepper name is derived from the “Pippali” in Sanskrit [3]. According to history, Greek people have used pepper as currency in fourth century and is the first spice that gained the value [3]. Black pepper is used to heal cough, asthma, kidney inflammations and joint pains in India and China as a folk medicine [3]. Scientists have discovered many types of phytochemicals *e.g.*, alkaloids, flavonoids, polyphenols, tannins, saponins *etc.*, are present in this plant which contains miraculous medicinal value [4].

Taxonomical Classification

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Piperales
Family	Piperaceae
Genus	<i>Piper</i>
Species	<i>Piper nigrum</i>

Morphology and Distribution

Black pepper is a native to the Southern India as it is a tropical perennial plant. However, it is also cultivated in the other tropical countries such as Brazil, Indonesia, Malaysia, China, Thailand, Sri Lanka, Vietnam, and Madagascar [5].

The stem of black pepper reaches a height of more than 9 m. which is around 1.2 cm in diameter [4,5]. It is grey and contains nodes and primary adventitious roots that helps it to attach support structures [4,5]. Simple, glossy, oval, sharply pointed dark green leaves are arranged alternatively on the stem [4,5]. The average width of the leaves varies between 4-12 cm, and the

length is about 8-20 cm [2]. The white, small flowers bloom on elongated slender spikes around 7-15 cm in length forming a glabrous inflorescence [4,5]. These flowers can be either monoecious or polygamous [4]. The pepper vine starts to bear fruit in 4th or 5th year and it continues up to 7th year [4]. Generally, 20-30 spikes with fruits can be seen on the stem at once [4]. The green, spherical unripe fruits turn in to dark crimson when ripe. A mature fruit with 5 mm diameter contains a single seed [4,5]. Sundried unripe fruits are known as peppercorns and they can be easily removed from the spike [4,5]. Not only sun-drying method, but also freeze-drying of unripe green fruits yields black pepper [4]. Black pepper seeds have a spicy, stinging, and highly strong flavor with an intense and aromatic odor [6].

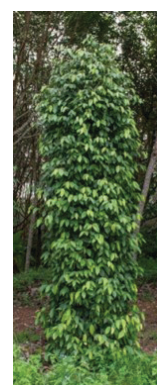
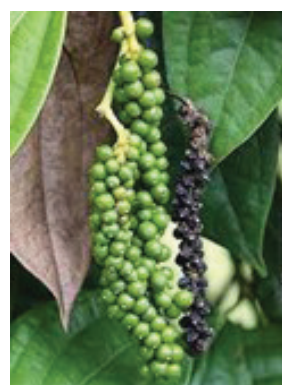


Figure 1: Pepper vine

There are more than 600 varieties of pepper are available in the nature, even though only a few are used as spices (*e.g.*, white pepper, green pepper, red pepper) [1].

Phytochemicals in black pepper

The medicinal importance of the plant depends on the chemical composition present in the plant which is also called phytochemicals. The major role of these compounds is to provide protection to the plant.

Alkaloids, flavonoids, tannins, terpenoids, polyphenols *etc.* are some of the common phytochemicals present in black pepper [2,4,5]. The most famous phytochemical present in the black pepper is an alkaloid called “Piperine” **1** [5]. It exists in four isomeric forms: piperine **1**, isochavicine **2**, isopiperine **3**, and chavicine **4** [2,7].

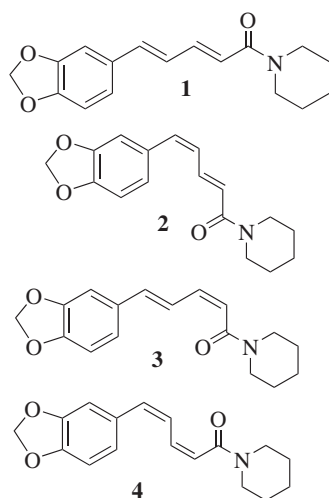


Figure 2: Isomers of piperine

Piperine percentage in the essential oil extract from seeds and leaves are 2.13- 5.80% and 0.12-20.86%, respectively [4]. Piperettine **5**, piperylin A **6**, piperolein B **7**, and pipericide **8** are some examples for other alkaloids (see Figure 3) [5].

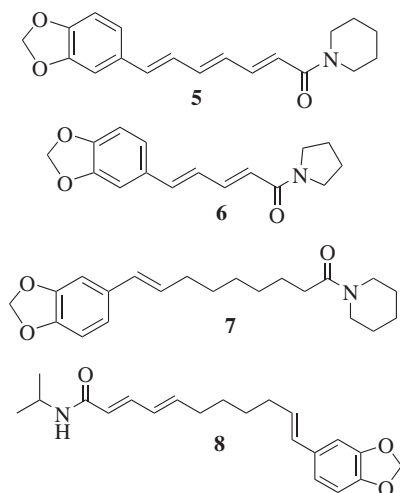


Figure 3: Some alkaloids present in black pepper

Flavonoids such as catechin **9**, quercetin **10**, and myricetin **11** (Figure 4) are present in 100 mg of black pepper seeds at levels of 410, 13 and 56 μg [2].

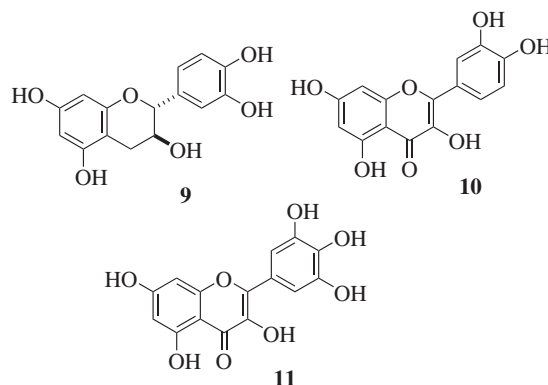


Figure 4: Some flavonoids present in black pepper

Monoterpenoids (*e.g.*, sabinene **12**, limonene **13**, camphene **14**, α -pinene **15**, β -phellandrene **16**), sesquiterpenoids (*e.g.*, α -copaene **17**, α -cubebene **18**, β -bisabolene **19**, β -caryophyllene **20**) and some volatile compounds such as cinnamic acid **21**, eugenol **22**, and phenyl acetic acid **23** (Figure 5, 6 and 7) give aroma to the black pepper [2].

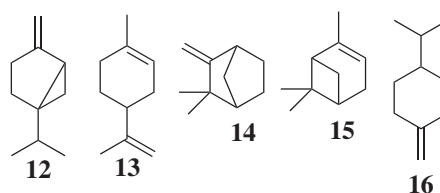


Figure 5: Some monoterpenoids present in black pepper

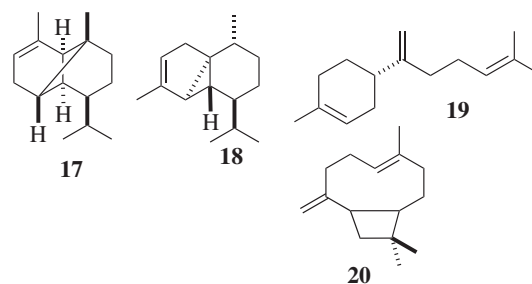


Figure 6: Some sesquiterpenoids present in black pepper

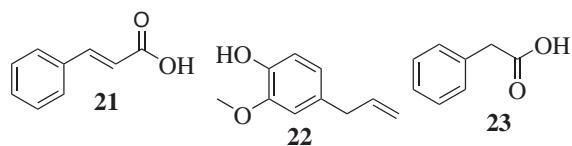


Figure 7: Some phenolics and acids present in black pepper

Black pepper contains high concentrations of essential elements such as Ca, Mg, K and P and rich in vitamins C, B1, B2 and B3 [5].

Health benefits of black pepper

According to one of the major Ayurveda literatures (Charaka Sanhithawa), pepper has been used for neurological, broncho-pulmonary and gastrointestinal disorders [6]. Pepper is one of the major three acrids (or “Thrikatu”) applied in Ayurvedic medicine (i.e., other two acrids are long pepper or “Pippali” and ginger) [6]. It is an ingredient in ayurvedic medicines used to treat asthma, catarrh, diarrhea, cough, and menstruation problems. Furthermore, black pepper is a well-known Chinese folk remedy for epilepsy and used as a traditional nerve tonic in Middle Eastern countries [6,8]. Nowadays, pepper spray has become a popular, powerful and effective tool for self-defense.

Recent scientific research has found that pepper contains antioxidant properties; 50% of black pepper can suppress free radicals and prevent lipid peroxidation by more than 90% [6]. Piperine in black pepper acts as a major inflammatory agent as well as a natural bio-enhancer increasing intestinal absorption [4,6,9-12].

Most of the phytochemicals including polyphenols play a vital role as anti-microbial agents [4]. Moreover, black pepper extracts inhibit bacteria such as *Staphylococcus*, *Bacillus*, and *Streptococcus*. It can be used to treat malaria and to repel insects and rodents [6].

Black pepper improves gastrointestinal activities, as piperine enhances nutrient absorption, enzyme synthesis, and defense capabilities in gastrointestinal system, making it useful for treating diarrhea and constipation [6].

Oral administration of black pepper extracts helps to suppress cancers [5]. Furthermore, this spice shows immunity-enhancing, antidiabetic, hepatoprotective and anti-obesity properties [5,10-15]. Piperine in black pepper can be used to treat neurodegenerative illnesses such as depression, Alzheimer’s and Parkinson’s diseases [6]. Recently, researchers have discovered that phytochemicals present in black pepper has an inhibitory property against covid-19 virus [6].

Conclusion

Black pepper enhances the flavor and the shelf-life of cuisines. It is a traditional medicine with various health benefits including anticancer, antioxidant, anti-inflammatory, antidiabetic, hepato-protective, antimicrobial, immunity enhancing, neuroprotective, anti-obesity properties etc. Black pepper is referred to as “Black Gold” due to its medicinal and economical value, akin to that of pure gold [6].

References

1. Ashwini, P.; Nithisha, M.; Shivani, K.; Jyothi, N. A.; Prasanthi, R. The *Piper nigrum* - An overview. *IJPREMS*. **2024**, 4 (3), 513-516. DOI: 10.58257/IJPREMS32932
2. Saha, M.; Chatterjee, S. A comprehensive review on nutritional aspects, chemical composition and pharmacological attributes of black and white pepper. *Int. J. Pharm. Sci. Rev. Res.* **2024**, 15(4), 1036-1043.
3. Dra. Lily Lara Romero (Ed.). *Proceedings of the International Pepper and Spices Conference, April 26, 2022, Tobasco, Mexico*. IKSAD Global Publishing House.
4. Ashokkumar, K.; Murugan, M.; Dhanya, M. K.; Pandian, A.; Warkentin, T. D. Phytochemistry and therapeutic potential of black pepper [*Piper nigrum* (L.)] essential oil and piperine: A Review. *Clin. Phytosci.* **2021**, 7 (1), 52. <https://doi.org/10.1186/s40816-021-00292-2>.
5. Akram, M.; Solosky, G.; Ali, A. Phytochemistry and pharmacology of *Piper nigrum*. *Comp. Clin. Path.* **2024**, 33 (3), 337–341. <https://doi.org/10.1007/s00580-023-03536-4>
6. Khan, A. U.; Talucder, M. S. A.; Das, M.; Noreen, S.; Pane, Y. S. Prospect of the black pepper (*Piper nigrum* L.) as natural product used to an herbal medicine. *Open Access Maced. J. Med. Sci.* **2021**, 9(F), 563-573. <https://doi.org/10.3889/oamjms.2021.7113>
7. Dlodla, P.V.; Cirilli, I.; Marcheggiani, F.; Silvestri, S.; Orlando, P.; Muvhulawa, N.; Moetlediwa, M.T.; Nkambule, B.B.; Mazibuko-Mbeje, S.E.; Hlengwa, N.; Hanser, S.; Ndwandwe, D.; Marnewick, J.L.;

- Basson, A.K.; Tiano, L. Bioactive properties, bioavailability profiles, and clinical evidence of the potential benefits of black pepper (*Piper nigrum*) and red pepper (*Capsicum annuum*) against diverse metabolic complications. *Molecules* **2023**, *28*, 6569. <https://doi.org/10.3390/molecules28186569>
8. Jan, U.; Kalam, M. A.; Wani, N. N.; Ayoub, M.; Farooq, S. F.; Yaqoob, F. Filfil Siyāh (*Piper nigrum*): Medicinal importance in perspective of Unani medicine and pharmacological studies. *J. Pharmacogn. Phytochem.* **2024**, *13* (2), 652-656. <https://doi.org/10.22271/phyto.2024.v13.i2d.14907>
 9. Alateeqi, D. I. M.; Al-Touby, S. S. J.; Hossain, M. A. Evaluation of bacteriostatic and antioxidant activities of various extracts from aerial part of *Piper nigrum* grown in Gulf countries traditionally used for the treatment of various infectious diseases. *J. Umm Al-Qura Univ. Appl. Sci.* **2024**. <https://doi.org/10.1007/s43994-024-00149-7>
 10. Umapathy, V. R.; Dhanavel, A.; Kesavan, R.; Natarajan, P. M.; S, B.; Vijayalakshmi, P. Anticancer potential of the principal constituent of *Piper nigrum*, piperine: A comprehensive review. *Cureus.* **2024**, *16* (2), e54425. DOI: 10.7759/cureus.54425.
 11. Gouthamchandra, K.; Sudeep, H. V.; Sathish, A.; Amritharaj, Lingaraju, H. B.; Puttaswamy, N.; Kodimule, S. P. Standardized extract of β -caryophyllene from *Piper nigrum* L (Piperaceae) and its associated mechanisms in mouse macrophage cells and human neuroblastoma SH-SY5Y cells. *Fortune Journal of Health Sciences* **2024**, *7*, 25-36.
 12. Ahmad, U.; Raja, N. I.; Mashwani, Z. R.; Qureshi, R.; Wali, R. W. Physicochemical properties of black pepper (*Piper nigrum* L.) seed oil as affected by different extraction methods. *Int. J. Biol. Biotech.* **2024**, *21*(2), 195-201.
 13. Sangroula, G.; Khatri, S. B.; Sangroula, P.; Basnet, A.; Khadka, N.; Khadka, M.. Essential oil of black pepper (*Piper nigrum*) and cardamom (*Amomum sublatum* roxb) as a natural food preservative for plum RTS. *J. Agric. Food Res.* **2024**, *16*, 101159.
 14. Goswami, A.; Malviya, N. Reassessing the restorative prospectives of the king of spices black pepper. *J. Drug Delivery Ther.* **2020**, *10*(3), 312-321. <http://dx.doi.org/10.22270/jddt.v10i3.4111>
 15. Majeed, M.; Prakash, L. The medicinal uses of pepper. *Int. Pepper News* **2000**, *25*(1), 23-31.

Professor K Sarath D Perera obtained his B.Sc. Degree from the University of Sri Jayewardenepura and completed his PhD in Queen's University Belfast, UK. He is currently serving as a Senior Professor at the Department of Chemistry of the Open University of Sri Lanka.

Ms. A. D. Theeshya Dulmini graduated from the Open University of Sri Lanka and obtained her M.Sc. in Analytical Chemistry from the University of Colombo.