

Black pepper fruit (*Piper nigrum* L.) as antibacterial agent: A mini-review

Abstract

Natural products have been a rich source of bioactive compounds, some of these compounds showed significant antibacterial activity. Black pepper fruit (*Piper nigrum* L.) is one of the most famous pungency and flavor spices in the world, it is known as the king of spices. However, its benefit is not restricted on food seasoning. It has numerous bioactive effects on the human body. One of these benefits is its noticeable antibacterial activity. This mini-review summarizes the findings of scientific studies on the antibacterial activity of black pepper fruit against Gram negative and Gram positive bacteria, highlights the methods used for testing the antibacterial activity and the best solvent for extraction of the plant. The findings validate the use of this spice in traditional medicine and recommend it as a source of innovative therapeutic agents against food borne pathogens and infectious diseases.

Keywords: spices, seasonings, black pepper fruit, *Piper nigrum*, antibacterial

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Introduction

Plants are known for their ability to maintain good health since antiquity. Nowadays, the interest in natural products as antimicrobial agents has greatly increased due to the gradual collapse of antibiotics in the front of the multi-drug-resistant pathogens.¹ Spices are rich in bioactive chemical compounds and they have been used by several cultures for many centuries as food seasoning, preservatives, insecticidal, colorants, and natural flavoring.^{2,3} Many spices are used to extend shelf-life of food, prevent food spoilage and food-borne diseases, though some spices are used in food production industry and also many spices are used to inhibit infectious diseases and eradicate pathogens, particularly in traditional medicine.⁴ The antibacterial efficacy of some spices and seasonings have been proved scientifically, as example of these spices; black seed (*Nigella sativa*),⁵ garlic bulb (*Allium sativum*),⁶ onion (*Allium cepa*),⁷ thyme (*Thymus vulgaris*) and clove (*Syzygium aromaticum*),⁸ cinnamon bark (*Cinnamomum verum*),⁹ oregano (*Origanum vulgare*),¹⁰ cumin (*Cuminum cyminum*)¹¹ and many more. According to recent global interest in natural products, medicinal plants and traditional medicine, studies on spices should be revived in order to innovate new natural drugs. Encouraging this, is the fact that up to 80% of the world populations are still rely on medicinal plants and natural products in their primary health-care needs.¹² The current brief review aimed to highlight the medicinal importance of black pepper fruits and its efficacy as antibacterial agent.

Black pepper (*Piper nigrum* L.), botanical information and applications

The genus *Piper* L. (family Piperaceae) consists of more than one thousand species, distributed mainly in tropical regions of the world.¹³ *Piper nigrum* L. (black pepper) is the most famous species of this genus, it is known as the “king of spices” due to its pungent principle piperine and the popularity in use for flavoring food throughout the world.¹⁴ On the other hand, *P. nigrum* (*Piper nigrum*) has been used for medicinal purposes in many parts of the world since ancient times. Medicinal uses of *P. nigrum* include antibacterial, antifungal, antiapoptotic, antidepressant, anti-diarrheal, anti-inflammatory,

antimutagenic, antioxidative, antipyretic, antispasmodic, antitumor, to improve appetite and digestive power, anti-cold, anti-cough, dyspnea, for curing from throat diseases, anti-intermittent fever, anticolitic, anti-dysentery, get rid of worms and piles,^{14,15} some of these uses are illustrated in Figure 1.



Figure 1 Some uses of the black pepper fruits in traditional medicine

P. nigrum is a woody climbing vine growing to 9 m (30 ft) or more in length. The grayish stem may reach 1.2 cm (0.5 in) diameter. Numerous rootlets grow from swollen stem nodes. Leaves dark green above and pale green beneath, glossy, ovate and acutely tipped, and range in size from 13–25cm (5–10 in) in length. Elongated, slender spikes or catkins (1.6–2cm [4–5 in] in length) bear minute, white flowers. The flower spikes, each producing from 50–60 single-seeded dark red berries, approximately 5 millimeters (0.20 in) in diameter, always appear on stems opposite the leaves.¹⁶

Different parts of the plant are used for medicinal purposes; however, the part commonly used as the spice black pepper is the cooked and dried unripe berry,¹⁷ that is why we focused only on the use of this plant part.

Bioactive chemical compounds of the black pepper

Almost all spices have aromatic features, regular grindings of spices lead to loss of important aroma compounds and accordingly resulted to considerable loss of aroma and flavor components and deterioration of quality.¹⁸ The dried black pepper fruit is rich in bioactive phytochemical compounds. Piperine (Figure 2) is one of the most abundant chemical alkaloids in the black pepper.¹⁹ Other similar alkaloids are also isolated from black pepper such as piperanine, piperettine, piperlylin A, piperolein B, and pipericine. However, the pungency of these piperine's analogs are less than Piperine.²⁰ Black pepper was also found to have a good quantity of polyphenols. The interesting findings are that, black pepper contains more polyphenols compared with white pepper. Moreover, it is believed that, after eating Black pepper, it hydrolyzed in the gut and liberating these bound polyphenols.²¹ In addition, some studies stated that the Black pepper contains aromatic compounds, flavonoids, alkaloids, amides and lignans.²¹ The volatile oils of the Black pepper fruits were analyzed using column chromatography, high resolution gas chromatography and gas chromatography mass spectrometry (GC-MS); up to 46 compounds were identified including δ -cadinol, δ -guaiene, (Z) (E)-farnesol, (E)- β -ocimene and guaiol.²² In another study, five phenolic amides were isolated from the black pepper, which revealed high antioxidant activity more effective than some naturally occurring antioxidants.²³ These investigations revealed the wealth of the black pepper in bioactive phytochemical components of promising medicinal importance.

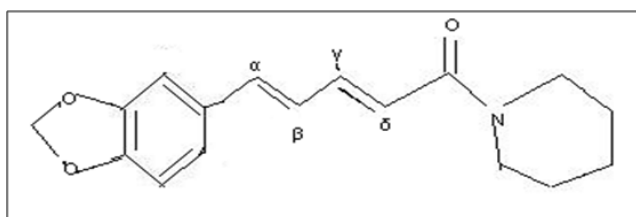


Figure 2 Piperine, the major compound in the Black pepper fruit¹⁹

Table 1 Antibacterial activity of Black Pepper fruit (*Piper nigrum* L.)

| Solvent used in extraction | Antibacterial Assay | Microorganism | | | | | | | | | | | | | Ref |
|----------------------------|---------------------|------------------------|------|------|------|-----|------|--------------|------------------------|------|------|------|------|------|-----|
| | | Gram negative bacteria | | | | | | | Gram positive bacteria | | | | | | |
| | | E.c. | K.p. | S.t. | Pa. | Ps. | S.tm | S.a. | S.e. | E.f. | S.f. | B.c. | B.m. | B.s. | |
| CHCl ₃ | RMI | 17.9 | - | - | - | - | - | 13.5 | - | - | - | - | - | - | 28 |
| EtOH | MIC (mg/ml) | - | 0.62 | - | - | - | - | - | - | - | - | - | - | - | 29 |
| Cold H ₂ O | DD | 23 | - | 20 | 15 | - | - | 20 | - | 21 | - | - | - | - | 30 |
| Hot H ₂ O | DD | 21 | - | 22 | 18 | - | - | 22 | - | 19 | - | - | - | - | |
| MeOH | DD | 21 | - | 21 | 21 | - | - | -ve | - | 20 | - | - | - | - | |
| Pet. ether | WD | -ve | - | -ve | -ve | - | - | 14 | - | - | - | - | - | - | 31 |
| EtOH | WD | 14 | - | 18 | 17 | - | - | 11 | - | - | - | - | - | - | |
| H ₂ O | WD | -ve | - | 12 | -ve | - | - | 15 | - | - | - | - | - | - | |
| Acetone | MIC (mg/ml) | 125 | 125 | 250 | 62.5 | - | - | 125 | - | 500 | - | 250 | - | - | 32 |
| DCM | MIC (mg/ml) | 125 | 125 | 250 | 125 | - | - | 125 | - | 125 | - | 62.5 | - | - | |
| EtOH | MIC (%) | - | - | - | - | - | - | 0.06 ->4% | - | - | - | - | - | - | 33 |
| CCl ₄ | DD | 5-9 | - | -ve | 5-9 | - | - | - | 5-9 | - | - | - | 5-9 | - | 34 |

Results and discussion

In the past 70 years, the antibiotics have saved lives of millions of people all over the globe and participated in the development of modern medicine.²⁴ However, in recent years, the human communities all over the world are suffering from the growing crisis of epidemic antibiotic resistant pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), *Streptococcus pneumoniae* and *Mycobacterium tuberculosis*.²⁵ Accordingly, this pandemic crisis requires development or innovation of new antibacterial drugs. WHO reported that, infectious diseases are a major cause of morbidity and mortality worldwide, it estimated that about 50% of all deaths in developing tropical countries in particular are because of microbial infectious diseases. Moreover, based on 2002 statistics, around 98% of the 10.5 million pediatric deaths of children under age of five in these countries were from infectious diseases.²⁶ When putting in consideration that, since more than 40 years ago, no new classes of antibiotics were launched in the Pharmacies, while most bacterial pathogens have developed resistance to the available antibiotics in the markets which threaten the health situation in the world as never before. This urge the scientific community to search for new alternatives from plants and natural products.²⁷ Spices are rich in phytochemical components of bioactive effects on the human body. In literature, the black pepper was extensively studied for its antibacterial properties. Table 1 summarizes most studies conducted on the antibacterial activity of the black pepper, which are tested *in vitro* using different antibacterial assays; initially, the cup-plate method, disc diffusion method, micro-dilution method or minimum inhibitory concentration (MIC), as other antibacterial assays. According to these studies, different black pepper extracts showed significant inhibitory effects against varied gram-negative and gram-positive bacteria, although some studies revealed that the black pepper have no antibacterial activity, which could be attributed to differences in plant varieties, microbiological methods, solvents used and tested microorganisms. In general, the majority of these studies suggest that the black pepper could be a potential candidate for developing new antibacterial drugs against the wide range of pathogenic bacteria either food borne, food spoilage or clinical isolates.

Table continued..

| | | | | | | | | | | | | | | | |
|-------------------|-------------|------|------|-------|------|-----|------|-------|-----|-----|---|-------|-----|-----|----|
| Benzene | DD | 5-9 | - | 5-9 | 5-9 | - | - | - | 5-9 | - | - | - | 5-9 | - | |
| CHCl ₃ | DD | -ve | - | 5-9 | 5-9 | - | - | - | 5-9 | - | - | - | -ve | - | |
| Ethyl acetate | DD | -ve | - | 5-9 | 5-9 | - | - | - | 5-9 | - | - | - | -ve | - | |
| Acetone | DD | -ve | - | 5-9 | 5-9 | - | - | - | 5-9 | - | - | - | -ve | - | |
| EtOH | DD | 5-9 | - | 10-14 | 5-9 | - | - | - | 5-9 | - | - | - | 5-9 | - | |
| H ₂ O | DD | 5-9 | - | 5-9 | -ve | - | - | - | 5-9 | - | - | - | 5-9 | - | |
| Essential oil | MIC (%) | -ve | - | - | - | - | - | 1.00% | - | - | - | 0.25% | - | - | 35 |
| EtOH | WD | 8 | - | - | 9 | - | - | 18 | - | - | - | - | - | 14 | 36 |
| MeOH | DD | 9.7 | - | - | 12.2 | - | 10.5 | 11.7 | - | - | - | - | - | - | 37 |
| H ₂ O | WD | 8 | - | - | - | - | - | 13 | - | - | - | - | - | - | 38 |
| EtOH | WD | 22 | - | 12 | 15 | - | - | 11 | - | - | - | - | - | - | 39 |
| CHCl ₃ | WD | 18 | - | 14 | 8 | 18 | - | 16 | - | - | - | - | - | - | |
| H ₂ O | DD | 19.3 | - | - | 13.3 | - | 16.3 | 18.3 | - | - | - | - | - | - | 40 |
| MeOH | DD | 11.3 | - | - | 9.6 | - | 9.3 | 10.6 | - | - | - | - | - | - | |
| EtOH | DD | 14.6 | - | - | 10.3 | - | 10 | 12.3 | - | - | - | - | - | - | |
| Pet. ether | DD | 11.3 | - | - | 9.6 | - | 9.3 | 10.6 | - | - | - | - | - | - | |
| MeOH | DD | -ve | -ve | - | -ve | - | - | 6.9 | - | - | - | - | - | - | 41 |
| Volatile oil | WD | -ve | -ve | -ve | -ve | -ve | - | 14 | - | - | - | - | - | - | 42 |
| Acetone | WD | 17 | -ve | -ve | -ve | -ve | - | 13 | - | - | - | - | - | - | |
| MeOH | WD | -ve | -ve | -ve | -ve | -ve | - | 13 | - | - | - | - | - | - | |
| Hexane | DD | 14 | - | 12 | - | - | - | 12 | - | - | - | - | - | 17 | 3 |
| DCM | DD | 15 | - | 16 | - | - | - | 14 | - | - | - | - | - | 19 | |
| EtOH | DD | 8 | - | 14 | - | - | - | 11 | - | - | - | - | - | 14 | |
| H ₂ O | DD | 8 | - | 8 | - | - | - | 7 | - | - | - | - | - | 9 | |
| Acetone | WD | - | 8 | - | - | - | - | 9 | - | - | - | - | - | - | 43 |
| MeOH | WD | - | 9 | - | - | - | - | 8 | - | - | - | - | - | - | |
| EtOH | WD | - | - | - | -ve | - | - | -ve | -ve | -ve | - | - | - | - | 44 |
| MeOH | WD | -ve | - | -ve | - | - | - | -ve | - | -ve | - | - | - | - | |
| Essential oil | DD | 26 | - | - | - | - | - | - | - | - | - | - | - | - | 45 |
| H ₂ O | WD | 24 | 27 | 7 | - | 7 | - | 9 | - | - | - | - | - | - | 46 |
| EtOH | WD | 36 | 38 | 15 | - | 6 | - | 38 | - | - | - | - | - | - | |
| Essential oil | WD | 7.3 | -ve | - | 7.7 | 7.1 | - | 14.5 | - | 8.8 | - | - | - | 9.5 | 47 |
| EtOH | DD | 20 | 15 | - | 8 | 17 | - | 12 | - | - | - | - | - | - | 48 |
| EtOH | MIC (mg/ml) | 15 | - | - | 5 | - | - | 12.5 | 15 | - | - | 12.5 | - | - | 49 |
| Essential oil | DD | - | - | - | 10.2 | - | - | - | - | - | - | - | - | 6 | 50 |
| Essential oil | MIC (mg/ml) | >2.0 | >2.0 | - | >2.0 | - | >2.0 | >2.0 | - | 1 | - | - | - | - | 51 |
| MeOH | WD | 7.3 | - | - | - | - | - | -ve | - | - | - | -ve | - | - | 52 |

CHCl₃, chloroform; MeOH, Methanol; H₂O, Water; EtOH, Ethanol; Pet.ether, Petroleum ether; DCM, Dichloromethane; CCl₄, Carbon tetrachloride; -ve, No activity; - , Not tested; E.c., *Escherichia coli*; S.a., *Staphylococcus aureus*; S.e., *Staphylococcus epidermidis*; K.p., *Klebsiella pneumoniae*; E.f., *Enterococcus faecalis*; S.t., *Salmonella typhi*; S.t.m. , *Salmonella typhimurium*; P.a., *Pseudomonas aeruginosa*; B.c., *Bacillus cereus*; B.s., *Bacillus subtilis*; B.m., *Bacillus megaterium*; S.f., *Streptococcus faecalis*; DD, Disc diffusion(mm); VVD, Well-diffusion (mm); MIC, Minimum inhibitory concentration; RMI, Respiratory metabolism Inhibition (%)

*Not all studied microorganisms are mentioned in the table

The above Table 1 revealed that the most bacterial strain tested is *Escherichia coli* (gram negative) and the highest inhibition value reached 36 mm using the well-diffusion method and the solvent used for extraction of the plant fruit was ethanol, while no activity was noticed when using the methanol as a solvent for extraction in most studies. On the other hand, the most tested gram positive bacterial species was *Staphylococcus aureus*, and the highest inhibition value reached 38mm zone of inhibition using the well-diffusion method using ethanol as a solvent for extraction of the plant fruit, while no activity was noticed when using methanol as a solvent in the extraction in most studies. These observations revealed that the antibacterial components could be extracted better using ethanol, which reflects some of its chemical characteristics. Accordingly, more chemical studies are required in order to isolate these antibacterial agents.

Conclusion

The human being used plants as the source of medicine since ancient time. Spices were part of these ancient traditional medicines. Until now, many drugs are obtained and produced from plants and natural products and the majority of inhabitants still depends on natural products (including spices) for their primary health care systems. Spices are used not only in food but also in medicine. The black pepper fruits (*Piper nigrum* L.) are the king of spices and used all over the world. This spice has many health benefits and used traditionally to treat different ailments. Numerous scientific studies, which have been summarized in this study, showed that the black pepper fruits have promising antibacterial activity.

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None.

Conflict of interest

There is no conflict to publish our article in this Journal.

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