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Antimicrobial Properties of Ginger, Fennel Seeds and Basil Seeds

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Abstract

Ginger (Zingiber officinale), Ocimum basilicum L. (Lamiaceae), and fennel seeds have been used since ancient times mainly as herbs and spices. Traditionally it is believed to have therapeutic properties to improve blood circulation, reduce inflammation, reduce the oxidation of cholesterol, and increase immune function, and control blood sugar levels. In various research studies the extracts were found to have antimicrobial, antioxidant, and anticancer properties as they are rich in polyphenolic aromatic compounds and all of them contain their specific bioactive compounds. Ginger, fennel seeds, and basil seeds are rich in bioactive compounds such as gingerol, rosmarinic acid, chlorogenic acid, quercetin, and apigenin. They also contain high levels of polyunsaturated fatty acids, particularly alpha-linolenic acid, along with essential vitamins and antioxidant-rich compounds like polyphenols and tocopherols. In most of food preservation food preservatives are used in small quantities as in large amounts may cause harm. These spices are generally regarded as safe (GRAS) and can be used as food preservatives as it has medicinal properties. It is good for health and also plays an important role as a-functional food.

Keywords: *Ginger, Fennel seed and Basil seed, vitamins and antioxidants*

Introduction

Ginger (*Zingiber officinale Roscoe*) is primarily cultivated for its medicinal properties and as a flavoring agent. It has traditionally been used to treat conditions such as the common cold, headaches, and various muscular and rheumatic disorders [34]. Several studies have explored the phytochemical makeup of ginger rhizomes, highlighting zingiberene, gingerol, shogaol, and their derivatives as the key active components [31]. The pharmacological properties of ginger encompass antimicrobial, antioxidant, anti-inflammatory, hepatoprotective, and antinociceptive activities. [1]. Ginger is native to the Indo-Malayan region and is now cultivated in numerous countries around the world, both as a spice and for its medicinal properties. [7, 23]. Ginger was exported from India to the Mediterranean region as early as the 1st century CE. In the 13th century, Arabs introduced ginger to East Africa, and later, the Portuguese spread it to West Africa and the Pacific Islands, where it was cultivated for commercial purposes [26].

Fennel seeds have a long history of use, dating back to ancient times. There is significant evidence of their medicinal use, found in written records, preserved monuments, and even original plant-based remedies [24]. Medicinal and aromatic plants, along with their derivatives, play a vital role in daily life in Sudan. The country's flora includes 3,137 species of flowering plants, belonging to 170 families and 1,280 genera, with an estimated 15% of these plants being endemic to Sudan. The country's diverse cultural heritage and unique geography offer significant potential for the development and practice of Sudanese herbal medicine[14]. In true sweet fennel oil, the concentration of trans-anethole ranges from 84% to 90%, while in bitter fennel oil, its concentration is approximately 61% to 70% [17]. The differences are observed primarily in the essential oil of the ripened seed, as the quantitative composition of the oil is strongly influenced by the plant's developmental stage and the specific plant organ [18].

Ocimum basilicum L. (Lamiaceae), commonly known as basil, is a fragrant herb widely used for its unique aroma and as a flavoring agent in food. The leaves, which can be used fresh or dried, serve as a spice. Essential oils derived from the fresh leaves and flowers are utilized as flavor enhancers in food, as well as in the pharmaceutical and cosmetic industries [12]. Traditionally, basil has been used as a medicinal plant to treat a variety of ailments, including headaches, coughs, diarrhea, constipation, warts, intestinal worms, and kidney disorders [30]. Basil, belonging to the genus *Ocimum*, takes its name from the Greek word "ozo," meaning "to smell," referring to its strong fragrance. In French, it is often called “Herbe Royale,” reflecting its esteemed status. While the exact etymology of basil is uncertain, several theories exist. One possibility is that it is derived from the Greek *basileus*, meaning "king," which is why basil is often referred to as “the king of herbs.” Another potential origin comes from the Latin word *basiliskos* (meaning "little king" or "dragon"), which may explain the symbolic associations between basil and creatures like scorpions, as well as its revered medicinal properties [4].

Historical Background

Ginger is believed to have originated in Southeast Asia, likely in India. The Sanskrit term "Singapura" led to the Greek word "Zingiberi," which eventually became the generic name *Zingiber*. Both Indians and Chinese have been using ginger as a root tonic for over 5,000 years, treating a variety of ailments. Over 2,000 years ago, ginger was exported from India to the Roman Empire, where it was especially prized for its medicinal properties. Even after the fall of the Roman Empire, ginger remained one of the most traded commodities in Europe. For centuries, Arab merchants controlled the spice trade, including ginger. In the 13th and 14th centuries, a pound of ginger was valued as much as a sheep. By medieval times, ginger was imported in preserved forms, often used in sweets. Queen Elizabeth I of England is credited with the invention of gingerbread, which became a beloved Christmas treat [15].

In ancient Egypt, fennel was valued both as food and for its medicinal properties. In China, it was regarded as a remedy for snake bites. During the Middle Ages, fennel was often hung over doorways, as it was believed to ward off evil spirits. Fennel is also linked to the origin of the marathon. According to legend, the ancient Athenian runner Pheidippides carried a fennel stalk on his 150-mile, two-day journey to Sparta to recruit soldiers for the Battle of Marathon against Persia in 490 B.C. Interestingly, the battle itself is said to have taken place in a field of fennel [6].

Basil is native to regions in Asia and Africa, and it also grows wild as a perennial on certain Pacific islands. It was introduced to Europe from India via the Middle East in the 16th century and later brought to America in the 17th century [32].

Morphology

Ginger

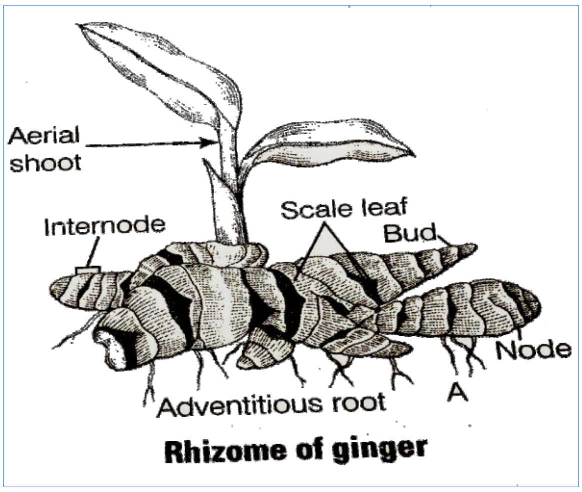

Fig: Rhizome of ginger
Source: *NCERT*

Zingiber officinale (ginger) is a perennial herb with a branched, fleshy, and aromatic rhizome that ranges in color from white to yellow. It typically grows up to 60 cm tall, with narrow leaves about 20 cm long and 1.5–2 cm wide. The plant also produces dense, spiked flower clusters that are yellow-green with purple tips [27]. The rhizome contains a variety of secondary metabolites, including phenolic compounds such as gingerol, paradol, and shogaol, volatile sesquiterpenes like zingiberene and bisabolene, as well as monoterpenoids such as curcumene and citral [2].

Fennel seed

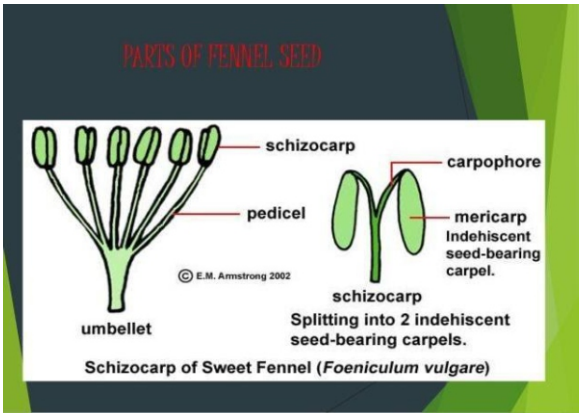

Fig: Parts of fennel seed
Source: *Fennelseedslideshare.net*

A study was conducted to compare 13 varieties of fennel (*Foeniculum vulgare* Mill. var. *vulgare*) based on morphological and chemical data collected over two consecutive years. The analysis of essential oil composition revealed significant variations in the plant organs, particularly in the relative amounts of anethole, fenchone, limonene, methyl chavicol, and α- and β-pinenes in the seed essential oil. Three primary chemotype groups were identified: fenchone-rich (31–42%), methyl chavicol-rich (20–43%), and anethole-rich (62–85%) [22].

Basil seed

Fig: Basil seed
Source: *basilseedgumsciencedirect.com*

Basil belongs to the *Ocimum* genus, exhibiting significant variability in both its morphology and chemical composition, with notable genetic diversity. It is a perennial herb and shrub native to Asia, Africa, and South and Central America, but it is widely cultivated in warm climates around the world. The most commonly grown species, which are of economic and medicinal importance, include *Ocimum basilicum* L., *O. africanum* Lour. (syn. *O. citriodorum* Vis.), *O. americanum* L. (syn. *O. canum* Sims.), *O. gratissimum* L., *O. minimum* L., and *O. tenuiflorum* L. (syn. *O. sanctum* L.). Among these, *Ocimum basilicum* L., commonly known as sweet basil, is considered the most economically significant species [33].

Scientific Classification

Ginger

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperm
Clade	Monocots
Clade	Commelinids
Order	Zingiberales
Family	*Zinzeber*
Species	*Z. officinale*
Binomial name	*Zingiber officinale*

Source: https://en.wikipedia.org/wiki/Ginger

Scientific classification	Fennel (*Foeniculum vulgare*)	Basil (*Ocimum basilium*)
Kingdom	Plantae	Plantae
Phylum	Magnoliophyta	Magnoliophyta
Class	Magnoliopsida	Magnoliopsida
Order	Apiales	Lamiales
Family	Apiacaea	Lamiacaea
Genus	*Foeniculum*	*Ocimum*
Species	*F. Vulgare*	*O. basilium*

Source: *Sullivan, 2009*

Health benefits and antimicrobial properties

Ginger

The study found that ginger leaves are rich in volatile oils containing various phytoconstituents. A nanoemulsion formulation of these oils was developed, demonstrating stability and effectiveness against *Streptococcus mutans*, making it a potential gargle for preventing dental caries and plaque formation. Gas chromatography and mass spectrometry analysis of the hydrolyzed oil from *Zingiber officinale* Roscoe leaves, conducted by the Egyptian chemotype, identified ninety compounds. Methyl cinnamate was the most abundant compound, comprising 29.21% of the oil. The analysis also revealed that monoterpene hydrocarbons made up 23.83% of the oil, with β-pinene at 8.59%, terpinolene at 7.46%, and δ-Cadinene at 7.05%, representing 20.86% of the sesquiterpene hydrocarbons. The nanoemulsion, with a diameter of 151.4 nm, was produced using a low-energy method and showed antimicrobial activity against *Streptococcus mutans* (when compared to clindamycin). Transmission electron microscopy (TEM) analysis revealed bacterial scattering and disruption of biofilm formation [20].

The study demonstrated that ginger extracts possess medicinal properties, including antibacterial activity. The extent of bacterial growth inhibition was dose-dependent and effective against various pathogenic bacteria responsible for food spoilage, as well as serving as a potential dietary supplement for food preservation. Ginger was extracted using aqueous, ethanol, and n-hexane solvents, followed by phytochemical screening and testing against six pathogenic bacteria: *Klebsiella pneumonia*, *Salmonella typhi*, *Shigella spp.*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus*. The analysis revealed the presence of alkaloids, anthraquinones, saponins, phenols, flavonoids, terpenoids, glycosides, steroids, and reducing sugars, while resin was absent. Notably, *E. coli* was found to be the most susceptible organism [2].

The antimicrobial efficacy of the ethanolic extract of *Zingiber officinale* (ginger) was evaluated against *Staphylococcus aureus* and *Enterococcus faecalis*. The rhizomes of *Z. officinale* were sourced commercially. The results indicated that the extract was more effective against *S. aureus* compared to *E. faecalis*, with significant activity observed at concentrations as low as 15 µl. The extract exhibited a broad range of activity, particularly against gram-positive aerobic bacteria, with a notable influence on the tested *staphylococci* [10].

The research aimed to determine the phytochemical composition of the methanolic extract of *Zingiber officinale* (ginger) and evaluate its antibacterial activity. Screening was performed using the GC-MS method. The methanolic extract of *Zingiber officinale* revealed forty-eight bioactive phytochemical compounds, including octanal, 2-naphthalenamine, 1,2,4a,5,6,7,8,8a-octahydro-4a-methyl, endoborneol, decanal, and methyl cinnamate, among others. Notably, compounds such as naphthalenamide, decanal, and α-copaene were identified as contributing to the antimicrobial activity. The antibacterial effects of the extract were tested against *Proteus mirabilis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Klebsiella pneumoniae* using the agar diffusion method. The results showed that the ginger extract exhibited significant antimicrobial activity, with *naphthalenamide*, *decanal*, and *α-copaene* being key contributors to its efficacy [28].

The objective of the experiment was to investigate the pharmacological effects of combining *Ocimum basilicum* essential oil with standard antibiotics on bacterial strains such as *Staphylococcus aureus* and *Pseudomonas aeruginosa*. The components of *O. basilicum* (leaves) were extracted using steam distillation. The study found that when *O. basilicum* essential oil was combined with ciprofloxacin, there was a synergistic effect against clinical bacterial strains. This combination enhanced the antibacterial activity of the standard antibiotics, leading to improved effectiveness against clinically significant bacterial strains. The antibacterial properties of *O. basilicum* essential oil were likely attributed to the presence of linalool [29].

Fennel seed

The study investigated the antimicrobial properties of *Foeniculum vulgare* (fennel) essential oil against a range of microorganisms. These included the Gram-positive bacterium *Staphylococcus aureus*, Gram-negative bacteria *Escherichia coli* and *Pseudomonas aeruginosa*, the anaerobic bacterium *Clostridium perfringens*, and three fungal strains: *Aspergillus flavus*, *Aspergillus niger*, and *Microsporum canis*. Minimum inhibitory concentrations (MICs) were determined using the broth macro-dilution method. The results demonstrated that fennel seed essential oil exerted moderate antibacterial activity against the bacterial strains and showed strong antifungal efficacy [25]. The broad-spectrum antimicrobial potential of fennel is attributed to its rich profile of bioactive constituents. These include aromatic compounds such as anethole, estragole, and fenchone, which contribute to its diverse pharmacological activities, including antioxidant, anticancer, anti-inflammatory, antifungal, and estrogenic effects [16].

The chemical composition and antimicrobial activity of essential oils extracted by hydrodistillation from the fruits of six *Foeniculum vulgare* (fennel) varieties were analyzed using Gas Chromatography-Flame Ionization Detection (GC-FID) and Gas Chromatography-Mass Spectrometry (GC-MS). The major constituents identified were fenchone (16.9–34.7%), estragole (2.5–66.0%), and trans-anethole (7.9–77.7%). These compounds were evaluated for their antifungal activity against six food spoilage fungi: *Aspergillus niger*, *A. japonicus*, *A. oryzae*, *Fusarium oxysporum*, *Rhizopus oryzae*, and *R. stolonifer*. Antibacterial activity was assessed against three Gram-positive bacteria (*Enterococcus faecalis*, *Staphylococcus epidermidis*, and *Staphylococcus aureus*) and six Gram-negative bacteria (*Escherichia coli*, *Morganella morganii*, *Proteus mirabilis*, *Salmonella enteritidis*, *S. enteritidis* serovar *Typhimurium*, and *Pseudomonas aeruginosa*) using the disc diffusion agar method. Minimum inhibitory concentrations (MICs) were determined by the broth macro-dilution method. The findings confirmed that fennel essential oil exhibits significant antifungal and antibacterial activities, supporting its potential use in food preservation and pharmaceutical applications [19].

The antifungal and antibacterial activities of essential oils derived from fennel (*Foeniculum vulgare*) and clove (*Syzygium aromaticum*) were evaluated, demonstrating varying degrees of microbial growth inhibition. Fennel oil exhibited antifungal activity ranging from 86% to 39% inhibition against pathogenic fungi, while its antibacterial activity ranged from 42% to 20%. Notably, fennel oil showed stronger fungitoxic effects against *Alternaria alternata*, *Fusarium oxysporum*, and *Aspergillus flavus*, whereas clove oil was more effective against *Aspergillus acculeatus* and *Aspergillus fumigatus*. The antibacterial efficacy of both oils was assessed against five common food spoilage bacteria: *Pseudomonas syringae*, *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus* spp., and *Aeromicrobium erythreum*. Fennel oil displayed notable bactericidal activity, especially against the Gram-positive bacterium *Bacillus subtilis* (inhibition zone of 3.8 cm), while showing the least activity against the Gram-negative *E. coli* (2.2 cm). Overall, fennel essential oil demonstrated broader and more potent antimicrobial properties than clove oil, except in cases involving specific *Aspergillus* strains and *E. coli* [13].

The study aimed to assess the antioxidant and antimicrobial properties of essential oil, methanolic, and ethanolic extracts derived from *Foeniculum vulgare* Mill. (fennel) seeds collected from Pakistan. Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) analysis of the essential oil identified 23 chemical constituents, with trans-anethole, fenchone, estragole, and limonene as the major components. All extracts, particularly the essential oil and the 80% ethanol extract, exhibited significant DPPH radical scavenging activity, indicating strong antioxidant potential. Furthermore, the essential oil demonstrated notable antimicrobial activity against various bacterial strains and pathogenic fungi.

In a complementary analysis, the methanolic extract of fennel was investigated for its polyphenolic and flavonoid content, as well as its antibacterial efficacy—particularly in light of increasing antimicrobial resistance and the demand for natural food preservatives. The extract was found to contain several bioactive polyphenols, including gallic acid, caffeic acid, ellagic acid, quercetin, and kaempferol. These compounds were shown to exert effective antimicrobial activity, particularly against Gram-positive pathogenic bacteria, supporting fennel's potential as a natural antimicrobial and antioxidant agent [5, 8].

Basil seed

Basil (*Ocimum basilicum*) seeds were analyzed for their bioactive compounds. The active components of the seeds were extracted using a Soxhlet apparatus with two different solvents, petroleum ether and methanol. The basil seed extract demonstrated strong antibacterial activity against nine pathogenic bacteria, with the most significant inhibition observed against *Pseudomonas aeruginosa*, *Escherichia coli*, *Shigella dysenteriae*, and *Klebsiella pneumoniae*. The DPPH assay showed a maximum free radical scavenging activity of 73.85%, indicating anticancer potential. This study highlights that basil seeds are a promising source of stable bioactive compounds with notable antimicrobial, antioxidant, and anticancer properties, making them valuable for functional food applications [9].

Conclusion

India is renowned as the birthplace of spices, and ginger (*Zingiber officinale*) is widely recognized both as a medicinal plant and as a popular spice used globally. *Ocimum basilicum* L. (Lamiaceae), commonly known as basil, is another important medicinal plant often used in cooking, valued for its various health benefits, including significant antioxidant and antinociceptive effects. Traditionally, basil seeds are believed to have therapeutic properties such as improving blood circulation, reducing inflammation, preventing cholesterol oxidation, boosting immune function, and controlling blood sugar levels. Ginger, a rhizome flowering plant, is utilized both as a spice and in folk medicine, while fennel, a member of the carrot family, is another beneficial plant. Basil seeds, which come from the sweet basil plant (*Ocimum basilicum*), are commonly used in South Indian sweets, especially in the beverage *faluda* (popular in Hyderabad). These seeds become gelatinous when soaked in water and help maintain body temperature, particularly in the summer months. Ginger contains bioactive compounds like gingerol, fennel seeds are rich in acids such as rosmarinic acid and chlorogenic acid, with quercetin and apigenin being the major flavonoids. Additionally, chia seeds are high in polyunsaturated fatty acids, especially alpha-linolenic acid, as well as vitamins and bioactive compounds like polyphenols and tocopherols that provide strong antioxidant activity. The compounds present in these plants act as antimicrobials and offer a wide range of health benefits.

Authors Biography

Jelang Jelku D. Sangma is serving as a Post-Doctoral Fellow under the IIP-PDF 3.0 program (2024). Her work focuses on developing innovative approaches to address pressing scientific and societal challenges, particularly in sustainable technologies. Throughout his academic journey, she has contributed to multiple peer-reviewed publications and continues to collaborate across institutions to promote impactful research.

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