Chapter

Antioxidant Effect and Medicinal Properties of Allspice Essential Oil

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Abstract

Pimenta dioica L. Merrill. Myrtaceae family, known for its berries called pimenta or allspice, is one of the oldest spices in the world, widely used for its culinary and medicinal qualities. The main commercial product obtained from this spice is its essential oil, the reason for the interest in essential oil is based on the versatility of its use in different industrial areas (food, cosmetics, perfumery, and pharmaceuticals) due to its harmless and beneficial effects for health. In addition, it contains compounds that have shown broad biological activity, which turns out to be useful in the treatment of diseases related to the excessive formation of oxygen radicals. As a result, the extraction process and operating conditions have a significant impact on the bioactivity of these molecules. As a consequence, selecting the correct mix of variables to improve oil extraction and functionality is essential. The most of study on this essential oil is being focused on resolving these issues, as well as purification and identification. This chapter will cover the methods for obtaining *P. dioica* essential oil, as well as the chemical profile of the oil and its biological properties, which include its effects on humans, plants, animals, insects, and microorganisms.

Keywords: *Pimenta dioica*, essential oil, eugenol, antioxidant effect, chemical composition

1. Introduction

Allspice (*Pimenta dioica* L. Merrill or Pepper officinalis) belongs to the Myrtaceae family native to the West Indies and Central America [1]. In Mexico, it is found in the wild and is cultivated toward the east and southeast [2]. The commercial spice, known in Mexico as pimienta gorda and in English as "allspice," is a small tree that grows up to 6–12 m tall [3] with small, whitish flowers with a peculiar aroma; its dry, almost spherical, reddish-brown berries are the commercial pepper spice, known in Mexico as pimienta gorda; and in English as "allspice" for flavors that resemble a mixture of cinnamon, cloves, and nutmeg [4]. This spice is known for its antioxidant qualities, which are attributed to the presence of bioactive components, most especially polyphenolic compounds [5]. *P. dioica* is one of the most important spices as a source of essential oils high in eugenol, a phenolic compound having antibacterial and antioxidant properties against a variety of pathogens. *P. dioica* produced in Central

America is sent to the international markets because its use in the local market is minimal. Its manufacture and drying, on the other hand, are entirely traditional [6].

Allspice contains its oils both in its leaves and in the berry itself [7], with fairly variable returns (1.5–4.5%) [8]. According to reports, the oil content varies depending on where it originates located [9]. González and Pino [10] and Shaik et al. [11] also discovered that environmental parameters, harvesting procedures, drying, and the age of the trees all influence the chemical composition of the oil.

It is important to mention that the oil obtained from the leaf is a brownish-yellow liquid with a dry, woody, warm, and spicy aromatic smell, while the oil extracted from the berry is yellow in color with a warm spicy-sweet smell and a note of sweet and fresh output, and placed in the spicy-sweet and warm group [12].

Allspice essential oil is utilized in the food sector, specifically in the meat and tanner industries, and also in perfumery and cosmetic products [13]. In addition, it has been useful for the treatment of gastrointestinal disorders, cramps, flatulence, indigestion, and nausea. Likewise, it has managed to help in cases of depression, nervous exhaustion, tension, neuralgia, and stress, it is also used as a natural repellent [14]. Anesthetic, analgesic, antibacterial, antioxidant, antiseptic, acaricide, carminative, muscle relaxant, rubefacient, stimulant, and tonic are some of the medicinal effects of this essential oil [15].

The versatility of essential oils' use in different industrial areas (pharmaceuticals, food, and cosmetics) has sparked interest in recent years, not only because of the possibility of obtaining aromatic compounds, but also because of their use as antioxidants, food preservatives, and medicines, as well as their use as crop and plant protectants, incorporating them into the packaging material of the products [16].

2. Essential oil extraction

Steam distillation, hydrodistillation, and the use of organic solvents are the most common extraction procedures. To produce the essential oil, steam distillation uses saturated steam at atmospheric pressure. When the steam breaks the cells of the plant walls, the water generates steam, and the essence is freed, the extraction is complete [17, 18]. They allow the process to be favorable for the creation of alcohols and acids when the esters disintegrate by employing high temperatures and the presence of water, resulting in a decrease in the extraction of the oil, which is one of the limitations of distillation by steam entrainment [19].

In recent years, several novel techniques for extracting essential oils have been developed, including ultrasound-assisted extraction, microwave-assisted extraction, and extraction using supercritical fluids, with the goal of reducing extraction time, reducing solvent consumption, increasing extraction yield, and improving the quality of the extracts [20]. Traditional organic solvent extraction, while easy, has drawbacks, such as expensive prices, is not environmentally friendly, and is nonselective, requiring post-treatment processes for product purification. Nonrecyclable organic solvent disposal can also be hazardous to human health and the environment.

On the other hand, at the laboratory and pilot scale, supercritical fluid extraction of flavonoid compounds presents a viable alternative for a more efficient and environmentally friendly extraction process. The volatile concentrate obtained from allspice by supercritical fluids was compared to the oil obtained by the hydrodistillation method by Marongiu [21], with the primary differences being the amount of eugenol, 77.9% against 45.4%. It was also demonstrated that by employing supercritical CO_2, the extract has an additional benefit in that it is free of hydrocarbons, which can conceal or degrade the oil's natural aroma.

Other studies compared the effects of microwave energy supply and hydrodistillation radiation time (MHD) on the performance and composition of allspice essential oil [22]. While there were no significant differences in the yields (2.68% versus 3.25%) and chemical composition of essential oils obtained by HD and MHD, the advantage was obtained in the reduction of the extraction cost in terms of time and energy.

3. Allspice essential oil chemical profile

Polyphenols, lignins, and terpenoids are the most prevalent components found in allspice essential oil currently [23]. The basic component of the oil is eugenol, finding that the oil content obtained from the leaves (65–96%) is somewhat higher than that of the berry oil [14]. **Table 1** shows the chemical composition of the essential

Country Of Origin	Component of the plant	Year	Method of extraction	Main constituents (%area)	References
Antilles	Leaves	2007	Commercial	Eugenol (47.78%) Myrcene (26.76%)	[15]
Australia	Leaves	2005	SCD	Eugenol (77.9%) β-caryophyllene (5.1%)	[21]
	Leaves	2005	HD	Eugenol (45.4%) β-caryophyllene (8.9%)	[21]
Brazil	Fruit	2011	HD	Eugenol (76.98%) β-pinene (6.52%) 5-indanol(5.88%) limonene (4.09%)	[24]
	Leaves	2014	HD	Eugenol (60.8%) Myrcene (19.3%) limonene (6.48%)	[25]
	Fruit	2020	HD	Eugenol (76.88%) β-Pinene (6.52%)	[26]
China	Fruit	2013	HD	Eugenol (28.84%) Methyl eugenol (43.01%)	[22]
Cuba	Leaves	1997	HD	Eugenol (28.04%) 1,8-cineole (14.5%) α-humulene(10.12%) γ-cadinene (11.12%)	[27]
	Leaves	1997	SCD	Eugenol (93.87%) thymol (1.82%)	[27]
	Leaves	1997	SE	Eugenol (91.68%) thymol (2.72%)	[27]
	Leaves	2003	HD	Eugenol (34.14%) 1,8-cineole (14.69%) α-humulene (10.12%)	[28]
Guatemala	Leaves	2020	HD	Eugenol (71.4%) Myrcene (10.0%)	[29]
	Fruit	2020	HD	Eugenol (65.9%) Myrcene (10.1%)	[29]

Country Of Origin	Component of the plant	Year	Method of extraction	Main constituents (%area)	References
India	Fruit	2013	HD	Eugenol (68.4%) chavicol (10.4%) methyl eugenol (6.1%)	[30]
	Fruit	2015	Commercial	Eugenol (35.42%) methyl eugenol (28.02%) β-caryophyllene (8.66%) β-Myrcene (8.55%)	[31]
Jamaica	Leaves	1991	SD	Eugenol (66.38%–79.24%)	[32]
	Leaves	2007	Commercial	Eugenol (76.02%) methyl eugenol (7.14%) β-caryophyllene (6.47%)	[33]
	Leaves	2007	HD	Eugenol (79.81–83.68)	[34]
	Berries	2007	Commercial	Eugenol (86.44%) β-caryophyllene (7.70%) Methyl eugenol (3.87%)	[35]
	Leaves	2009	Commercial	Eugenol (76.0%)	[36]
	Berries	2016	SCD	Eugenol (63.94%) β-caryophyllene (4.65%)	[37]
	Berries	2016	HD	Eugenol (66.8%) β-caryophyllene (4.69%)	[37]
México	Berries	1997	SD	Methyl eugenol (48.3%) Myrcene (17.7%) Eugenol (17.3%)	[38]
	Berries	1997	HD	Methyl eugenol (62.7%) Myrcene (16.5%) eugenol (8.3%)	[38]
	Berries	1997	SCD	Methyl eugenol (67.9%) Eugenol (14.9%) Myrcene (6.0%)	[38]
	Berries	2011	SD	Methyl eugenol (62.7%) Eugenol (8.3%)	[39]
	Fruit	2011	HD	Methyl eugenol (48.7%) Myrcene (17.1%) Eugenol (16.3%)	[40]
	Leaves	2013	HD	Eugenol (94.86%) α-terpineol (2.45%)	[41]
	Berries	2018	HD	Methyl eugenol (65.14%) β-Myrcene (12.72%)	[42]
	Fruit	2020	HD	Eugenol (48.5%) Methyl eugenol (35.0%)	[43]
Sri Lanka	Leaves	2015	HD	Eugenol (85.33%) β-caryophylene (4.36%) Cineole (4.19%)	[44]
USA	Leaves	2012	HD	Eugenol (62.1%) Methyl eugenol (22.9%)	[45]

SD = steam distillation; HD = hydrodistillation; SCD = supercritical carbon dioxide; SE = solvent extraction.

Table 1.
Chemical composition of the essential oil of Pimenta dioica.

oil of *P. dioica* obtained by using gas chromatography coupled to mass spectrometry (GC-MS) analysis technique, as well as data from the literature obtained from various researchers denoting the main compounds present in the essential oil, according to the extraction method, geographical origin, and plant part used in the extraction. Essential oils are complicated combinations with a high number of elements, and their physicochemical qualities are controlled by factors, such as harvest time, soil type, and fruit storage conditions and time [24]. The quality of Jamaican berries is greater than that of other islands, and they are preferred for commerce. Allspice's oil content and flavor deteriorate when it is stored for an extended period of time [1].

Because of the extraction process used, the quantity and quality of compounds found vary. Essential oil composition has an important role in determining the spice's pharmacological potential [16]. The essential oil of *P. dioica* extracted using HD, SCD, SE, and SD have significant qualitative and quantitative changes in their chemical composition. Hydrodistillation was the most used procedure. Eugenol, methyl eugenol, and myrcene are the three main constituents of this oil.

4. Antioxidant effect

Spices and herbs are recognized as sources of natural antioxidants [46]. Some of the biological functions of essential oils are dependent on their antioxidant properties. These properties are attributable to some essential oil components' inherent potential to prevent or delay aerobic oxidation of organic matter. However, it is important to be cautious before thinking that essential oils' antioxidant properties are just a result of their chemical components. However, taking into account its composition can help to estimate its antioxidant capacity [47].

In terms of free radical scavenging activity against the radicals DPPH, ABTS, and superoxide anion, the composition and antioxidant activity of the essential oil obtained by hydrodistillation of the berries were studied [48]. A total of 45 components were discovered. Eugenol (74.71, 73.35%) was the most common component found, followed by methyl eugenol (4.08, 9.54%) and caryophyllene (4.08, 9.54%). The antioxidant evaluation revealed that the oil had a high rate of radical scavenging. The total phenolic content, total reducing power, and metal chelating capacity were also calculated, and the metal chelating capabilities and reducing power were both found to be extremely high. The essential oil has a substantial antioxidant activity that is comparable to pure eugenol, according to the results.

Another study showed a positive correlation between the anticancer and antioxidant effects of allspice essential oil [42]. As a member of the Myrtaceae family, this oil has been shown to have a great cytotoxic effect against cancer cells. As a result, it might be considered a natural source of anticancer medicines. According to research, consuming foods containing synthetic antioxidants can result in health problems, such as cancer owing to the accumulation of free radicals in the body. As a result, research has been done to return to using natural compounds as an alternative for synthetic substances and as a source of novel food preservatives. These essential oils with high inhibitory percentages can now be utilized to replace synthetic additives since they help to eliminate pollutants and chemical residues, which can cause issues and diseases [17].

Allspice is a powerful hydroxyl radical scavenger. The berries of *P. dioica* had a high level of antioxidant activity and scavenging activity for 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical [49]. The capacity of *P. dioica* leaf essential oil to combat

DPPH (2,2-diphenyl-1-picrylhydrazyl), hydroxyl (OH), and superoxide radicals was studied to determine its antioxidant characteristics [33]. The intrinsic characteristics of many of their bioactive components, particularly phenols, to block or delay oxidation, are responsible for the antioxidant potential of *P. dioca* essential oil.

Although not all phenolic molecules had antibacterial activity, antioxidant activity was significantly related to total phenol content. *P. dioica* leaf extracts include phenolic chemicals that can be employed as antioxidants in the food, cosmetics, and pharmaceutical industries [50].

Allspice essential oil showed a high concentration of antioxidants The antioxidant characteristics of the essential oil were compared to those of propyl gallate, a synthetic antioxidant, and it was discovered that the essential oil's free radical scavenging activity was dependent on the concentration and higher than that of propyl gallate [51]. Antioxidants were found in abundance in allspice essential oil. (i.e. > 75 mmol/100 g) [52]. Applications in medicine have been reported due to the presence of antioxidant chemicals in *P. dioica*'s essential oil.

5. Medicinal properties

The essential oil of allspice is a significant source of phytochemicals in medicine. Phytochemicals are a large group of plant-derived bioactive that may have disease-fighting properties [53]. Plants are one of the most important natural sources of secondary metabolites for medical purposes, due to their biological capacity to combat lethal or endemic diseases, as well as disorders that impact living beings.

Anticancer, antidermatophytic, antihemorrhagic, anti-inflammatory, antimicrobial, antimutagenic, antipyretic, central nervous system depressant, hypoglycemic, hypotensive, an inhibitor of the enzyme histone acetyltransferase, and inhibitor of the enzyme histidine have all been discovered as pharmacological effects of allspice essential oil [54–57].

5.1 Nematicidal activity

In other studies, Park et al. [35] discovered allspice essential oil looks to be effective as a natural nematicide for B. xylophilus, but more research on systemic action, phytotoxicity, and formulation is needed to improve nematicidal potency and stability while reducing cost.

5.2 Antimicrobial activity

The presence of antioxidant properties and antimicrobial effects of allspice suggests that it can be used against human pathogenic bacteria and for the control of other diseases and the support of immunity for rejuvenation. The ability of allspice to alleviate bacterial infections and its use in traditional medicine in different parts of the world was observed. Due to its use, it is possible that this plant has anti-QS properties [58]. Its important bacteriostatic and inhibitory properties of pathogenic and decomposition microorganisms against *Bacillus subtilis*, *Clostridium botulinum*, *Escherichia coli*, *Listeria monocytogenes*, *Salmonella typhimurium*, and *Staphylococcus aureus* were also reported [59].

In another study, the essential oil extracted from *P. dioica* (Myrtaceae) was evaluated for its antimicrobial activities using a panel of gram-positive pathogens, gram-negative strains, and fungi [60]. Antimicrobial activity was measured by the minimum inhibitory concentration required to inhibit the growth of microorganisms. The cytotoxicity of the essential oil was tested *ex vivo* using the THP-1 macrophage cell model. The results showed that it had antimicrobial activity.

Allspice oil reduced xanthine oxidase activity, resulting in a decrease in superoxide radical formation. Both the synthesis of conjugated dienes and the development of secondary products from lipid peroxidation were effectively inhibited by allspice oil. Infections caused by *Klebsiella*, *Pseudomonas*, *A. niger*, *A. flavus*, and *T. versicolor* can be treated with *P. offcinalis* as an alternative to synthetic medications, according to the literature, depending on the chemical composition of the allspice oil [61]. Allspice has been shown to suppress *Escherichia coli*, *Salmonella enterica*, and *Listeria monocytogenes* [62].

The antibacterial activity of allspice essential oil was tested by using the agar diffusion method against three microorganism strains. *B. cereus*, *S. typhimurium*, and *S. aureus* were found to be inhibited by it. *B. cereus* was found to be the microbe most vulnerable to the presence of oil in the microdilution. The predominant component of *P. dioica* was eugenol, which had an abundance proportion of 94.86% as determined by GC-MS [41].

5.3 Anticancer activity

Cancer is a worldwide health issue. In breast (MCF-7), hepatocellular (HepG-2), colon (HCT-116), prostate (PC-3), and cervical cancer cell lines, allspice essential oil was examined for cytotoxicity. The MTT assay was used on HeLa cells. The essential oil had cytotoxic action against the cell lines that were examined [42]. The results showed that the essential oil of Mexican allspice has cytotoxic activity (IC_{50} < 15 μg/mL) against the cancer cell lines examined.

5.4 Antifungal activity

The antifungal efficacy of *P. dioica* leaf essential oil against toxin-producing Aspergillus flavus was investigated in one study. Antifungal activity of *P. dioica* leaf EO was shown on *A. flavus in vitro* experiments (IISRaf1). These tests revealed that this EO could be used as a food additive because of its antifungal properties and capacity to decrease ergosterol formation, which would extend the storage life of post-harvest items [63].

Allspice oil was found to have a superior antifungal impact against *Fusarium oxysporum*, *Fusarium verticillioides*, *Penicillium expansum*, *Penicillium brevicompactum*, *Aspergillus flavus*, and *Aspergillus fumigatus*. As a result, its efficacy is comparable to that of synthetic fungicides often used to treat severe human mycoses. The MIC values of *P. dioica*, which were detected against all pathogens tested, are very remarkable [64].

The fungal activity and chemical composition of the essential oil obtained from the fruits of *P. dioica* in the mycelial development of *Fusarium oxysporum* f. sp. *lycopersici*, *Fusarium oxysporum* f. sp. *passiflorae*, *Fusarium subglutinans* f. sp. *ananas*, *Fusarium oxysporum* f. sp. *vasinfectum*. The oil contained 76.88% eugenol and suppressed fungal mycelial development by up to 97.78% in an average of 7.2 days, according to the findings. As a result, the oil could be used as a natural fungicide [26].

Aspergillus niger, *Candida blanki*, *Candida tropicalis*, *Candida cylindracea*, *Saccharomyces cerevisiae*, and *Candida albicans* were found to have strong inhibitory activity, while *Candida glabrata*, *Candida krusei*, *C. albicans*, and *C. albicans* were found to have moderate inhibitory activity. With an activity index of 1.20–2.80, all of the test fungi were suppressed. This suggests that ketoconazole has a stronger antifungal effect against *C. albicans*, *Candida glabrata*, *C. tropicalis*, *Candida cylindracea*, *C. albicans*, and *Aspergillus niger* [65].

It has also recently become a research hub for the development of novel insecticides for ecologically friendly plants. Its insecticidal action has been demonstrated in numerous studies, and it can be utilized as a natural repellant [66].

5.5 Antidiabetic effect

Allspice berry extract was reported to inhibit protein glycation, indicating its potential to be used as an effective antidiabetic agent [67]. Studies have shown that individual flavonoids inhibit glycation by 50%.

5.6 Acaricidal effect

The essential oil derived from *P. dioica* berries was found to be highly harmful to *R. microplus* 10-day-old larvae in this investigation. As a result, the findings point to a viable new technique that could be utilized as an alternative to synthetic acaricides for tick management. The main components, methyl eugenol (62.7%) and eugenol (62.7%), could be responsible for acaricidal activity (8.3%) [39].

The active components of allspice essential oil were used in one investigation to cause mortality and limit the development of *B. microplus* to a level comparable to commercial acaricides. The phenylpropanoid molecules responsible for this activity, eugenol and methyl eugenol, could be studied for use as Acarina chemosterilants and as templates for the synthesis of further acaricides. All extracts, commercial acaricides, and methyl eugenol were found to be less effective in suppressing oviposition and causing tick mortality than berry essential oil. Eugenol, a component contained in more than 65% of the oil composition, is responsible for the effectiveness of berry essential oil [68].

6. Conclusions

Over the years, researchers have studied the enormous range of biological activities of allspice essential oil and its potential applications. *P. dioica* essential oil contains a large number of medicinal compounds. Currently, the need to extract compounds of interest from plant materials drives the continuous search for economically and ecologically viable extraction technologies. We have given a quick rundown of the medicinal characteristics of allspice essential oil, with a focus on the chemical components that have biological activity.

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