

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 CO₂,

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 -caryophyllene (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. dioica* 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. officinalis* 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 ($IC_{50} < 15 \mu\text{g/mL}$) 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 (IISRa1). 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 anti-fungal 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 repellent [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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References

- [1] Krishnamoorthy B, Rema J. Allspice. In: Handbook of Herbs and Spices. United Kingdom: Woodhead Publishing. Sawston; 1981. pp. 5-15
- [2] Barco MJM. La Pimienta De Jamaica [*Pimenta Dioica* (L.) Merrill, Myrtaceae] En La Sierra Norte De Puebla (México). Anales Del Jardin Botanico de Madrid. 1998;**56**(2):337-349
- [3] Badura M. *Pimenta officinalis* Lindl. (pimento, myrtle pepper) from early modern latrines in Gdańsk (northern Poland). Vegetation History and Archaeobotany. 2003;**12**(4):249-252. DOI: 10.1007/s00334-003-0023-6
- [4] Lim TK. *Pimenta dioica*. Edible Medicinal and Non Medicinal Plants. 2012;**3**:655-664. DOI: 10.1007/978-94-007-2534-8_89
- [5] Mercado-Mercado G, Carrillo L d l R, Wall-Medrano A, Díaz JAL, Álvarez-Parrilla E. Compuestos polifenólicos y capacidad antioxidante de especias típicas consumidas en México. Nutricion Hospitalaria. 2013;**28**(1):36-46. DOI: 10.3305/nh.2013.28.1.6298
- [6] Jarquín-Enríquez L, Ibarra-Torres P, Jiménez-Islas H, Flores-Martínez NL. *Pimenta dioica*: A review on its composition, phytochemistry, and applications in food technology. International Food Research Journal. 2021;**28**(5):893-904
- [7] Cruz-Olivares J, Perez AC, Barrera-Pichardo JF. Extracción de aceite esencial de hojas y fruto de pimienta gorda mexicana *Pimenta dioica* L. Revista Ciencias Agrícolas: Merrill; 2007
- [8] Weyerstahl P, Marschall-Weyerstahl H, Christiansen C, Oguntimein BO, Adeoye AO. Volatile constituents of *Eugenia uniflora* leaf oil. Planta Medica. 1988;**54**(6):546-549. DOI: 10.1055/s-2006-962544
- [9] Green, Espinosa CLyF. Jamaican and central American pimento (allspice; *Pimenta dioica*): Characterization of flavour differences and other distinguishing features, development. Food Science. 1988;**1**:3-20
- [10] González, Pino AyJA. Efecto del envejecimiento del árbol de *Pimenta dioica* L. sobre el rendimiento y composición del aceite esencial de la fruta, Revista de Agroquímica y Tecnología de Alimentos. 1990;**30**:277-281
- [11] Shaikh J, Bhosale R, Singhal R. Microencapsulation of black pepper oleoresin. Food Chemistry. 2006;**94**:105-110
- [12] Rema J, Krishnamoorthy B. Allspice. In: Handbook of Herbs and Spices. 2nd ed. Vol. 2. Sawston, United Kingdom: Woodhead Publishing; 2012. pp. 166-192. DOI: 10.1533/9780857095688.166
- [13] Rao PS, Navinchandra S, Jayaveera KN. HPTLC analysis of the essential oil from *Pimenta dioica* leaf. Journal of Applied Pharmaceutical Science. 2012;**2**(12):141-148. DOI: 10.7324/JAPS.2012.21226
- [14] Rao PS, Navinchandra S, Jayaveera K. An important spice, *Pimenta dioica* (Linn.) Merrill: A Review. International Current Pharmaceutical Journal. 2012a;**1**(8):221-225. DOI: 10.3329/icpj.v1i8.11255
- [15] Oussalah M, Caillet S, Saucier L, Lacroix M. Antimicrobial effects of

selected plant essential oils on the growth of a *Pseudomonas putida* strain isolated from meat. *Meat Science*. 2006;**73**(2):236-244. DOI: 10.1016/j.meatsci.2005.11.019

[16] Contreras-Moreno BZ. Chemical Composition of Essential Oil of Genus *Pimenta* (Myrtaceae): Review. Potential of Essential Oils. London, UK: IntechOpen Limited; 2018. DOI: 10.5772/intechopen.78004

[17] Minango MB. Aplicación de los aceites esenciales de albahaca (*Ocimum Basilicum*), cilantro (*Coriandrum Sativum*), y guayaba (*Psidium Guajava*) como antioxidante en salchichas de pollo tipo Frankfurt. Quito: Universidad de las Américas; 2017

[18] Segovia SRA. Utilización de aceites esenciales naturales como conservantes en la elaboración de salchichas de pollo. Universidad Politecnica Salesiana Ecuador. 2014;**2014**:129. Available from: <http://dspace.ups.edu.ec/bitstream/123456789/7009/1/UPS-CT003676.pdf>

[19] Quispe Díaz KF, Taco Huamani RJ. Evaluación del tiempo de extracción, factor de empaquetamiento, humedad del rizoma, en el rendimiento de la extracción del aceite esencial de jengibre (*Zingiber Officinale* Roscoe) por arrastre de vapor, caracterización fisicoquímica del aceite esencial y aplicación antioxidante en el aceite de oliva. Tesis de Licenciatura, Universidad Nacional de San Agustín de Arequipa. Repositorio Institucional-Universidad Nacional de San Agustín de Arequipa. 2017

[20] Velasco RJ, Villada HS, Carrera JE. Aplicaciones de los fluidos supercríticos en la agroindustria. *Informacion Tecnologica*. 2007;**18**(1):53-66. DOI: 10.4067/s0718-07642007000100009

[21] Marongiu B, Piras A, Porcedda S, Casu R, Pierucci P. Comparative analysis of supercritical CO₂ extract and oil of *Pimenta dioica* leaves. *Journal of Essential Oil Research*. 2005;**17**(5):530-532. DOI: 10.1080/10412905.2005.9698985

[22] Jiang ZT, Feng X, Li R, Wang Y. Composition comparison of essential oils extracted by classical hydro distillation and microwave-assisted Hydrodistillation from *Pimenta dioica*. *Journal of Essential Oil-Bearing Plants*. 2013;**16**(1):45-50. DOI: 10.1080/0972060X.2013.764178

[23] Zhang L, Lokeshwar L, B. Medicinal properties of the Jamaican pepper plant *Pimenta dioica* and allspice. *Current Drug Targets*. 2012;**13**(14):1900-1906. DOI: 10.2174/138945012804545641

[24] Monteiro OS, Souza AG, Soledade LEB, Queiroz N, Souza AL, Mouchrek Filho VE, et al. Chemical evaluation and thermal analysis of the essential oil from the fruits of the vegetable species *Pimenta dioica* Lindl. *Journal of Thermal Analysis and Calorimetry*. 2011;**106**(2):595-600. DOI: 10.1007/s10973-011-1438-4

[25] Faria LR, Machado RUD, Pimenta PH, Oliveira LDAR, de Castro Peixoto J, de Paula JER, et al. Structural organization and phytochemical analysis of *Pimenta dioica* L Merrill Myrtaceae leaves collected from Gois State, Brazil. *Journal of Medicinal Plants Research*. 2014;**8**(38):1134-1147. DOI: 10.5897/jmpr2014.5395

[26] Barros Gomes PR, Da Silva Barros Junior FR, Reis JB, Oliveira Everton G, Santos de Oliveira RW, Costa Louzeiro H, et al. Chemical composition and biological activity of the essential oil of the fruits *Pimenta dioica* against formae speciales of fungus *Fusarium*

oxysporum. Revista Colombiana de Ciencias Químico-Farmacéuticas. 2020;**49**(1):89-100. DOI: 10.15446/rcciquifa.v49n1.87010

[27] Pino JA, Garcia J, Martinez MA. Solvent extraction and supercritical carbon dioxide extraction of *Pimenta dioica* merrill, Leaf. Journal of Essential Oil Research. 1997;**9**(6):689-691. DOI: 10.1080/10412905.1997.9700812

[28] Hernández L, Rodríguez M, García D, Pino J. Actividad antidermatofítica in vitro de aceites esenciales. Revista Cubana de Plantas Medicinales. 2003;**8**(2):1059865. ISSN: 1028-4796. Available from: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1028-47962003000200004&lng=es&nrm=iso

[29] Mérida-Reyes MS, Muñoz-Wug MA, Oliva-Hernández BE, Gaitán-Fernández IC, Simas DLR, Ribeiro da Silva AJ, et al. Composition and Antibacterial Activity of the Essential Oil from *Pimenta dioica* (L.) Merr. from Guatemala. Medicines. 2020;**7**(10):59. DOI: 10.3390/medicines7100059

[30] Amma KPP, Rani MP, Sasidharan I, Sreekumar MM. Comparative chemical composition and in vitro antioxidant activities of essential oil isolated from the leaves of *Cinnamomum tamala* and *Pimenta dioica*. Natural Product Research. 2013;**27**(3):290-294. DOI: 10.1080/14786419.2012.668691

[31] Misharina TA, Alinkina ES, Medvedeva IB. Antiradical properties of essential oils and extracts from clove bud and pimento. Applied Biochemistry and Microbiology. 2015;**51**(1):119-124. DOI: 10.1134/S0003683815010093

[32] Tucker AO, Maciarello MJ, Landrum LR. Volatile leaf oils of

Caribbean Myrtaceae. II. *Pimenta dioica* (L.) Merr. of Jamaica. Journal of Essential Oil Research. 1991;**3**(3):195-196. DOI: 10.1080/10412905.1991.9700504

[33] Jirovetz L, Buchbauer G, Stoilova I, Krastanov A, Stoyanova A, Schmidt E. Spice plants: Chemical composition and antioxidant properties of *Pimenta* Lindl. Essential oils, part 2: *Pimenta racemosa* (Mill.) JW Moore leaf oil from Jamaica. Nutrition-Vienna. International Journal of Biosciences (IJB). 2007;**31**((7/8)):293

[34] Minott DA, Brown HA. Differentiation of fruiting and non-fruiting *Pimenta dioica* (L.) merr. Trees based on composition of leaf volatiles. Journal of Essential Oil Research. 2007;**19**(4):354-357. DOI: 10.1080/10412905.2007.9699303

[35] Park IK, Kim J, Lee SG, Shin SC. Nematicidal activity of plant essential oils and components from Ajowan (*Trachyspermum ammi*), Allspice (*Pimenta dioica*) and Litsea (*Litsea cubeba*) essential oils against pine wood nematode (*Bursaphelenchus xylophilus*). Journal of Nematology. 2007;**39**(3):275-279

[36] Höferl M, Buchbauer G, Jirovetz L, Schmidt E, Stoyanova A, Denkova Z, et al. Correlation of antimicrobial activities of various essential oils and their main aromatic volatile constituents. Journal of Essential Oil Research. 2009;**21**(5):459-463. DOI: 10.1080/10412905.2009.9700218

[37] Toni-Moy AS, Lowe H, Watson C. Quantification and characterization of *Pimenta dioica* (allspice) essential oil extracted via hydrodistillation, solvent and super critical fluid extraction methodologies. American Journal of Essential Oils and Natural Products. 2016;**4**(3):27-30

- [38] García-Fajardo J, Martínez-Sosa M, Estarrón-Espinosa M, Vilarem G, Gaset A, de Santos JM. Comparative study of the oil and supercritical CO₂ extract of Mexican pimento (*Pimenta dioica* Merrill). Journal of Essential Oil Research. 1997;**9**(2):181-185. DOI: 10.1080/10412905.1997.9699456
- [39] Martinez-Velazquez M, Castillo-Herrera GA, Rosario-Cruz R, Flores-Fernandez JM, Lopez-Ramirez J, Hernandez-Gutierrez R, et al. Acaricidal effect and chemical composition of essential oils extracted from *Cuminum cyminum*, *Pimenta dioica* and *Ocimum basilicum* against the cattle tick *Rhipicephalus (Boophilus) microplus* (Acari: Ixodidae). Parasitology Research. 2011;**108**(2):481-487. DOI: 10.1007/s00436-010-2069-6
- [40] Sánchez-Sáenz EO, Pérez-Alonso C, Cruz-Olivares J, Román-Guerrero A, Baéz-González JG, Rodríguez-Huezo ME. Establishing the most suitable storage conditions for microencapsulated allspice essential oil entrapped in blended biopolymers matrices. Drying Technology. 2011;**29**(8):863-872. DOI: 10.1080/07373937.2010.545495
- [41] Vazquez-Cahuich DA, Moreno JE, Hidalgo DC, Martinez JRV, Borges-Argaez R, Farfan MC. Antimicrobial activity and chemical composition of the essential oils of *malvaviscus arboreus* cav, *Pimenta dioica* (L.) merr., *Byrsonima crassifolia* (L.) kunth and *Psidium guajava* l. Tropical and Subtropical Agroecosystems. 2013;**16**(3):505-513
- [42] Morsy NFS, Hammad KSM. Volatile constituents, radical scavenging and cytotoxic activities of Mexican allspice (*Pimenta dioica* L. Merrill) berries essential oil. Journal of Essential Oil-Bearing Plants. 2018;**21**(4):859-868. DOI: 10.1080/0972060X.2018.1524793
- [43] Milenković A, Stanojević J, Stojanović-Radić Z, Pejić M, Cvetković D, Zvezdanović J, et al. Chemical composition, antioxidative and antimicrobial activity of allspice (*Pimenta dioica* (L.) Merr.) essential oil and extract. Advanced Technologies. 2020;**9**(1):27-36. DOI: 10.5937/savteh2001027m
- [44] Dharmadasa RM, Abeysinghe DC, Dissanayake DMN, Abeywardhane KW, Fernando NS. Leaf essential oil composition, antioxidant activity, total phenolic content and total flavonoid content of *Pimenta dioica* (L.) Merr (Myrtaceae): A superior quality spice grown in Sri Lanka. Universal Journal of Agricultural Research. 2015;**3**(2):49-52. DOI: 10.13189/ujar.2015.030203
- [45] Kloucek P, Smid J, Frankova A, Kokoska L, Valterova I, Pavela R. Fast screening method for assessment of antimicrobial activity of essential oils in vapor phase. Food Research International. 2012;**47**(2):161-165. DOI: 10.1016/j.foodres.2011.04.044
- [46] Mariutti LRB, Barreto GPDM, Bragagnolo N, Mercadante AZ. Free radical scavenging activity of ethanolic extracts from herbs and spices commercialized in Brazil. Brazilian Archives of Biology and Technology. 2008;**51**(6):1225-1232. DOI: 10.1590/S1516-89132008000600018
- [47] Amorati R, Foti MC, Valgimigli L. Antioxidant activity of essential oils. Journal of Agricultural and Food Chemistry. 2013;**61**(46):10835-10847. DOI: 10.1021/jf403496k
- [48] Padmakumari KP, Sasidharan I, Sreekumar MM. Composition and antioxidant activity of essential oil of pimento (*Pimenta dioica* (L) Merr.) from Jamaica. Natural Product

- Research. 2011;**25**(2):152-160.
DOI: 10.1080/14786419.2010.526606
- [49] Miyajima Y, Kikuzaki H, Hisamoto M, Nakatani N. Antioxidative polyphenols from berries of *Pimenta dioica*. BioFactors. 2004;**22**(1-4):301-303.
DOI: 10.1002/biof.5520220159
- [50] Sánchez-Zarate A, Hernández-Gallegos MA, Carrera-Lanestosa A, López-Martínez S, Chay-Canul AJ, Esparza-Rivera JR, et al. Antioxidant and antibacterial activity of aqueous, ethanolic and acetic extracts of *Pimenta dioica* L. leaves. International Food Research Journal. 2020;**27**(5):825-834
- [51] Feng X, Jiang Z, Li R, Wang X. Antioxidant activities and free radical scavenging potentials of natural spice essential oil, China Condiment. Journal of Agricultural and Food Chemistry. 2010;**4**:52-55
- [52] Dragland S, Senoo H, Wake K, Holte K, Blomhoff R. Several culinary and medicinal herbs are important sources of dietary antioxidants. The Journal of Nutrition. 2003;**133**(5):1286-1290
- [53] Murali VS, Devi VNM, Parvathy P, Murugan M. Phytochemical screening, FTIR spectral analysis, antioxidant and antibacterial activity of leaf extract of *Pimenta dioica* Linn. Materials Today: Proceedings. 2021;**45**:2166-2170.
DOI: 10.1016/j.matpr.2020.10.038
- [54] Hari Kumar B, Badarudin A, Jose A. DPPH radical scavenging activity and antibacterial activity of *Pimenta dioica* (L.) Merr. Oriental Journal of Chemistry. 2010;**26**(4):1501-1505
- [55] Mueller M, Hobiger S, Jungbauer A. Anti-inflammatory activity of extracts from fruits, herbs and spices. Food Chemistry. 2010;**122**(4):987-996.
DOI: 10.1016/j.foodchem.2010.03.041
- [56] Shamaladevi N, Lyn DA, Shaaban KA, Zhang L, Villate S, Rohr J, et al. Ericifolin: A novel antitumor compound from allspice that silences androgen receptor in prostate cancer. Carcinogenesis. 2013;**34**(8):1822-1832.
DOI: 10.1093/carcin/bgt123
- [57] Kikuzaki H, Miyajima Y, Nakatani N. Phenolic glycosides from berries of *Pimenta dioica*. Journal of Natural Products. 2008;**71**(5):861-865.
DOI: 10.1021/np0705615
- [58] Vasavi HS, Arun AB, Rekha PD. Inhibition of quorum sensing in *Chromobacterium violaceum* by *Syzygium cumini* L. and *Pimenta dioica* L. Asian Pacific Journal of Tropical Biomedicine. 2013;**3**(12):954-959.
DOI: 10.1016/S2221-1691(13)60185-9
- [59] Tajkarimi MM, Ibrahim SA, Cliver DO. Antimicrobial herb and spice compounds in food. Food Control. 2010;**21**(9):1199-1218. DOI: 10.1016/j.foodcont.2010.02.003
- [60] Lorenzo-Leal AC, Palou E, López-Malo A, Bach H. Antimicrobial, cytotoxic, and anti-inflammatory activities of *Pimenta dioica* and *Rosmarinus officinalis* essential oils. BioMed Research International. 2019;**2019**(8):1-8.
DOI: 10.1155/2019/1639726
- [61] Vadlapudi V, Kaladhar DSVGK. Phytochemical evaluation and molecular characterization of some important medicinal plants. Asian Pacific Journal of Tropical Disease. 2012;**2**(1):S26-S32.
DOI: 10.1016/S2222-1808(12)60118-2
- [62] Friedman M, Henika PR, Mandrell RE. Bactericidal activities of plant essential oils and some of their isolated constituents against

Campylobacter jejuni, *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella enterica*. Journal of Food Protection. 2002;**65**(10):1545-1560.
DOI: 10.4315/0362-028X-65.10.1545

[63] Sarathambal C, Rajagopal S, Viswanathan R. Mechanism of antioxidant and antifungal properties of *Pimenta dioica* (L.) leaf essential oil on *Aspergillus flavus*. Journal of Food Science and Technology. 2021;**58**(7):2497-2506.
DOI: 10.1007/s13197-020-04756-0

[64] Zabka M, Pavela R, Slezakova L. Antifungal effect of *Pimenta dioica* essential oil against dangerous pathogenic and toxinogenic fungi. Industrial Crops and Products. 2009;**30**(2):250-253. DOI: 10.1016/j.indcrop.2009.04.002

[65] Kamble VA, Patil SD. Spice-derived essential oils: Effective antifungal and possible therapeutic agents. Journal of Herbs, Spices and Medicinal Plants. 2008;**14**(3-4):129-143.
DOI: 10.1080/10496470802598677

[66] Pavela R. Insecticidal and repellent activity of selected essential oils against of the pollen beetle, *Meligethes aeneus* (Fabricius) adults. Industrial Crops and Products. 2011;**34**(1):888-892.
DOI: 10.1016/j.indcrop.2011.02.014

[67] Dearlove RP, Greenspan P, Hartle DK, Swanson RB, Hargrove JL. Inhibition of protein glycation by extracts of culinary herbs and spices. Journal of Medicinal Food. 2008;**11**(2):275-281.
DOI: 10.1089/jmf.2007.536

[68] Brown HA, Minor DA, Ingram CW, Williams LAD. Biological activities of the extracts and constituents of pimento, *Pimenta dioica* L. against the southern cattle tick, *Boophilus microplus*. Insect Science and its Application. 1998;**18**(1):9-16. DOI: 10.1017/s1742758400007402