Journal of
Current Opinion in Crop Science
Journal homepage:: www.jcocs.com

REVIEW ARTICLE

Phytochemistry and pharmacological properties of *Ocimum gratissimum* (L.) extracts and essential oil - A critical review

Kaliyaperumal Ashokkumar[1*], Arjun Pandian[2], Muthusamy Murugan[1], M. K. Dhanya[1], and Sampathrajan Vellaikumar[3]

Citation:

Ashokkumar, K., Pandian, A., Murugan, M., Dhanya, M. K., & Vellaikumar, S. (2021). Phytochemistry and pharmacological properties of *Ocimum gratissimum* (L.) extracts and essential oil - A critical review. *Journal of Current Opinion in Crop Science*, *2*(1), 138-148.

ABSTRACT

The plant *Ocimum gratissimum* is well-known from the ancient Indian medicine system. *O. gratissimum* has wide variety of therapeutic applications. Folk medicine says that it can help with headaches, fevers, diarrhoea, pneumonia, and other ailments. *O. gratissimum* contains several bioactive constituents widely used as food additives, food colorants, pharmaceuticals, pesticides, and fragrances. This review discusses up to this point data on the phytochemical and pharmacology of *O. gratissimum* extracts and oil from numerous locations worldwide. Pertinent data of *O. gratissimum* was earned from numerous electronic scientific databases, and additional information was obtained from books, thesis and different relevant websites. The yield of the *O. gratissimum* essential oil (OGEO) varied between 0.12% and 1.66%. OGEO was predominantly accumulated phenylpropenes, (55.7%-57.3%) followed by sesquiterpenes (27.5% - 38.1%), and monoterpenes (4.0%-16.1%). Eugenol, germacrene-D, β-ocimene, 1,8-cineole, β-selinene, caryophyllene, γ-murolene, p-cymene, and thymol, are major constituents of OGEO from various origins.

Keywords: *Ocimum gratissimum*; Essential oil; Eugenol; β-ocimine; Phytochemistry; Biological activities

*Corresponding author email address: biotech.ashok@gmail.com (K. Ashokkumar)

INTRODUCTION

Ocimum gratissimum (L.) is known as Ram tulsi in India. A native of Asia, it is primarily grown in India, Sri Lanka and Nepal (Nadkarni, 1999). This plant's leaves are used to cure anxiety, headaches, and bronchitis (Rabelo et al., 2003; Matasyoh et al., 2007). Traditional medicine has long used O. gratissimum. It is also used medicinally, as a condiment, and in cooking. Locally, it is used to treat diarrhoea (Effraim et al., 2003).

Hydrodistillation, steam distillation, microwave, ultrasound-assisted extraction, and supercritical fluid extraction are all methods used to extract essential oils from plants (Azwanida, 2015; Ashokkumar et al. 2020a; Ashokkumar et al., 2020b). Due to the lower cost of the Clevenger apparatus and the use of water as a solvent, the hydrodistillation procedure is the most extensively employed by researchers worldwide (Ashokkumar et al., 2020c). The amount of essential oil produced by O. The gratissimum ranges from 0.21 to 0.70 percent (Dubey et al., 2000; Matasyoh et al., 2007; Joshi, 2013; Ashokkumar et al., 2020d). Several studies on the OGEO have been carried out all across the world (Matasyoh et al., 2007; Joshi, 2013; Matasyoh et al., 2007; Padalia and Verma, 2011).

The OGEO is rich in phytonelypropene (eugenol & methyl eugenol), sesquiterpenes (germacrene D & caryophyllene, - muurolene), monoterpenes (- ocimene), and other components. free of charge (Matasyoh et al., 2007; Padalia and Verma, 2011; Joshi, 2013). Many research papers claim that O. Antioxidant, antibacterial, anti-inflammatory, anthelmintic, cardiovascular, antimutagenic, antidiarrheal, and other properties are found in gratissimum (Offiah and Chikwendu, 1999; Aguiyia et al., 2000; Lahlou et al., 2004; Trevisan et al., 2006; Joshi, 2013; Ajayi et al., 2014; Gontijo et al., 2014; Aderibigbe and Idowu, 2020). This review looks on the phytochemical compositions of O. gratissimum and their possible pharmacological activities. However, to better understand the mechanism of bioactive elements and their intake in animals and humans, which can aid in the prevention of many diseases.

O. GRATISSIMUM ESSENTIAL OIL (OGEO) AND ITS COMPOSITION

The EO yield from *O. gratissimum* varied between 0.12% and 1.66% (Table 1). The profiling of EO of aerial parts of *O. gratissimum* sampled from Western Ghats of southern India predominantly exhibited eugenol (54.42%), germacrene D (15.43%), β-ocimene (12.37%), caryophyllene (4.59%), and γ-muurolene (3.05%), (Ashokkumar et al., 2020d). However, the Brazil grown leaves of OGEO chiefly contained eugenol, 1,8-cineole, and β-selinene. Furthermore, grown aerial parts of *OGEO* was predominant in p-cymene and thymol (Table 2).

OGEO was predominantly accumulated phenylpropenes, (55.7%- 57.3%) followed by sesquiterpenes (27.5% - 38.1%), monoterpenes (4.0%-16.1%), (Joshi, 2017; Ashokkumar et al., 2020d). The yield of minor constituents of OGEO include β-pinene (0.1%), borneol (0.1%), carvenone (0.1%), α-humulene (0.1%), elemol (1.2%), caryophyllene oxide (0.15%), α-thujene (0.17%), γ-elemene (0.2%), γ-terpinene (0.2%), α-pinene (0.2%), camphor (0.3%), humulene (0.3%), δ-Cadinene (0.4%), sabinene (0.5%), linalool (0.5%), β-bourbonene (0.5%), α-copaene (0.6%), cis-verbenol (0.7%), terpin-4-ol (0.7%), isobornylformate (0.9%), isoledene (1.0%), (Joshi, 2017; Ashokkumar et al., 2020d). Figure 1 depicts the major EO components' molecular structures extracted from O. gratissimum.

PHARMACOLOGICAL PROPERTIES OF OGEO AND EXTRACTS

Antioxidant activity

Antioxidants are naturally or artificially derived compounds that could prevent the free radical formation and suppress chronic and degenerative diseases by scavenging free radicals (Haliwell, 2000). Natural antioxidants derived from herbal sources are currently gaining popularity (Velioglu et al., 1998).

Table 1. Yield of EO from *O. gratissimum*

Technique or method	Oil yield (%)	Authors
Hydro-distillation	1.66	Melo et al. (2019)
Hydro-distillation	0.60	Ashokkumar et al. (2020d)
Hydro-distillation	0.65	Padalia et al. (2014)
Hydro-distillation	1.10	Verma et al. (2016)
Hydro-distillation	0.12 – 0.78	Matasyoh et al. (2008)
Hydro-distillation	0.65-0.78	Kpadonou Kpoviessi et al. (2012)
Steam distillation	1.33	Ibeh et al. (2017)

Table 2. Major EO composition of *Ocimum gratissimum* L.

Origin	Major constituents	Yield (%)	Authors
Western Ghats, South India (Kerala)	eugenol	54.4%	Ashokkumar et al. (2020d)
	germacrene D	15.4%	
	β-ocimene	12.4%	
	caryophyllene	4.6%	
	γ-muurolene	3.1%	
Brazil	Eugenol	74.3%	Melo et al. (2019)
	1,8-cineole	15.2%	
	β-selinene	2.8%	
North India	eugenol	78.0%	Padalia et al. (2014)
	germacrene D	4.4%	
Peninsular India (Karnataka)	eugenol	53.0%	Verma et al. (2016)
	caryophyllene oxide	7.2%	
	(Z)-β-ocimene	3.5%	
Kenya	eugenol	68.8 %	Matasyoh et al. (2008)
	methyl eugenol	13.2%	
Portugal	Thymol	48.1%	Martins et al. (1999)
	p-cymene	12.5%	
Colombia	eugenol	43.2%	Benitez et al. (2009)
	1,8-cineole	12.8%	
	β-selinene	9.0%	
Benin	*p*-cymene	28.1–53.8%	Kpadonou Kpoviessi et al. (2012)
	thymol	3.3–29.1%	
	γ-terpinene	1.1–10.9%	
	α-thujene	3.4-10.8%	
	myrcene	4.2–8.3%	

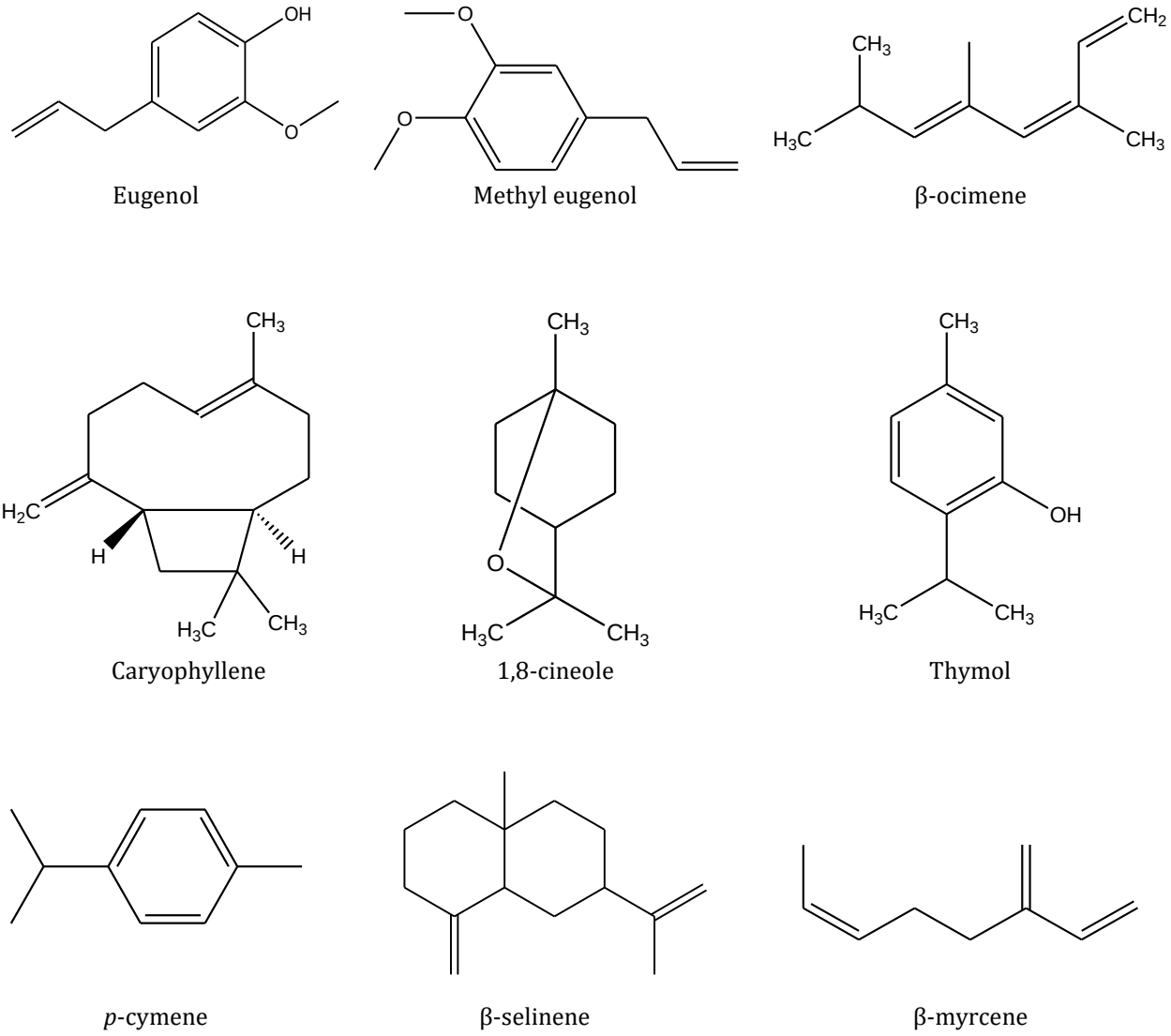

Figure 1. Molecular structures of major OGEO constituents

In another study, DPPH and ABTS models, OGEO demonstrated comparative antioxidant activity with IC_{50} values of 23.66 and 23.91 g ml^{-1}, respectively. This study also noted that eugenol had marginally lower antioxidant activity than OGEO. In contrast, *O. sanctum* oil had very low antioxidant activity (Joshi et al. 2013)

Antimicrobial activities

OGEO has antifungal action against Candida albicans. On average, 0.24 mg ml-1 inhibited the most (Kpadonou Kpoviessi et al., 2012). O. ethanolic extract In human dental plaque, gratissimum was antibacterial against Actinobacillus actinomycetemcomitans. Compared to 0.2 percent chlorhexidine and dimethyl sulfoxide (DMSO), 0.6 percent extract has potential antibacterial action (Eswar et al., 2016).

In another investigation, OGEO at 0.24 mg ml-1 and 0.95 mg ml-1 demonstrated considerable

antibacterial action (Kpadonou Kpoviessi et al., 2012). Joshi (2017) tested OGEO and eugenol against 13 bacterial species, including S. S. S. faecalis, M. flavus, M. luteus, B. subtilis, E. O157:H7, Proteus mirabilis Eugenol had a MIC of 0.33 – 3.33 mg ml^{-1} and considerable inhibitory action at 1.04 mg ml^{-1} against S. aureus. The essential oil had a substantial inhibitory impact at 0.29 mg ml^{-1} against S. marcescens.

Insecticidal activity

The insecticidal activity of OGEO was tested against *Sitophilus zeamais* (a major stored pest of maize) by mixtures OGEO (5%) and kaolin (10%). Results remarked that OGEO on the test insects was possessed an 85.7% knockdown effect (Jirovetz et al., 2005; Benelli et al., 2019). Other insecticidal and acaricidal activities were also summarized in Table 3.

Miscellaneous activities

Eugenol from *O. gratissimum* has reported that antiviral activity, which inhibits the HSV-1,2 replication. The bioactive constituent thymol also destructs the virion of HSV-1 (Tshilanda et al., 2020). Other miscellaneous activities were summarized in Table 3.

CONCLUSION

This review discusses the phytochemistry and pharmacology of O. gratissimum, Ancient and modern Indians have utilised gratissimum to treat a variety of diseases. O. gratissimum, has been used to treat anxiety, headaches, and bronchitis. O. gratissimum, say Indian medicinal texts. Historically, gratissimum has been trustworthy, but current pharmacological experiments on O. gratissimum.

O. gratissimum, has over 75 secondary metabolites. According to current research, eugenol is the most important bioactive molecule with numerous potential health benefits. Also, O. research on gratissimum extracts and OGEO (Table 3). However, O research is lacking. gratissimum, and we have suggested some themes for additional research.

First, investigations on metabolite structure in O. Phytochemistry reports limit the use of gratissimum leaves and aerial portions. Second, little research has been done on preserving OGEO's shelf life.

Future studies need to focus on studying structural characterization of metabolites, shelf-life quality of OGEO, proper experimental setup conduct with negative or positive control and correct MIC values, and finally, clinical investigation implemented with humans is essential.

Table 3. The activities of *O. gratissimum* extracts and essential oil components

Pharmacological activities	Extract/ essential oil	*In vitro*/ *In vivo*	Target/ Model	Control(s)	IC 50/ Dosage	Results / Remarks	Reference
Antibacterial activity	Essential oil	*In vitro*	*Staphylococcus aureus*	Positive: Doxycycline	MIC : 0.24mg ml^{-1} MBC: 0.95mg ml^{-1}	Moderate antibacterial activity	Kpadonou Kpoviessi et al. (2012)
Antibacterial activity	Essential oil	*In vitro*	*E. coli*	Positive: Doxycycline	MIC: 0.48mg ml^{-1}	Noteworthy antibacterial activity	Kpadonou Kpoviessi et al. (2012)
Antibacterial activity	Essential oil	*In vitro*	*17 microbial species*	Positive: Erythromycin & Amikacin	MIC: 0.29 to 1.51 mg ml^{-1}	Best inhibitory effect @ 0.29 mg/ml against *S. marcescens*	Jhoshi, (2017)
Antibacterial activity	Eugenol	*In vitro*	*17 microbila species*	Positive: Erythromycin & Amikacin	MIC: 0.33 to 3.33mg ml^{-1}	Best inhibitory effect @ 1.04 mg/ml against *S. aureus*	Jhoshi, (2017)
Antifungal activity	Essential oil	*In vitro*	*Candida albicans*	Positive: Nystatin Negative: Solvent	MIC: 0.06 to 0.25 mg ml^{-1} MFC: 6.25 to 12.50 mg ml^{-1}	Greatest inhibitory effect @ 0.24 mg/ml against *Candida albicans*	Kpadonou Kpoviessi et al. (2012)
Antioxidant activity	Essential oil	*In vitro*	DPPH	-	IC_{50}: 23.66 µg ml^{-1}	Significant antioxidant activity observed	Jhoshi, (2013)
			ABTS	-	IC_{50}: 23.91 µg ml^{-1}		
Antioxidant activity	Eugenol	*In vitro*	DPPH	-	IC_{50}: 27.16 µg ml^{-1}	Eugenol showed lesser antioxidant activity compared to OGEO	Jhoshi, (2013)
			ABTS	-	IC_{50}: 32.16 µg ml^{-1}		

Anthelmintic activity	Acetone extract	*In vitro*	Adult *H. placei* nematodes using adult worm motility assay	Negative: Normal Saline	IC_{50}: 5-60 mg ml^{-1}	Best anthelmintic activity recorded @ 56.04 mg/mL against H. placei	Segun & Sunday (2020)
Anti-inflammatory activity	Hydroethanolic extract	*In vivo*	Rats anesthetized by intraperitoneal injection of 25 mg/kg of thiopental sodium	Positive: - Negative: Distilled water	100, 200 or 400 mg kg^{-1} b.w	The inhibition by the extract was not dose dependent as it was 15.2, 26.7 and 22.4% for 100, 200 and 400 mg/kg respectively	Ajayi, et al. (2014)
Anti-inflammatory activity	Aqueous extract	*In vivo*	Carrageenan-induced paw oedema in rats.	Negative: Distilled water	100, 200 and 400 mg kg^{-1}	Concentration 400 mg kg^{-1} substantially increased glutathione level.	Alabi et al. (2019)
Antinociceptive activity	Essential oil	*In vivo*	Swiss albino mice (25-30g) induced pain. Writhing and formalin test	Positive: Indomethacin	30, 100, 300mg kg^{-1} (p.o)	Dose dependent inhibition observed. OGEO possessed antinociceptive properties in the writhing and formalin test	Rabelo et al. (2003)
Antinociceptive activity	Aqueous extract	*In vivo*	Acetic acid-induced nociception in mice. Hot plate test	Negative: Distilled water	200 and 400mg kg^{-1}	Dose dependent Inhibition was observed at TADP concentration of 100–400 mg kg^{-1}.	Alabi et al. (2019)
Gastroprotective activity	Methanolic extract	*In vivo*	Stress induced ulcer in rats	-	200, 400, 800 mg kg^{-1}	Decreased ulcer indices in a dose dependent manner	Akah et al. (2007)
Antidiabetic activity	Aqueous extract	*In vivo*	Intraperitoneal administration of (65 mg/kg), Type 1 Diabetes mellitus (DM 1) rats	Negative: Distilled water	Not reported	OG extract showed antidiabetic activity	Okon and Umoren (2017)

Insecticidal activity	Essential oil	*In vivo*	Cockroach (*Nauphoeta cinerea)* nymphs (20 days of age) were used	-	LC $_{50}$: 50 to 1000 µg of oil per ml of air.	OGEO has substantial insecticidal properties at lethal concentration (LC50) of 516 µg ml^{-1}	Rodrigues et al. (2020)
Acaricidal activity	Essential oil	*In vivo*	*Rhipicephalus microplus* (Acari: Ixodidae)	-	LC_{50}: 0.84 mg ml^{-1} LC_{50}: 1.58 mg ml^{-1}	Study remarked that seasonal variation in the OGEO and its influences acaricidal activity	Silva Lima (2018)

REFERENCES

Aderibigbe, S. A. & Idowu, S. O. (2020). Anthelmintic activity of *Ocimum gratissimum* and *Cymbopogon citratus* leaf extracts against *Haemonchus placei* adult worm. *Journal of Pharmacy and Bioresources*, *17*(1), 8-12.

Aguiyia, J. C., Obia, C. I., Gang, S. S., & Igweh, A. C. (2000). Hypoglycaemic activity of *Ocimum gratissimum* in rats. Fitoterapia, 71, 444-446. https://doi.org/10.1016/S0367-326X(00)00143-X

Ajayi, A. M., Tanayen, J. K., Ezeonwumelu, J, Dare, S., Okwanachi, A., Adzu, B., & Ademowo, O.G (2014). Anti-inflammatory, anti-nociceptive and total polyphenolic content of hydroethanolic extract of *Ocimum gratissimum* L. Leaves. *African Journal of Medicine and Medical Sciences*, *43*(S1), 215-224.

Akah, P. A., John-Africa, L., & Nworu (2007). Gastroprotective properties of the leaf extracts of *Ocimum gratissimim* L. against experimental Ulcers in rat. *International Journal of Pharmacology, 3*(6), 461-467.

Akinmoladun, A.C., Ibukun, E.O., Emmanuel, A., Obuotor, E. M., & Farombi, E. O. (2007). Phytochemical constituent and antioxidant activity of extract from the leaves of *Ocimum gratissimum. Scientific Research Essay, 2*, 163-166.

Alabi, A.O., Ajayi, A.M., Omorogbe, O. *et al.* Anti-nociceptive and anti-inflammatory effects of an aqueous extract of blended leaves of *Ocimum gratissimum* and *Psidium guajava*. *Clinical Phytoscience, 5,* 34 (2019). https://doi.org/10.1186/s40816-019-0130-2.

Ashokkumar, K., Dhanya, M. K., Murugan, M., Haritha., K. V., Nimisha, M., & Aiswarya, S. (2020b). Assessment of variation in volatile oil content in cardamom [*Elettaria cardamomum* (L.) Maton. *Electronic Journal of Plant Breeding*, *11*(4), 1007-1014. http://www.ejplantbreeding.org/index.php/ EJPB/article/view/3426

Ashokkumar, K., Murugan, M., Dhanya, M. K. & Warkentin, T. D. (2020a). Botany, traditional uses, phyto-chemistry and biological activities of cardamom [*Elettaria cardamomum* (L.) Maton] – a critical review. *Journal of Ethnopharmacology*, 246,112244.https://doi.org/10.1016/j.jep.2019.112244

Ashokkumar, K., Vellaikumar, S., Murugan, M., Dhanya, M. K., Aiswarya, S., & Nimisha, M. (2020d). Chemical composition of Ocimum gratissimumessential oil from the South Western Ghats, India. *Journal of Current Opinion in Crop Science, 1*(1), 27-30. https://jcocs.com/index.php/ej/article/view/14/17

Ashokkumar, K., Vellaikumar, S., Muthusamy, M., Dhanya, M. K. & Aiswarya, S. (2020c). Compositional variation in the leaf, mace, kernel, and seed essential oil of nutmeg (*Myristica fragrans* Houtt.) from the Western Ghats, India. *Natural Product Research*, https://doi.org/10.1080/14786419.2020.1771713

Azwanida, N. N. (2015). A review on the extraction methods use in medicinal plants, principle, strength and limitation. *Medicinal & Aromatic Plants*, *4*, 3–8.

Benelli, G., Pavela, R., Maggi, F., Wandjou, J. G. N., Fofie, N. G. B. Y., Koné-Bamba, D., Vittori, G. S. S., & Caprioli, G. (2019). Insecticidal activity of the essential oil and polar extracts from *Ocimum gratissimum* grown in Ivory Coast: Efficacy on insect pests and vectors and impact on non-target species. Industrial Crops and Products, 132,377-385. https://doi.org/10.1016/j.indcrop.2019.02.047.

Benitez, N. P., Meléndez León, E. M., & Stashenko, E. E. (2009). Eugenol and methyl eugenol chemotypes of essential oil of species *Ocimum gratissimum* L. and *Ocimum campechianum* Mill. from Colombia. *Journal of Chromatographic Science, 47*(9), 800-803. https://doi.org/10.1093/chromsci/47.9.800

Dubey, N. K., Tiwari, T., Mandin, D., Andriamboavonjy, H., Chaumont, J-P. (2000). Antifungal properties of *Ocimum gratissimum* essential oil (ethyl cinnamate chemotype). *Fitoterpia,* 71(5), 567-569. https://doi.org/10.1016/S0367-326X(00)00206-9

Effraim, K. D., Jacks, T. W., & Sodipo, O. A. (2003). Histopathological studies on the toxicity of *Ocimum gratissimum* leave extract on some organs of rabbit. *African Journal of Biomedical Research, 6*, 21-25.

Eswar, P., Devaraj, C. G., Agarwal, P. (2016). Antimicrobial activity of Tulsi {Ocimum Sanctum (Linn.)} extract on a periodontal pathogen in human dental plaque: an in vitro study. *Journal of Clinical and Diagnostic Research, 10*(3), ZC53-ZC56.

Gontijo, D. C., Fietto, L. C., & Leite, J. P. V. (2014). Phytochemical assessment and antioxidant, antimutagenic and toxicological activity of *Ocimum gratissimum* L. leaf aqueous extract. *Revista Brasileira de Plantas Medicinais*, *16*(4), 874-880.

Gupta, S. K., Prakash, J., & Srivastav, S. (2002). Validation of claim of Tulsi, *Ocimum sanctum* Linn as a medicinal plant. *Indian Journal of Experimental Biology, 40*, 65–773.

Ibeh, S. C., Akinlabi, O. D., Asmau, I., Audu, J., & Muritala A. M. (2017). Extraction of *Ocimum Gratissimum* using different distillation techniques. *International Journal of Scientific & Technology Research*, 6(5), 26-28.

Ijeh, I. I., Omodamiro, O. D., & Nwanna, I. J. (2005). Antimicrobial effects of aqueous and ethanolic fractions of two spices, *Ocimum gratissimum* and *Xylopia aethiopica*. *African Journal of Biotechnology, 4*, 953-956.

Istiana, M., Murbach, F., M´arcia, O.M., & Mirtes, C. (2006). Effects of seasonal variation on the central nervous system activity of *Ocimum gratissimum* L. essential oil. *Journal of Ethnopharmacololgy*, *105*, 161-166. https://doi.org/10.1016/j.jep.2005.10.013

Jirovetz, L., Buchbauer, G., Ngassoum, M.B., Ngamo, L. T., & Adjoudji, O. (2005). Combined investigation of the chemical composition of essential oils of *Ocimum gratissimum* and Xylopia aethiopica from Cameroon and their insecticidal activities against stored maize pest *Sitophilus zeamais*. *Ernähr, 29*, 55-56.

Joshi, R. K. (2013). Chemical composition, in vitro antimicrobial and antioxidant activities of the essential oils of *Ocimum gratissimum*, *O. Sanctum* and their major constituents. *Indian Journal of Pharmaceutical Sciences, 75*(4), 457-462. DOI: 10.4103/0250-474X.119834

Joshi, R. K. (2017). GC–MS analysis of the essential oil of *Ocimum gratissimum* L. growing desolately in South India. *Acta Chromatographica*, *29*(1), 111–119. https://doi.org/10.1556/1326.2017.29.1.10

Kpadonou Kpoviessi, B. G., Ladekan, E. Y., Kpoviessi, D. S., Gbaguidi, F., Yehouenou, B., Quetin-Leclercq, J., Figueredo, G., Moudachirou, M., & Accrombessi, G. C. (2012). Chemical variation of essential oil constituents of *Ocimum gratissimum* L. from Benin, and impact on antimicrobial properties and toxicity against Artemia salina leach. *Chemical Biodiversity, 9*(1), 139-50. doi: 10.1002/cbdv.201100194.

Lahlou, S., Interaminense Lde, F., Leal-Cardoso, J. H., Morais, S. M., & Duarte, G. P. (2004). Cardiovascular effects of the essential oil of *Ocimum gratissimum* leaves in rats: role of the autonomic nervous system. *Clinical and Experimental Pharmacology & Physiology*, *31*(4), 219-225. doi:10.1111/j.1440-1681.2004.03976.x.

Martins, A. P., Salgueiro, L. R., Vila, R., Tomi, F., Cañigueral, S., Casanova, J., da Cunha, A. P., & Adzet, T. (1999). Composition of the essential oils of *Ocimum canum, O. gratissimum* and *O. minimum*. *Planta Medica, 65*(2),187-189. doi: 10.1055/s-2006-960465.

Matasyoh, L. G., Matasyoh, J. C., Wachira, F. N., Kinyua, M. G., Muigai, A. W. T. & Mukiama, T. K. (2007). Chemical composition and antimicrobial activity of the essential oil of *Ocimum gratissimum* L. growing in Eastern Kenya. *African Journal of Biotechnology, 6*(6), 760-765.

Matasyoh, L.G., Matasyoh, J. C., Wachira, F. N., Kinyua, M. G., Muigai, A. W., & Mukiama, T. K. (2008). Antimicrobial activity of essential oils of *Ocimum gratissimum* L. From different populations of Kenya. *African Journal of Traditional, Complementary and Alternative Medicines, 5*(2),187-93. doi: 10.4314/ajtcam.v5i2.31272.

Melo, R. S., Albuquerque Azevedo, Á. M., Gomes Pereira, A. M., Rocha, R., Bastos Cavalcante, R. M., Carneiro Matos, M. N., Ribeiro Lopes, P. H., Gomes, G. A., Soares Rodrigues, T. H., Santos, H. S. D., Ponte, I. L., Costa, R. A., Brito, G. S., Catunda Júnior, F. E. A., & Carneiro, V. A. (2019). Chemical Composition and Antimicrobial Effectiveness of *Ocimum gratissimum* L. essential oil against multidrug-resistant isolates of *Staphylococcus aureus* and *Escherichia coli*. *Molecules, 24*(21), 3864. doi: 10.3390/molecules24213864.

Nadkarni, K.M. (1999). Indian Materia Medica, 3rd edn., Popular Prakashan Pvt. Ltd., India.

Offiah, V. N., & Chikwendu, U. A. (1999). Antidiarrhoeal effects of *Ocimum gratissimum* leaf extract in experimental animals. *Journal of Ethnopharmacology*, *68*(1-3), 327-330.

Okon, U.A., & Umoren, I.U. (2017). Comparison of antioxidant activity of insulin, *Ocimum gratissimum* L., and *Vernonia amygdalina* L. in type 1 diabetic rat model. *Journal of Integrative Medicine, 15*(4), 302-309. doi: 10.1016/S2095-4964(17)60332-7.

Padalia, R. C., & Verma, R. S. (2011). Comparative volatile oil composition of four Ocimum species from northern India. *Natural Product Research, 25*,569–575. https://doi.org/10.1080/14786419.2010.482936

Padalia, R. C., Verma, R. S., Chauhan, A., Goswami, P., Chanotiya, C. S., Saroj, A., Samad, A., & Khaliq, A. (2014). Compositional variability and antifungal potentials of *Ocimum basilicum, O. tenuiflorum, O. gratissimum* and *O. kilimandscharicum* essential oils against *Rhizoctonia solani* and *Choanephora cucurbitarum*. *Natural Product Communications, 9*(10), 1507-1510.

Pessoa, L. M., Morais, S. M., Bevilaqua, C. M., & Luciano, J. H. (2002). Anthelmintic activity of essential oil of *Ocimum gratissimum* Linn. and eugenol against *Haemonchus contortus*. *Veterinary Parasitology, 109*(1-2), 59-63. doi: 10.1016/s0304-4017(02)00253-4

Rabelo, M., Souza, E. P., Soares, P. M. G., Miranda, A. V., Matos, F. J. A., &. Criddle, D. N. (2003). Antinociceptive properties of the essential oil of *Ocimum gratissimum*L. (Labiatae) in mice. *Brazilian Journal of Medical and Biological Research, 36*, 521-524.

Rodrigues, F. C., Almeida-Bezerra, J. W., Fidelis, K. R., Costa, A. R., Souza, M. A. De., Costa, M. H. N. Da., Santos, L. T. Dos., Gonçalo, M. A. B. F., Menezes, S. A. De., Sousa, S. M. De., Araujo, E. K. R. De., Braga, A. V. P., Ribeiro, T. G., Costa, A. R. De S., Santos, M. A. F. Dos., Nunes, R. G. Dos S., & Rocha, M. I. (2020). Chemical characterization

and insecticidal potential of the essential oil of *Ocimum gratissimum* L. (Lamiaceae) against *Nauphoeta cinerea* (Blaberidae). *Research, Society and Development*, 9(9), p.e72996412, https://doi.org/10.33448/rsd-v9i9.6412

Segun, A. A., & Sunday, O. I. (2020). Anthelmintic activity of *Ocimum gratissimum* and *Cymbopogon citratus* leaf extracts against *Haemonchus placei* adult worm. *Journal of Pharmacy and Bioresources. 17*(1), 8-12.

Silva Lima, A., Milhomem, M. N., Santos Monteiro, O., Arruda, A. C. P., de Castro, J. A. M, Fernandes, Y. M. L., Maia, J. G. S., & Costa-Junior, L. M. (2018). Seasonal analysis and acaricidal activity of the thymol-type essential oil of Ocimum gratissimum and its major constituents against Rhipicephalus microplus (Acari: Ixodidae). *Parasitology Research, 117*(1), 59-65. doi: 10.1007/s00436-017-5662-0.

Trevisan, M. T., Vasconcelos, M. G. S., Pfundstein, M. B., Spiegelhalder, B., & Owen, R. W. (2006). Characterization of the volatile pattern and antioxidant capacity of essential oils from different species of the genus *Ocimum*. *Journal of Agricultural and Food Chemistry*, *54*(12), 4378-4382.

Tshilanda, D. D., Ngoyi, E. M., Kabengele, C. N., Matondo, A., Bongo, G. N., Inkoto, C. L., Mbadiko, C. M., Gbolo, B. Z., Lengbiye, E. M., Kilembe, J. T., Mwanangombo, D. T., Kasiama, G. N., Tshibangu, D. S. T., Ngbolua, K. N., & Mpiana, P. T. (2020). *Ocimum* species as potential bioresources against COVID-19: a review of their phytochemistry and antiviral activity. *International Journal of Pathogen Research, 5*(4), 42-54.

Venuprasad, M. P., Farhath, K., Hemanth Kumar, K., & Sakina, R. (2014). Phytochemical analysis of Ocimum gratissimum by LC-ESI–MS/MS and its antioxidant and anxiolytic effects. South African Journal of Botany, 92, 151-158. https://doi.org/10.1016/j.sajb.2014.02.010

Verma, R. S., Kumar, A., Mishra, P., Kuppusamy, B., Padalia, R. C., & Sundaresan, V. (2016) Essential oil composition of four *Ocimum* spp. from the Peninsular India. *Journal of Essential Oil Research, 28*, 35-41, http://dx.doi.org/10.1080/10412905.2015.1076742

Yung-Wei, C., Hung-Jen, L., Hsin-Yu, H., Pei-Yu, C., Jin-Ming, H., Pei-Yun, H., Shyh-Jer, H., Jer-Yuh, L, & Te-Jen, L. (2013). The antioxidant and cytoprotective activity of *Ocimum gratissimum* extracts against hydrogen peroxide-induced toxicity in human HepG2 cells. *Journal of Food and Drug Analysis, 21*(I3), 253-260. https://doi.org/10.1016/j.jfda.2013.07.002