Food Chemistry Advances 3 (2023) 100481

Contents lists available at ScienceDirect

Food Chemistry Advances

journal homepage: www.elsevier.com/locate/focha

Essential oils from unconventional food plants (*Murraya* spp., *Ocimum* spp., *Piper* spp.) as alternative food flavorings

Débora Nogueira Cavalcante [a], Renilto Frota Corrêa [a], Pedro Henrique Campelo [b], Edgar Aparecido Sanches [c], Jaqueline de Araújo Bezerra [a,*]

[a] Analytical Center of the Federal Institute of Education, Science and Technology of Amazonas (IFAM), Campus Manaus Centro, Manaus 69020-120, AM, Brazil
[b] Department of Food Technology, Federal University of Viçosa (UFV), Viçosa 36570-900, MG, Brazil
[c] Laboratory of Nanostructured Polymers (NANOPOL), Materials Physics Department, Federal University of Amazonas (UFAM), Manaus 69067-005, AM, Brazil

A R T I C L E I N F O

Keywords:
Essential oils
Murraya spp.
Ocimum spp.
Piper spp.

A B S T R A C T

In this analysis, literary sources and patents addressing the use of essential oils from various aromatic species were compared. The objective was to evaluate the potential of these essential oils in research focused on the production of foods with beneficial properties for conservation. Plant species from the genera *Murraya* spp., *Piper* spp., and *Ocimum* spp. were considered, which have compounds such as linalool, limonene, geranyl acetate, linalyl acetate, and eugenol, all approved for use in food. The investigated patents were classified into preservatives (17.64 %) and flavorings (52.94 %), based on the 17 patents selected for the research. Publications from the past ten years were also analyzed to determine the chemical composition of the essential oils and their applications as flavorings. Additionally, the beneficial properties of these oils, such as antioxidants and antimicrobials, were considered in order to offer natural alternatives to conventional flavorings and preservatives.

1. Introduction

Essential oils are often used in food industries to preserve products due to their rich properties. Most food products are prepared and stored using synthetic and chemical preservatives to maintain their quality, however these preservatives can pose risks to consumers' health and damage the environment (Faleiro, 2020). For these reasons, the high demand for the use of essential oils from plants as an alternative for use in foods is a promising option for consumers who are looking for healthier products with greater stability, safety, and a preference for foods with fresh sensory properties (Rehman et al., 2021).

The chemical studies of essential oils is the main starting point to be carried out due to its biological applications (Properzi et al., 2013). During the 16th century, essential oil was referred to as Quinta Essentia, a medication used by Swiss physician, Bombastus Paracelsus von Hohenheim. By definition, essential oils are natural, volatile, aromatic liquids extracted from plants, having a variety of secondary metabolites (terpenes, phenolic compounds, alcohol) (Guenther,1948).

Essential oils are composed of terpenoids, which are secondary metabolites with distinct biological properties and which are separated through different extraction processes from the aromatic tissues of these materials. These components are used in pharmaceutical and food industries. Essential oils are obtained from a variety of aromatic materials, including herbs, fruits, flowers, wood and roots (Mahanta et al., 2021).

According to a report from the European Essential Oils Federation, the food and beverage sector is the main driver for the highest demand for essential oils, followed by the industries of perfumery, cosmetics and aromatherapy (Barbieri & Borsotto 2018). After a series of studies and analyses, it was discovered that essential oils have biological and medicinal characteristics, such as antioxidant and antibacterial properties, comparable to the most widely used synthetic preservatives in the food industry (Jafarizadeh-malmiri et al., 2022).

The Flavor and Extract Manufacturers Association (FEMA) is the primary body that evaluates the safety of flavoring ingredients for human consumption foods in the United States. The ingredients undergo an evaluation called "Expert Panel" to determine if they are "Generally Recognized As Safe" (GRAS), and thus the body determines whether it is safe to use in food, according to the criteria set by the 1958 Food Additive Amendment to the Federal Food, Drug, and Cosmetic Act (Hallagan, Hall & Drake 2020; Hallagan & Hall, 1995). The National Sanitary Surveillance Agency (Anvisa), according to Resolution RDC 2/2007, recognizes the use of essential oils as natural flavorings. This

* Corresponding author.
E-mail address: jaqueline.araujo@ifam.edu.br (J.A. Bezerra).

https://doi.org/10.1016/j.focha.2023.100481
Received 28 June 2023; Received in revised form 30 August 2023; Accepted 9 October 2023
Available online 10 October 2023

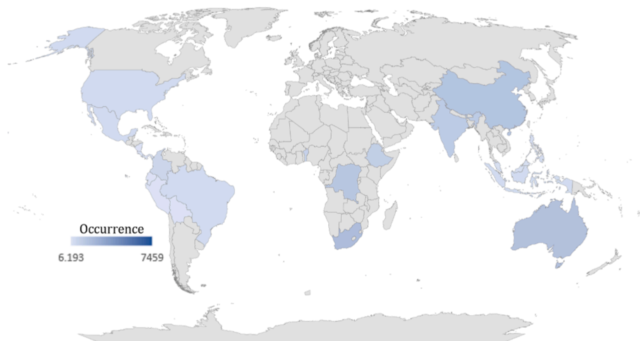

Fig. 1. Occurrence of Species Across the World (www.gbif.org).

resolution characterizes food additives that have odor properties, which can intensify the aroma and taste of food, being of natural or synthetic origin (ANVISA, 2007). The control of food additives and their concentrations vary between countries, and in Brazil, Anvisa is the agency responsible for evaluating the safety of ingredientes

This article aims to provide an analysis of the data published in the last 10 years on the chemical composition of essential oils of species known as unconventional food plants. These essential oils offer an alternative for flavoring foods as well as important biological activities.

2. Scientific reports and eligibility criteria

This review was developed to assess the chemical composition and use of essential oils from aromatic plants as natural flavourers in the food industry. To that end, an online search was carried out in the ScienceDirect, PubMed, Web of Science, Scopus, Capes Periodicals and Google Scholar databases, considering the terms ("essential oil" and "food"); ("essential oil" and "*Murraya* spp."); ("essential oil" and "*Ocimum* spp."), ("essential oil" and "*Piper* spp."), with regard to title, abstract and keywords, restricted to works published between 2012 and 2022. The results provided detailed information about the chemical composition of essential oils of aromatic plants and their use in food production. Furthermore, a research was conducted in the patent databases Google Patents, USPTO, Espacenet and WIPO to explore the topic: use of extracts and essential oils of non-conventional food plants, as flavorings and alternative food preservatives, with antimicrobial and antioxidant properties, of the genres *Murraya* spp., *Ocimum* spp. and *Piper* spp. Fig. 1 shows the global distribution of the studied species. The darkest locations represent the highest presense.

3. Essential oils in food

In recent years, manufacturers and consumers have become more aware of food composition and additives. The increase in concern for health has led the public to search for more natural foods, free of synthetic substances that can cause allergies, poisoning, cancer and other diseases when used in excess (Ballester-Costa et al., 2017; Faleiro, 2020). For centuries, the essential oils of aromatic plants have been applied in the preservation and flavoring of food, as they present many benefits, such as antioxidant effects and significant antimicrobial properties (Álvarez et al., 2012; Ghabraie et al., 2016).

Essential oils, formed by secondary metabolites of plants, have significant medicinal properties due to the presence of chemical compounds such as terpenes, flavonoids, and phenolics (Bouyahya et al., 2017), over the last few years, food industries have been turning to essential oils due to their potential to control the growth of pathogenic microorganisms and the fact that they pose no risk to human health.

The main goal of the use of essential oils is to ensure that they are safe and effective in place of conventional additives (Falleh et al., 2019). The (FDA | U.S. Food & Drug Administration.), ecognizes essential oils labeled as GRAS (Generally Recognized as Safe) those containing a series of safe components, including thymol, carvacrol, eugenol, linalool, carvone, vanillin, cinnamaldehyde, citral and limonene, which meet the limitations of the accepted daily intake described in the Federal Code of Regulations, Title 21, Part 182. These components are commonly found in essential oils of aromatic plants.

4. Unconventional food plants as flavoring alternatives in food

In Brazil, Unconventional Food Plants are known by the acronym PANC ("Non-Conventional Food Plants") (Kinupp & Lorenzi, 2014), These are those that have parts that can be used for food preparation. These plants include those that provide essential oils, spices, and condiments used in cooking (Leal et al., 2018). Human nutrition benefits from the use of non-conventional food plants, as studies show they are rich in minerals and bioactive compounds. These species are widely used in popular cuisine as seasoning, and their access and low cost encourage their cultivation and consumption in several countries. The food industry also benefits from the use of these foods, as it contributes to the preservation of biodiversity (Kibar & Temel, 2016).

Botanical families such as Lamiaceae, Rutaceae and Piperaceae are widely used in food applications, since their oils can be used as natural flavourings. These aromatic plants are widely used for food purposes (Prakash et al., 2018). The US FDA has approved some essential oils from aromatic species as food additives, due to its great commercial demand for use as preservatives and decontamination agents, the plants *Ocimum gratissimum* (family Lamiaceae) and *Piper nigrum* (family Piperaceae) have been confirmed as natural aromas and declared as GRAS (Generally Recognized as Safe) by (FDA | U.S. Food & Drug Administration.). This approval offers excellent development opportunities for the species of aromatic plants (Ballester-Costa et al., 2016), in addition to having antimicrobial and antioxidant properties, which provides a promising perspective for the preservation of various foods (Ballester-Costa et al., 2013).

5. Chemical composition of essential oils

Essential oils from aromatic plants are widely used to add flavor and aroma to food. These natural flavorings and preservatives are composed of chemical compounds that directly act on the human olfactory system. According to the study Bora et al. 2020, Aromatic terpenoids such as hydrocarbons (α-pinene, sabinene, β-felandrene, and farnesene), oxides (linalol oxide, ascaridole, and cineole), lactones (citroptene and bergapten), esters (eugenol acetate and linalyl acetate), alcohols (linalol, geraniol, and borneol), phenols (thymol and eugenol), ketones (camphor, fenchone, and carvone), and aldehydes (citral) are included in these compounds. Majority compounds that play a vital role in preventing oxidative damage and inhibiting microorganisms, which improves their utilization in food products. The selection of species for this analysis was based on their significant potential as flavoring agents due to the presence of compounds such as linalool, limonene, geranyl acetate, linalyl acetate, and eugenol. All these compounds are approved for human use according to Section 409 of the FDA Law in the United States (FDA | U.S. Food & Drug Administration). Research has proven that the essential oils of these species possess broad antibacterial activity and antioxidant properties, which are essential for food preservation and processing.

6. Essential oils of *Murraya* spp. (Rutaceae)

The Rutaceae family has approximately 150 genera and 1600 species. The genus *Murraya* is composed of about 35 species, native to Southeast Asia. Some examples of these species are: *Murraya euchrestifolia, M. koenigii* (L.) Spreng, *M. paniculata* (L.) Jack, *M. sumatrana, M. amoena, M. omphalocarpa Hayata, M. alata Drake, M. caloxylon* Ridl*, M. crenulata* (Turcz.) Oliv, *M. brevifolia, M. burmanni, M. alternans and M.*

Table 1
Chemical composition of essential oils of leaf species of *Murraya* spp.

No	Compounds	Specie	(%)	References
1	β-elemene	*M. paniculata*	3.09	(Saikia et al., 2022)
		M. koenigii	0.73	(Tripathi et al., 2018)
2	α-copaene	*M. microphylla*	1.08	(Xia et al., 2020)
3	α-cubebene	*M. paniculata*	2.45	(Saikia et al., 2022)
		M. microphylla	0.62	(Xia et al., 2020)
4	β-caryophyllene	*M. paniculata*	20.93	(Saikia et al., 2022)
		M. microphylla	20.36	(Xia et al., 2020)
		M. koenigii	0.75	(Tripathi, Anjum & Rana, 2018)
5	spathulenol	*M. paniculata*	2.31	(Saikia et al., 2022)
6	γ-gurjunene	*M. paniculata*	2.73	(Saikia et al., 2022)
7	α-pinene	*M. koenigii*	9.38	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	1.20	(Xia et al., 2020)
8	camphene	*M. koenigii*	0.86	(Tripathi, Anjum & Rana, 2018)
9	linalool	*M. koenigii*	5.42	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	1.48	(Xia et al., 2020)
10	limonene	*M. koenigii*	1.58	(Tripathi, Anjum & Rana, 2018)
11	1,8-cineole	*M. koenigii*	0.55	(Tripathi, Anjum & Rana, 2018)
12	α-terpinene	*M. koenigii*	1.16	(Tripathi, Anjum & Rana, 2018)
13	β-phellandrene	*M. koenigii*	0.18	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	7.24	(Xia et al., 2020)
14	(*E*)-β-ocimene	*M. koenigii*	1.16	(Tripathi, Anjum & Rana, 2018)
15	(*Z*)-β-ocimene	*M. koenigii*	1.38	(Tripathi, Anjum & Rana, 2018)
16	γ-terpinene	*M. koenigii*	3.48	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	8.74	(Xia et al., 2020)
17	myrcene	*M. koenigii*	2.43	(Tripathi, Anjum & Rana, 2018)
18	α-eudesmol	*M. koenigii*	4.55	(Tripathi, Anjum & Rana, 2018)
19	β-pinene	*M. koenigii*	13.57	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	0.53	(Xia et al., 2020)
20	*allo*-ocimene	*M. koenigii*	2.75	(Tripathi, Anjum & Rana, 2018)
21	α-terpineol	*M. koenigii*	1.48	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	11.60	(Xia et al., 2020)
22	germacrene D	*M. koenigii*	0.62	(Tripathi, Anjum & Rana 2018)
23	cubenol	*M. koenigii*	0.22	(Tripathi, Anjum & Rana, 2018)
24	α-amorphene	*M. koenigii*	3.38	(Tripathi, Anjum & Rana, 2018)
25	viridiflorol	*M. koenigii*	0.78	(Tripathi, Anjum & Rana, 2018)
26	humulene	*M. microphylla*	5.60	(Xia et al., 2020)
27	(E)-nerolidol	*M. paniculata*	1.51	(Saikia et al., 2022)
28	β-eudesmol	*M. koenigii*	2.16	(Tripathi, Anjum & Rana, 2018)
29	aromandendrene	*M. microphylla*	1.38	(Xia et al., 2020)
30	δ-cadinene	*M. paniculata*	8.31	(Saikia et al., 2022)
		M. koenigii	0.56	(Tripathi, Anjum & Rana, 2018)
31	δ-elemene	*M. paniculata*	7.24	(Saikia et al., 2022)
32	5-methyl thiazole	*M. paniculata*	2.06	(Saikia et al., 2022)
33	γ-elemene	*M. microphylla*	6.03	(Xia et al., 2020)
34	*allo*-aromadendrene	*M. paniculata*	1.19	(Saikia et al., 2022)
35	*Z*-caryophyllene	*M. paniculata*	4.37	(Saikia et al., 2022)
36	β-cadinene	*M. paniculata*	2.04	(Saikia et al., 2022)
37	β-cubebene	*M. paniculata*	9.26	(Saikia et al., 2022)
38	viridiflorene	*M. paniculata*	1.61	(Saikia et al., 2022)
39	elixene	*M. paniculata*	4.68	(Saikia et al., 2022)
40	4,4-dimethyl-3-(3-methylbut-3-enylidene)−2-methylenebicyclo[4.1.0] heptanes	*M. paniculata*	1.62	(Saikia et al., 2022)
41	naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)	*M. paniculata*	0.96	(Saikia et al., 2022)
42	patchoulane	*M. paniculata*	1.11	(Saikia et al., 2022)
43	longifolene	*M. paniculata*	2.37	(Saikia et al., 2022)
44	guaiol	*M. paniculata*	2.17	(Saikia et al., 2022)
45	rosifoliol	*M. paniculata*	1.83	(Saikia et al., 2022)
46	dehydro-aromadendrene	*M. paniculata*	2.18	(Saikia et al., 2022)
47	γ-muurolene	*M. paniculata*	1.95	(Saikia et al., 2022)
		M. microphylla	1.50	(Xia et al., 2020)
48	α-muurolene	*M. koenigii*	0.25	(Tripathi, Anjum & Rana, 2018)
49	τ-cadinol	*M. paniculata*	1.74	(Saikia et al., 2022)

(*continued on next page*)

Table 1 (*continued*)

No	Compounds	Specie	(%)	References
50	α-cadinol	*M. paniculata*	2.70	(Saikia et al., 2022)
51	isophytol	*M. paniculata*	0.77	(Saikia et al., 2022)
52	n-hexadecanoic acid	*M. paniculata*	1.80	(Saikia et al., 2022)
53	3,3′-bi-*p*-menthane	*M. paniculata*	0.73	(Saikia et al., 2022)
54	bicyclo[5.3.0]decane, 2-methylene-5-(1-methylvinyl)−8-methyl	*M. paniculata*	1.91	(Saikia et al., 2022)
55	α-thujene	*M. koenigii*	1.12	(Tripathi, Anjum & Rana, 2018)
56	3-carene	*M. koenigii*	18.52	(Tripathi, Anjum & Rana, 2018)
57	*m*-cymene	*M. koenigii*	0.45	(Tripathi, Anjum & Rana, 2018)
58	geranyl acetate	*M. koenigii*	0.57	(Tripathi, Anjum & Rana, 2018)
59	nerol	*M. koenigii*	0.78	(Tripathi, Anjum & Rana, 2018)
60	carvone	*M. koenigii*	1.68	(Tripathi, Anjum & Rana, 2018)
61	linalool acetate	*M. koenigii*	2.46	(Tripathi, Anjum & Rana, 2018)
62	lavandulyl acetate	*M. koenigii*	0.56	(Tripathi, Anjum & Rana, 2018)
63	myrtenyl acetate	*M. koenigii*	0.83	(Tripathi, Anjum & Rana, 2018)
64	neryl acetate	*M. koenigii*	0.76	(Tripathi, Anjum & Rana, 2018)
65	z-jasmone	*M. koenigii*	0.86	(Tripathi, Anjum & Rana, 2018)
66	α-gurjunene	*M. koenigii*	0.69	(Tripathi, Anjum & Rana, 2018)
		M. microphylla	0.49	(Xia et al., 2020)
67	elemol	*M. koenigii*	0.67	(Tripathi, Anjum & Rana, 2018)
68	γ-eudesmol	*M. koenigii*	0.95	(Tripathi, Anjum & Rana, 2018)
69	α-phellandrene	*M. microphylla*	0.29	(Xia et al., 2020)
70	2-carene	*M. microphylla*	6.95	(Xia et al., 2020)
71	1-methyl-3-(1-methylethyl)-benzene	*M. microphylla*	1.36	(Xia et al., 2020)
72	bicyclo[3.1.0] hexan-2-ol, 2-methyl-5-(1-methylethyl)-(1α−2α−5α)	*M. microphylla*	2.93	(Xia et al., 2020)
73	1-methyl-4-(1-methylethyl)-cyclohexene	*M. microphylla*	2.12	(Xia et al., 2020)
74	p-menth-8-en-1-ol, stereoisomer	*M. microphylla*	4.35	(Xia et al., 2020)
75	*cis*-2-cyclohexen-1-ol, 1-methyl-4-(1-methylethyl)	*M. microphylla*	1.24	(Xia et al., 2020)
76	*trans*-2-cyclohexen-1-ol, 1-methyl-4-(1-methylethyl)	*M. microphylla*	0.72	(Xia et al., 2020)
77	*trans*-2-cyclohexen-1-ol, 3-methyl-6-(1-methylethyl)	*M. microphylla*	0.35	(Xia et al., 2020)
78	2,6,6-trimethyl-1,4-cyclohexadiene-1-carboxaldehyde	*M. microphylla*	0.43	(Xia et al., 2020)
79	(3*R*-*trans*)-cyclohexene, 4-ethenyl-4-methyl-3-(1-methylethenyl)−1-(1-methylethyl)	*M. microphylla*	0.39	(Xia et al., 2020)
80	1,7,7-trimethyl-bicyclo(2.2.1) heptan-2-one	*M. microphylla*	1.85	(Xia et al., 2020)
81	1-isopropyl-4,7-dimethyl-1,2,3,5,6,8α-hexahydronaphthalene	*M. microphylla*	2.12	(Xia et al., 2020)
82	naphthalene, 1,2,4a,5,6,8α-hexahydro-4,7-dimethyl-1-methylethyl)	*M. microphylla*	1.12	(Xia et al., 2020)

siamensis. These plants have been used as medicine for many years (Jack, 2011). The main chemical compounds of these species that comprise the genus are mentioned in (Table 1).

M. paniculata, commonly known as orange-jasmine or fragrant myrtle, which has great commercial value due to its characteristics and strong aroma. This species is widely used in the food and cosmetics industry (Arya et al., 2017).

It is widely used in Indian, Pakistani and Malaysian cuisine as a seasoning. Its leaves have been incorporated into dishes to add a characteristic flavor and give a touch of color (Saqib et al., 2015). Research has shown that *M. paniculata* has antioxidant properties and can be used as a dietary supplement (Gautam et al., 2012).

A study using GC–MS analysis of the essential oil obtained from fresh leaves of *M. paniculata* revealed 29 compounds, the major being sesquiterpene hydrocarbons (80 %) and the minority being oxygenated sesquiterpenes (12.26 %), diterpenoids (1.50 %), fatty acids (1.80 %) and nitrogenous heterocyclic compounds (2.06 %) (Saikia et al., 2022).

Murraya koenigii (L.) Spreng, popularly known as curry leaf, is a small

Table 2
Chemical composition of *Ocimum* spp. essential oils reported in literature.

No	Compounds	Specie	Part	%	References
1	β-elemene	*O. gratissimum*	leaves	0.85	(Cesar et al., 2022)
2	α-copaene	*O. viride*	aerial parts	0.58	(Raina & Gupta, 2018)
4	β-caryophyllene	*O. viride*	aerial parts	1.87	(Raina & Gupta, 2018)
11	1,8-cineole (eucalytol)	*O. gratissimum*	leaves	10.83	(Cesar et al., 2022)
14	(E)-β-ocimene	*O. viride*	aerial parts	0.34	(Raina & Gupta, 2018)
15	(Z)-β-ocimene	*O. viride*	aerial parts	9.13	(Raina & Gupta, 2018)
20	*allo*-ocimene	*O. viride*	aerial parts	0.22	(Raina & Gupta, 2018)
21	α-terpineol	*O. gratissimum*	leaves	0.85	(Cesar et al., 2022)
83	α-humulene	*O. gratissimum*	leaves	1.00	(Cesar et al., 2022)
84	eugenol	*O. gratissimum*	leaves	63.25	(Cesar et al., 2022)
85	α-selinene	*O. gratissimum*	leaves	3.01	(Cesar et al., 2022)
86	β-selinene	*O. gratissimum*	leaves	8.43	(Cesar et al., 2022)
87	*cis*-ocimene	*O. gratissimum*	leaves	1.88	(Cesar et al., 2022)
88	*trans*-caryophyllene	*O. gratissimum*	leaves	6.85	(Cesar et al., 2022)
89	germacrene-D	*O. gratissimum*	leaves	3.04	(Cesar et al., 2022)
		O. viride	aerial parts	6.58	(Raina & Gupta, 2018)

Table 3
Chemical composition of essential oils from *Piper* ssp. reported in the literature.

No	Compounds	Specie	Part	%	References
1	β-elemene	*P. umbellatum*	leaves	0.4	(Carneiro et al., 2020)
2	α-copaene	*P. nigrum*	fruits	2.83	(Ghosh et al., 2021)
		P. mikanianum	leaves	0.3	(Carneiro et al., 2020)
		P. betle	leaves	2.68 ± 0.39	(Subaharan et al., 2021)
3	α-cubebene	*P. nigrum*	fruits	0.28	(Ghosh et al., 2021)
4	β-caryophyllene	*P. nigrum*	fruits	13.38	(Ghosh et al., 2021)
		P. umbellatum	leaves	1.41	(do Nascimento Silveira Dorneles et al., 2019)
		P. xylosteoides	leaves	10.5	(Morais-Braga et al., 2022)
		P. betle	leaves	5.98 ± 0.61	(Subaharan et al., 2021).
		P. mikanianum	leaves	1.7	(Carneiro et al., 2020)
5	spathulenol	*P. xylosteoides*	leaves	1.5	(Morais-Braga et al., 2022)
		P. mikanianum	leaves	0.5	(Carneiro et al., 2020)
6	γ-gurjunene	*P. regnellii*	leaves	1.2	(Braga et al., 2021)
7	α-pinene	*P. regnellii*	leaves	0.50	(Braga et al., 2021)
		P. xylosteoides	leaves	3.2	(Morais-Braga et al., 2022)
		P. nigrum	fruits	7.84	(Ghosh et al., 2021)
		P. mikanianum	leaves	1.4	(Carneiro et al., 2020)
		P. betle	leaves	0.32 ± 0.01	(Subaharan et al., 2021)
8	camphene	*P. xylosteoides*	leaves	3.5	(Morais-Braga et al., 2022)
		P. nigrum	fruits	0.22	(Ghosh et al., 2021)
		P. umbellatum	leaves	0.16	(do Nascimento Silveira Dorneles et al., 2019)
		P. mikanianum	leaves	0.2	(Carneiro et al., 2020)
9	linalool	*P. umbellatum*	leaves	0.72	(do Nascimento Silveira Dorneles et al., 2019)
		P. umbellatum	leaves	2.2	(Carneiro et al., 2020)
		P. betle	leaves	0.34 ± 0.08	(Subaharan et al., 2021)
10	limonene	*P. xylosteoides*	leaves	11.5	(Morais-Braga et al., 2022)
		P. nigrum	fruits	25.34	(Ghosh et al., 2021)
		P. mikanianum	leaves	1.8	(Carneiro et al., 2020)
12	α-terpinene	*P. xylosteoides*	leaves	1.8	(Morais-Braga et al., 2022)
		P. nigrum	fruits	0.11	(Ghosh et al., 2021)
		P. betle	leaves	0.42 ± 0.01	(Subaharan et al., 2021)
13	β-phellandrene	*P. xylosteoides*	leaves	2.2	(Morais-Braga et al., 2022)
15	(*Z*)-β-ocimene	*P. rivinoides*	leaves	16.88	(Alves Borges Leal et al., 2019)
		P. nigrum	fruits	0.15	(Ghosh et al., 2021)
16	γ-terpinene	*P. xylosteoides*	leaves	1.5	(Morais-Braga et al., 2022)
		P. nigrum	fruits	0.18	(Ghosh et al., 2021)
		P. betle	leaves	1.08 ± 0.25	(Subaharan et al., 2021).
17	myrcene	*P. xylosteoides*	leaves	27.5	(Morais-Braga et al., 2022)
		P. nigrum	fruits	1.68	(Ghosh et al., 2021)
		P. umbellatum	leaves	10.27	(do Nascimento Silveira Dorneles et al., 2019)
		P. umbellatum	leaves	0.3	(Carneiro et al., 2020)
18	α-eudesmol	*P. regnellii*	leaves	2.14	(Braga et al., 2021)
19	β-pinene	*P. xylosteoides*	leaves	2.5	(Morais-Braga et al., 2022)
		P. nigrum	fruits	10.43	(Ghosh et al., 2021)
		P. mikanianum	leaves	0.3	(Carneiro et al., 2020)
		P. betle	leaves	0.23 ± 0.008	(Subaharan et al., 2021)
21	α-terpineol	*P. nigrum*	fruits	0.18	(Ghosh et al., 2021)
22	germacrene D	*P. regnellii*	leaves	0.80	(Braga et al., 2021)
		P. xylosteoides	leaves	2.5	(Morais-Braga et al., 2022)
		P. nigrum	fruits	0.10	(Ghosh et al., 2021)
		P. rivinoides	leaves	1.56	(Alves Borges Leal et al., 2019)
		P. mikanianum	leaves	0.9	(Carneiro et al., 2020)
23	cubenol	*P. umbellatum*	leaves	1.67	(do Nascimento Silveira Dorneles et al., 2019)
24	α-amorphene	*P. umbellatum*	leaves	0.07	(do Nascimento Silveira Dorneles et al., 2019)
25	viridiflorol	*P. nigrum*	fruits	0.23	(Ghosh et al., 2021)
26	humulene	*P. nigrum*	fruits	0.38	(Ghosh et al., 2021)
27	(*E*)-nerolidol	*P. umbellatum*	leaves	0.70	(do Nascimento Silveira Dorneles et al., 2019)
28	β-eudesmol	*P. regnellii*	leaves	2.98	(Braga et al., 2021)
		P. umbellatum	leaves	9.73	(do Nascimento

(continued on next page)

Table 3 (*continued*)

No	Compounds	Specie	Part	%	References
					Silveira Dorneles et al., 2019)
29	aromandendrene	*P. regnellii*	leaves	0.40	(Braga et al., 2021)
30	δ-cadinene	*P. umbellatum*	leaves	0.5	(Carneiro et al., 2020)
31	δ-elemene	*P. umbellatum*	leaves	0.3	(Carneiro et al., 2020)
83	α-humulene	*P. regnellii*	leaves	0.30	(Braga et al., 2021)
		P. betle	leaves	2.63 ± 0.06	(Subaharan et al., 2021)
84	eugenol	*P. betle*	leaves	5.16 ± 0.66	(Subaharan et al., 2021)
85	α-selinene	*P. betle*	leaves	5.27 ± 0.38	(Subaharan et al., 2021)
86	β-selinene	*P. betle*	leaves	5.93 ± 0.29	(Subaharan et al., 2021)
90	bicyclogermacrene	*P. regnellii*	leaves	2.27	(Braga et al., 2021)
		P. xylosteoides	leaves	2.3	(Morais-Braga et al., 2022)
		P. mikanianum	leaves	1.2	(Carneiro et al., 2020)
91	dilapiol	*P. regnellii*	leaves	15.05	(Braga et al., 2021)
92	sabinense	*P. regnellii*	leaves	1.30	(Braga et al., 2021)
		P. xylosteoides	leaves	3.7	(Morais-Braga et al., 2022)
		P. nigrum	fruits	22.86	(Ghosh et al., 2021)
		P. betle	leaves	1.04 ± 0.006	(Subaharan et al., 2021)
		P. umbellatum	leaves	0.3	(Carneiro et al., 2020)
93	terpinel-4-ol	*P. regnellii*	leaves	0.70	(Braga et al., 2021)
		P. nigrum	fruits	0.56	(Ghosh et al., 2021)
		P. betle	leaves	0.88 ± 0.22	(Subaharan et al., 2021)
94	cadalene	*P. regnellii*	leaves	0.20	(Braga et al., 2021)
95	apiol	*P. regnellii*	leaves	70.79	(Braga et al., 2021).
		P. umbellatum	leaves	0.3	(Carneiro et al., 2020)
96	*p*-cymene	*P. xylosteoides*	leaves	9.5	(Morais-Braga et al., 2022)
		P. umbellatum	leaves	0.08	(do Nascimento Silveira Dorneles et al., 2019)
		P. betle	leaves	0.51 ± 0.18	(Subaharan et al., 2021)
97	β-cymene	*P. nigrum*	fruits	0.22	(Ghosh et al., 2021)
98	α-phellaldrene	*P. nigrum*	fruits	1.12	(Ghosh et al., 2021)
		P. mikanianum	leaves	0.2	(Carneiro et al., 2020)
		P. umbellatum	leaves	0.37	(do Nascimento Silveira Dorneles et al., 2019)
99	safrole	*P. xylosteoides*	leaves	5.5	(Morais-Braga et al., 2022)
		P. mikanianum	leaves	82	(Carneiro et al., 2020)
		P. betle	leaves	44.25 ± 6.37	(Subaharan et al., 2021).
100	*E*-caryophyllene	*P. rivinoides*	leaves	4.5	(Alves Borges Leal et al., 2019)
101	germacrene B	*P. xylosteoides*	leaves	2.0	(Morais-Braga et al., 2022)
102	thujene	*P. nigrum*	fruits	2.76	(Ghosh et al., 2021)
103	δ−3-carene	*P. nigrum*	fruits	0.49	(Ghosh et al., 2021)
104	*cis*-limonene oxide	*P. nigrum*	fruits	0.12	(Ghosh et al., 2021)
105	*trans*-limonene oxide	*P. nigrum*	fruits	0.11	(Ghosh et al., 2021)
106	α-bergamotene	*P. nigrum*	fruits	0.39	(Ghosh et al., 2021)
107	β–copaene	*P. nigrum*	fruits	0.17	(Ghosh et al., 2021)
		P. umbellatum	leaves	0.19	(do Nascimento Silveira Dorneles et al., 2019)
108	zingiberene	*P. nigrum*	fruits	0.56	(Ghosh et al., 2021)
109	β-farnesene	*P. nigrum*	fruits	1.12	(Ghosh et al., 2021)
110	cubebol	*P. nigrum*	fruits	0.14	(Ghosh et al., 2021)
111	α-guainene	*P. nigrum*	fruits	0.32	(Ghosh et al., 2021)
112	bisabolene	*P. nigrum*	fruits	3.98	(Ghosh et al., 2021)
113	caryophyllene oxide	*P. nigrum*	fruits	0.14	(Ghosh et al., 2021)
114	α–cadinol	*P. nigrum*	fruits	0.15	(Ghosh et al., 2021)
115	cadinol	*P. umbellatum*	leaves	2.26	(do Nascimento Silveira Dorneles et al., 2019)
116	α- bisabolol	*P. nigrum*	fruits	0.11	(Ghosh et al., 2021)
117	tricyclene	*P. umbellatum*	leaves	0.47	(do Nascimento Silveira Dorneles et al., 2019)
118	*p*-mentha-1(7), 8-diene	*P. umbellatum*	leaves	9.16	(do Nascimento Silveira Dorneles et al., 2019)
119	sylvestrene	*P. umbellatum*	leaves	0.84	(do Nascimento Silveira Dorneles et al., 2019)
120	terpinolene	*P. umbellatum*	leaves	0.39	(do Nascimento Silveira Dorneles et al., 2019)
121	camphor	*P. umbellatum*	leaves	0.06	(do Nascimento Silveira Dorneles et al., 2019)

(*continued on next page*)

Table 3 (*continued*)

No	Compounds	Specie	Part	%	References
		P. umbellatum	leaves	0.7	(Carneiro et al., 2020)
122	piperitone	*P. umbellatum*	leaves	27.77	(do Nascimento Silveira Dorneles et al., 2019)
123	α-neoclovene	*P. umbellatum*	leaves	0.39	(do Nascimento Silveira Dorneles et al., 2019)
124	cadina-1(6),4-diene	*P. umbellatum*	leaves	0.23	(do Nascimento Silveira Dorneles et al., 2019)
125	α-macrocarpene	*P. umbellatum*	leaves	3.91	(do Nascimento Silveira Dorneles et al., 2019)
126	δ-amorphene	*P. umbellatum*	leaves	3.12	(do Nascimento Silveira Dorneles et al., 2019)
127	sesquisabinene hydrate	*P. umbellatum*	leaves	0.45	(do Nascimento Silveira Dorneles et al., 2019)
128	muurol-5-en-4-β-ol	*P. umbellatum*	leaves	0.68	(do Nascimento Silveira Dorneles et al., 2019)
129	occidentalol	*P. umbellatum*	leaves	0.77	(do Nascimento Silveira Dorneles et al., 2019)
130	dillapoiole	*P. umbellatum*	leaves	22.37	(do Nascimento Silveira Dorneles et al., 2019)
131	eremoligenol	*P. umbellatum*	leaves	1.46	(do Nascimento Silveira Dorneles et al., 2019)
132	β-macrocarpene	*P. rivinoides*	leaves	2.66	(Alves Borges Leal et al., 2019)
133	α-murolene	*P. rivinoides*	leaves	12.45	(Alves Borges Leal et al., 2019)
134	(*Z*)-carpacin	*P. rivinoides*	leaves	8.13	(Alves Borges Leal et al., 2019)
135	(*E*)-isoelemicin	*P. rivinoides*	leaves	40.81	(Alves Borges Leal et al., 2019)
136	valencene	*P. umbellatum*	leaves	0.7	(Carneiro et al., 2020)
137	terpinolene	*P. betle*	leaves	0.64 ± 0.39	(Subaharan et al., 2021)
138	methyl eugenol	*P. betle*	leaves	1.01 ± 0.08	(Subaharan et al., 2021)
139	β-bourbonene	*P. betle*	leaves	2.66 ± 0.045	(Subaharan et al., 2021)
140	α-guaiene	*P. betle*	leaves	0.47 ± 0.003	(Subaharan et al., 2021)
141	eugenol acetate	*P. betle*	leaves	9.77 ± 4.61	(Subaharan et al., 2021)
142	α-cadinene	*P. betle*	leaves	2.14 ± 0.24	(Subaharan et al., 2021)

shrub or tree native to India, Pakistan, Sri Lanka, Bangladesh and Andaman Islands. Widely cultivated in Southeast Asia as well as in some parts of the United States and Australia. This species is often used in traditional medicine and as a food condiment due to its characteristic flavor. The analysis of the essential oil obtained from curry leaves revealed 43 compounds, with 3-carene (18.52 %) and β-pinene (13.57 %) as the predominant ones (Tripathi et al., 2018).

M. microphylla (Merr. & Chun) Swingle is a bush mainly found in northeastern Australia and in tropical and subtropical regions of Asia. This species is similar to *M. koenigii* (L.) Spreng. Upon analyzing the essential oil of the leaves by GC–MS, 30 compounds were identified, the main ones being: caryophyllene (20.36 %), α-terpineol (11.60 %), β-terpinene (8.74 %), β-phellandrene (7.24 %), (+) −2-carene (6.95 %), γ-elemene (6.03 %) and humulene (5.60 %) (Xia et al., 2020).

After several reports and documents, it has been proven that the essential oils of *Murraya* spp. have cytotoxic, antitrypanosomal, anti-cancer, antidiabetic, antidermatophyte, antioxidant, hepatoprotective, antimicrobial, and antihypertensive properties (Arun et al., 2017; Gautam et al., 2012; LIANG et al., 2021; Salwe et al., 2017; Samanta et al., 2018; You et al., 2014).

7. Essential oils of *ocimum* spp. (Lamiaceae)

The Lamiaceae family contains about 200 genera and over 6900 diverse species, with the genus *Ocimum* being one of them. This genus has been noteworthy for its medicinal and cosmetic properties present in various regions around the globe, in addition to being a rich source of essential oil (Lal et al., 2021). Due to its aromatic characteristic, *Ocimum* leaves are widely used as food and flavoring. (Srivastava et al., 2021). Table 2 compiled the main chemical compounds contained in the essential oils of the analyzed species.

Known as white pepper, bush basil or clove-scented basil, *O. gratissimum* L. is a strongly aromatic edible herb found in Africa, Asia and South America (Tanko 2012). Essential oils extracted from *O. gratissimum* leaves containing 10 chemical compounds were obtained. Of these, eugenol was the majority (63.25 %), followed by cineole (10.83 %), β-selinene (8.43 %) and trans-caryophyllene (6.85 %) among others represented in Table 2 (Cesar et al., 2022).

The *Ocimum viride*, commonly known as basil, is grown on a large scale in South Africa and produces a fragrant essential oil. (Isu, 2006). Investigations have discovered that the species *O. viride* has promising results as an anticancer agent (Bhagat et al., 2020), your essential oils contain invaluable medicinal properties, such as antimalarial, cytotoxic and repellent. Scientific studies have revealed that the natural chemical compounds present in these essential oils have antibacterial, anti-inflammatory, antifungal, antimicrobial and antioxidant activities (Ahmed et al., 2019; Ali et al., 2018; Melo et al., 2019; Saleem et al., 2017). The essential oil from the aerial parts of *O. viride* contains as main constituents: eugenol (77.86 %), (Z)-β-ocimene (9.13 %), germacrene D (6.58 %) and β-caryophyllene (1.87 %) (Raina & Gupta, 2018).

8. Essential oils of *Piper* spp. (Piperaceae)

The Piperaceae family comprises approximately 3600 species,

Table 4
Patents of the food flavoring.

Patent title	Application	Patent number	Country	Reference
I.1- Chili oil and preparation method thereof	The invention belongs to the field of flavoring foods, in particular relates to a pepper oil and a method of preparation of it. Pepper oil uses: vegetable oil, chili powder, Chinese red pepper, anise, pepper, bandits, *Murraya paniculata* (L.) Jack and others. Its application has effect on health care and has the advantages of delicious taste and be convenient in use.	CN101352227A	China	(Li Xinshe, 2008)
I.2- Flavoring for cooking lobster	The invention reveals a flavoring for cooking lobster. The flavoring is prepared by the following raw materials by parts: parts of angelica dahuriana root, parts of *Murraya paniculata* (L.) Jack. and others	CN103099169A	China	(Sand in the forest, 2011)
I.3- Butter hotpot condiment formula	The invention reveals a butter hotpot condiment formula. Constituents: bay leaves, *M. paniculata* (L.) Jack., sweet herbs and vanilla are taken as flavoring substances and others. A butter hotpot condiment adopting the formula has an intense and thick taste, and is suitable for wet and cold regions or winter, and customers' requirements on hotpot flavors can be met.	CN105011085A	China	(Zhang Xiaobo, 2011)
I.4- Tasty and tasty fragrant tea for health and its method of preparation	The invention reveals a tasty fragrant tea and a method of preparation. Fragrant tea comprises the following raw materials: black tea base, white orchid, hollyhockflower flower, *M. jasminorage,* a flavoring agent, carbohydrates and others. The invention provides fragrant tea with heavy flavor and tasty sensation in the mouth, has abundant nutrition, can effectively improve the physique of human body and has a good health care effect.	CN108029808A	China	(Yin Jiaxuan, 2017)
I.5- Simple condiment liquid	The invention reveals a simple tempering solution. The solution is prepared from parts of *M. paniculata* and others. The simple seasoning solution has the advantages of being good at dispersing performance, high in flavoring speed, convenient to use and unique in flavor.	CN106213427A	China	(Liang Jian, 2016)
II.1- Aromatic flavouring seasoning poder	The present invention reveals an aromatic flavoring seasoning powder that is composed of the following components: parts of *O. basilicum* and others. The aromatic seasoning powder flavoring has a wide source of raw materials, and a simple production equipment and technology, and is suitable for medium and small businesses and family businesses	CN104738509A	China	(Hao Yongming, 2013)
III.1- A kind of spicy spareribs with chili face seasoning packet and preparation method thereof	The invention reveals a kind of spicy spareribs with pepper face seasoning packets and method of preparation of them, belong to the field of flavor of food. The sauce comprises the following materials: a sparerib soup and others, the auxiliary material comprises: *Cinnamomum tamala* powder, *Piper nigrum* L. powder and others, the original taste of food materials are completely retained, and the product is delicious, and has functions of promoting appetite and strengthening the stomach.	CN109380676A	China	(Xu Chaoqun, 2017)
III.2- Flavor and fragrance modifier for perfume and modifying method	The present invention refers to a modifier agent and a modifier method to modify the aroma and flavor of a fragrance itself. Provide a modifier for use, in addition to a perfume that provides an improvement in flavor and fragrance characteristics, by a method comprising the submission of piper betle line leaf optionally crushing to extraction with an alcohol that does not contain water.	JPH1077495A	Japan	(Joji Yamahara, Taro Aoki, Kazuyuki Miyake, 1996)
IV.1- A method of preparing ethno-herbal farm produce sanitizer	The present invention is a method of preparing antiseptic herbal sanitizer developed by the combination of different plant extracts like *O. sanctum, Indigofera tinctora, Terminalia chebula, Andrographis paniculata, Curcurma longa, Azaridachta Indica, Aloe vera, M. koeniga*. The invention showed promising significant antimicrobial and antioxidant activity.	AU2021103471A4	Australia	(Pravda Chidambaranath, Joseph, Wilson & Santhoshkumar, 2021)
V.1- Fragrant formulations, methods of manufacture thereof and articles comprising the same	This disclosure refers to perfume and flavouring formulations (called perfume formulations). More specifically, the present invention is directed to antimicrobial formulations derived from extracts of *Ocimum* sp., which employ alquylic esters such as solvents, co-solvents or fasteners.	US9301910B2	United States	(Dorie J. Yontz., 2016)
VI.1- Natural preservatives, antimicrobial agents, and compositions thereof	The present invention refers to compositions and related methods that can act as preservatives, antimicrobialagents or combinations thereof. Using derivatives of *Albizia amara* extracts, *Magnolia officinalis* and *Piper* sp, which can be used for food preservatives, cosmetics, dietary supplements, oral hygiene products and pharmaceuticals.	JP6903656B2	Japan	(Zhao, Pingjia, Chiihong, Mei Fengkim, 2016)
VI.2- Dietary nutritional supplements for healthcare	The present invention refers specifically to nutritional dietary formulations of fermented soy products in combination with selected herbs and spices. Although spices are generally added to foods to improve taste, in addition to	US8227013B2	United States	(Nair, 2012)

(continued on next page)

Table 4 (*continued*)

Patent title	Application	Patent number	Country	Reference
	adding to the flavor, they have a variety of functions that include providing antimicrobial activity, antioxidant functions and a wide range of medicinal benefits. Related to the generos *Murraya* sp., *Ocimum* sp and *Piper* sp.			
VII.1- A composition of encapsuled feed additives for animal	The present invention comprises a metallic salt of encapsulated butyric acid, the production of hydrochloric acid in the stomach is reduced, a metabolic function by the action of butyric acid is improved and antibacterial activity by the expression of antibacterial and antioxidant functions, improvement of intestinal environments, palatability and immunity are enhanced, thus increasing livestock productivity, like pigs, cows, chickens and the like. Related to the generos *Murraya* sp., *Ocimum* sp. and *Piper* sp.	KR101950919B1	South Korea	(Neuron Sub, 2019)
VII.2- A nutraceuticals formulation with an enhanced organoleptic properties used for skin care	The present invention relates to a nutraceuticals formulation, which could be used for wholistic skin care and treatment purposes, with an enhanced organoleptic properties. Said formulation have elements of biological origin more particularly a herbal formulation(s). Related to the generos *Murraya* sp., *Ocimum* sp. and *Piper* sp.	WO2022153337A1	WIPO (PCT)	(Vr. Ramanathan, Siva Vallabhaneni, 2022)
VII.3- Process for stabilizing and aromating unsaturated substances and oils containing unsaturated and polyunsaturated fatty acids	Process for the stabilization and aromatization of unsaturated and polyunsaturated oils for aromatic and food use. The invention makes use of the properties of fish oils, in particular for the simultaneous extraction of natural flavoring and antioxidant substances, with a view to improve their conservation and acceptability.It also allows access to original aromatic compositions in smell, taste and flavor. Related to the generos *Ocimum* sp. and *Piper* sp.	FR2915350A1	France	(Letavernier, Jean Francois, 2007)
VII.4- A composition of feed additives for cattle	The present invention contains a *Pimpinella anisum* extract and a fenugreek extract, which are plant extracts, to control microbial fermentation in a digestive organ of cattle, thereby increasing digestion of nutrients and metabolic efficiency, increasing the amount of feed intake by improving palatability, and improving quality of cattle and a milk yield by reinforcing immunity and an antioxidant effect. Related to the generos *Murraya* sp., *Ocimum* sp. and *Piper* sp.	KR101940544B1	South Korea	(Neuron Sub, 2018a)
VII.5- A composition of feed additives for pig and poultry	The present invention refers to a composition of food additives for animals, and more particularly, to a composition of animal feed composed of anise extract and fenugreek extract, improving feed intake, increasing palatability, immunity and antioxidant activity, the effects are enhanced to improve the productivity of livestock, pigs and poultry, which can increase egg productivity. Related to the generos *Murraya* sp., *Ocimum* sp. and *Piper* sp.	KR101940539B1	South Korea	(Neuron Sub, 2018b)

ranging from herbs, shrubs and trees (Smith et al., 2008). The *Piper* genus is the largest of its family and is found mainly in tropical and subtropical regions of the globe (Da Silva et al., 2016). The genus *Piper* is the most numerous, with approximately 2000 species (Ki & July 2004). Table 3 compiled the main chemical compounds contained in the essential oils of the analyzed species.

Pariparoba (*P. regnellii* (Miq.) C. DC.), is a shrub used in traditional medicine for the treatment of skin lesions. Studies have also shown its pharmacological efficacy against pathogens (Salehi et al., 2019). The CG-EM analysis of the essential oils from *P. regnellii* (Miq.) leaves revealed that the main compounds present were apiol (70.79 %), dilapiol (15.05 %), β-eudesmol (2.98 %), bicyclogermacrene (2.27 %), α-eudesmol (2.14 %) and γ-gurjunene (1.25 %) (Table 4) (Braga et al., 2021).

P. umbellatum L., is a native American plant that is widely used in traditional medicine of many countries. It is known by many names in Brazil, such as pariparoba, caapeba, caapeba-do-nordeste, guaxima, caafeba, caa-pena, caá-peuá, caena, capeba, catajé, jaguarandi, malvarisco, oguaxima. This species has pharmacological characteristics, including antibacterial, antifungal, antioxidant, antimalarial, anti-inflammatory, analgesic and antithermogenic properties (Roersch, 2010). The analysis of *P. umbellatum* was performed using GC–MS, resulting in the identification of 28 substances, with the main ones being piperitone (27.77 %), dillapiole (22.37 %) and myrcene (10.27 %) (do Nascimento Silveira Dorneles et al., 2019).

P. xylosteoides (Kunth) Steud, native from Brazil, is found in the Amazon, Cerrado and Atlantic Forest. (Guimarães et al., 2020). This species is also known as *P. pabstii* C. DC and *P. xylostioides* Kunth. (Sanquetta et al., 2010). The essential oil extracted from the dried leaves of *P. xylosteoides* was identified by GC–MS as the major compounds: myrcene (27.5 %), limonene (11.5 %), β-caryophyllene (10.5 %), *p*-cymene (9.5 %) and safrole (5.5 %) (Morais-Braga et al., 2022).

Black pepper *(P. nigrum)*, which belongs to the pepper family, is a spice widely used in the Southeast Asian region, but is also very well known in Brazil (Zhang et al. 2021). GC–MS analyses of the constituents present in the essential oil of *P. nigrum* resulted in 33 compounds, with the most abundant ones being limonene (25.34 %), sabinene (22.86 %) and β-pinene (10.43 %) (Ghosh et al., 2021).

According to data from the Rio de Janeiro Botanical Garden, the species *P. rivinoides* Kunth, also known as "aperta-ruão", "murta", "ruão" or "white betis", is native to Brazil. Through the analysis of the compounds by GC–MS of the essential oil of the dried leaves, 7 compounds were identified, among the main ones are E-isoelemicin (40.81 %) and δ−3-carene (16.88 %) (Alves Borges Leal et al., 2019).

GC–MS analysis was used to identify the chemical components of essential oils from the leaves of *P. mikanianum*, commonly known as jaguarandi. The main compounds found were: linalool (2.2 %), limonene (1.8 %), β-caryophyllene (1.7 %), α-pinene (1.4 %), bicyclogermacrene (1.2 %), and Z-nerolidol (1.3 %)(Carneiro et al., 2020).

P. betle L. leaves, known as betel leaves and recognized for their medicinal benefits in Asia, have a strong aroma (Karak et al., 2016). GC–MS analysis of the *P. betle* leaves revealed that the essential oil was

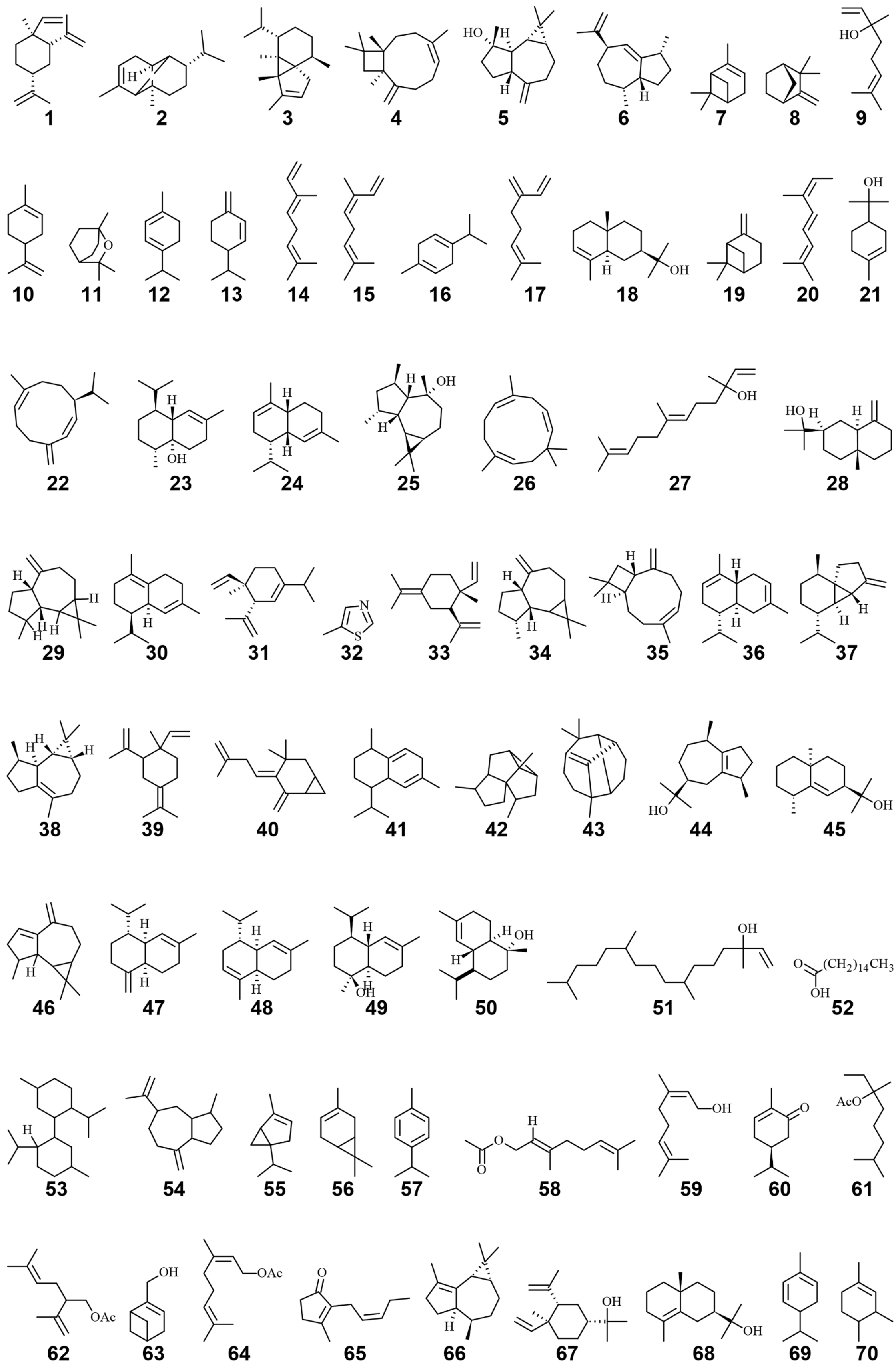

Fig. 2. Chemical structures corresponding to the compounds listed in the tables.

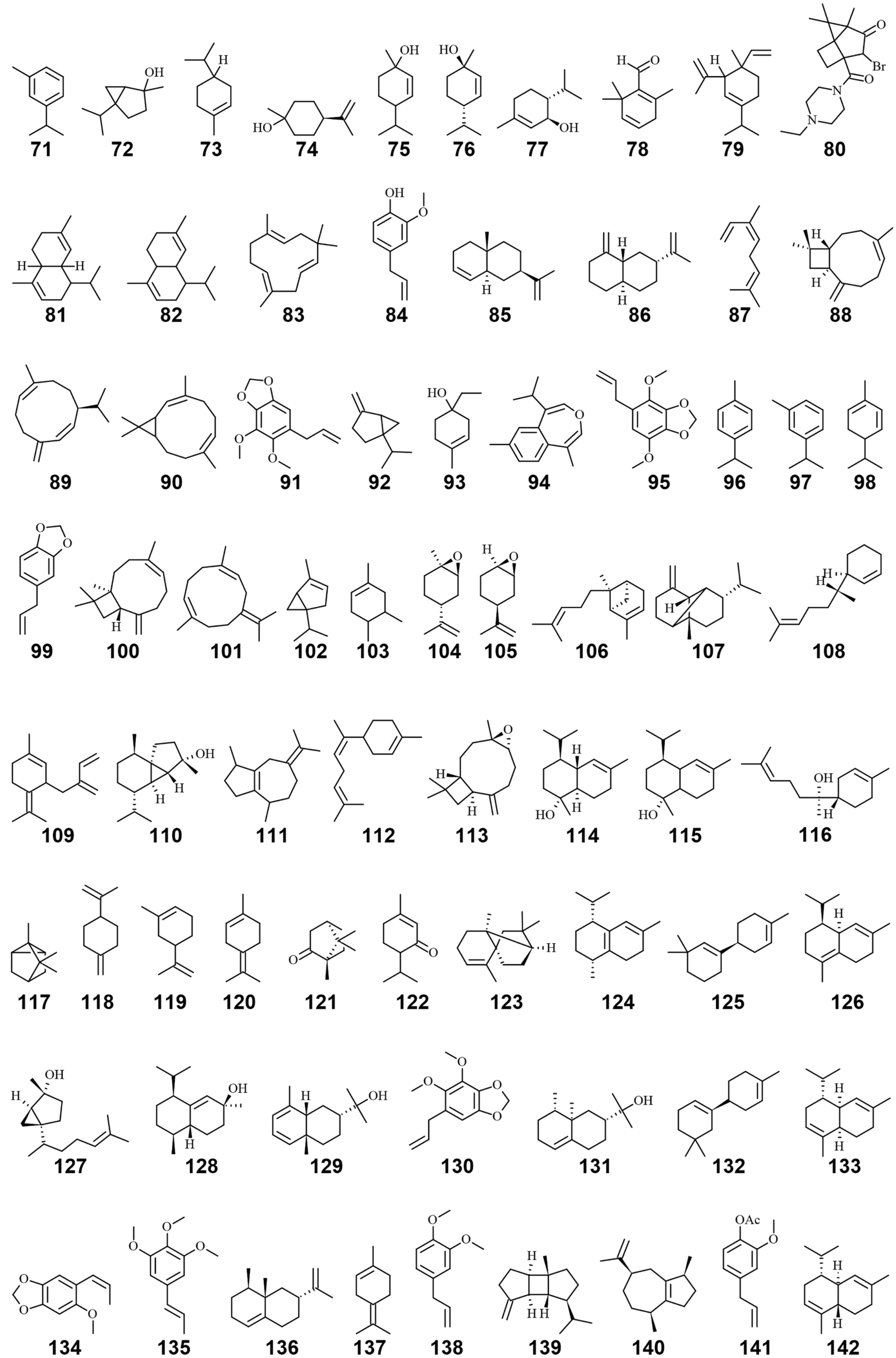

Fig. 2. (*continued*).

mainly composed of safrole (44.25 %), eugenol acetate (9.77 %), eugenol (5.16 %), β-caryophyllene (5.98 %), β-selinene (5.93 %) and α-selinene (5.27 %) (Subaharan et al., 2021).

Piper spp. essential oils demonstrate wide pharmacological properties as well as biological activities such as antioxidant, anti-inflammatory, antibacterial, antinociceptive and cytotoxicity capacities (J. K. da Silva et al., 2017; de Souza et al., 2020; Oyemitan et al., 2015; Rodrigues de Oliveira et al., 2021) Fig. 2.

9. Patents of the food flavoring

The importance of applying patented products and processes ensures and encourages inventors and institutions to develop research aimed at topics of relevant interest to science and human societies. Adding value to innovative products and processes, as well as promoting social and economic human development.

The epistemological profile of the research was divided into VII groups and two categories, properties and genus of the studied plants. A total of 294,039 results were obtained and 50 patents were randomly selected per group from I to VI, and in group VII the maximum number of patents were 29, totaling 329 patents analyzed. Of which, the patents of interest to the study were separated: 5 patents in group I, 1 patent in II, 2 patents in III, 1 patent in IV, 1 patent in V, 2 in vi and 5 patents in VII, totaling 17 important patents, both for verification of applications, as the interest of the specific market.

I Food flavoring AND *Murraya* - 24,734 results, 50 random / 5 interest for the study;
II Food flavoring AND *Ocimum* - 50,173 results, 50 random / 1 interest for the study;
III Food flavoring AND *Piper* −100,000 results, 50 random / 2 interest for the study;
IV Food antimicrobial AND *Murraya* - 48,152 results, 50 random / 1 interest for the study;
V Food antimicrobial AND *Ocimum* - 38,296 results, 50 random /1 interest for the study;
VI Food antimicrobial AND *Piper* - 32,655 results, 50 random / 2 interest for the study;
VII Antioxidant for food conservation AND *Murraya*, Antioxidant for food conservation AND *Ocimum*, Antioxidant for food conservation AND *Piper* - 29 results, 29 random / 5 interest for the study.

Of the countries that patented were: China with 7 deposits 41.17 %, South Korea with 3 deposits 17.64 %, United States 11.76 % and Japan 11.76 % with 2 deposits each, (WIPO (PCT) 5.88 %, Australia 5.88 % and France 5.88 %) with 1 deposit each.

The applications in patents evaluated as: preservatives 17.64 % and flavorings 52.94 % of foods, and antimicrobial properties 35.29 % and antioxidant 35.29 %, being possible more than one application and properties per patent, so the percentages are related to the 17 patents selected in the scope of the research.

10. Conclusions and new perspectives

The essential oils of the plants highlighted in this review are ideal for use as natural preservatives in the food industry, as they have proven antimicrobial activities. Studies show that the oils are rich in compounds such as linalool, limonene, geranyl acetate, linalyl acetate, and eugenol, which are recognized as safe by Section 409 of the US FDA Act. Based on these facts, we highlight their potential for use as a substitute for synthetic preservatives. We therefore promote here new research and experiments to investigate the characteristics of these oils as well as the toxicity for use as flavoring agents. This promising, approach to health protection with various possibilities for future research, particularly in vivo biological studies.

CRediT authorship contribution statement

Débora Nogueira Cavalcante: Conceptualization, Writing – review & editing. **Renilto Frota Corrêa:** Writing – review & editing. **Pedro Henrique Campelo:** Writing – review & editing. **Edgar Aparecido Sanches:** Writing – review & editing. **Jaqueline de Araújo Bezerra:** Conceptualization, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgments

The authors wish to acknowledge to FAPEAM for financial support and fellowships Fundação de Amparo à Pesquisa do Estado do Amazonas (PAIC IFAM CMC 2021-2022, PAIC/FAPEAM 2022-2023, Edital n. 013/2022–Produtividade-CT&I) and Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq (Process number 311522/2020-3) and Analytical Center at IFAM-CMC for infrastructure.

References

Agência Nacional de Vigilância Sanitária - ANVISA (2007). Resolução de diretoria colegiada - RDC n° 05 de 15 de Janeiro de 2007. Diário Oficial Da União - DOU, 1–11.

Ahmed, B., Solanki, B., Zaidi, A., Khan, M. S., & Musarrat, J. (2019). Bacterial toxicity of biomimetic green zinc oxide nanoantibiotic: Insights into ZnONP uptake and nanocolloid-bacteria interface. *Toxicology Research, 8*(2), 246–261. https://doi.org/10.1039/C8TX00267C

Ali, K., Ahmed, B., Khan, M. S., & Musarrat, J. (2018). Differential surface contact killing of pristine and low EPS Pseudomonas aeruginosa with Aloe vera capped hematite (α-Fe_2O_3) nanoparticles. *Journal of Photochemistry and Photobiology B: Biology, 188* (September), 146–158. https://doi.org/10.1016/j.jphotobiol.2018.09.017

Álvarez, A., García García, B., Jordán, M. J., Martínez-Conesa, C., & Hernández, M. D. (2012). The effect of diets supplemented with thyme essential oils and rosemary extract on the deterioration of farmed gilthead seabream (Sparus aurata) during storage on ice. *Food Chemistry, 132*(3), 1395–1405. https://doi.org/10.1016/j.foodchem.2011.11.127

Alves Borges Leal, A. L., Machado, A. J. T., Bezerra, C. F., Serra Inácio, C. E., Rocha, J. E., Sales, D. L., de Freitas, T. S., de Oliveira Almeida, W., Amaral, W.do, Everson da Silva, L., Ferriani, A. P., de Noronha Sales Maia, B. H. L., Bezerra Morais-Braga, M. F., Barreto, H. M., & Coutinho, H. D. M (2019). Chemical identification and antimicrobial potential of essential oil of Piper rivinoides kunth (BETIS-WHITE). *Food and Chemical Toxicology, 131*(February), Article 110559. https://doi.org/10.1016/j.fct.2019.06.006

Arun, A., Patel, O. P. S., Saini, D., Yadav, P. P., & Konwar, R. (2017). Anti-colon cancer activity of Murraya koenigii leaves is due to constituent murrayazoline and O-methylmurrayamine A induced mTOR/AKT downregulation and mitochondrial apoptosis. *Biomedicine and Pharmacotherapy, 93*, 510–521. https://doi.org/10.1016/j.biopha.2017.06.065

Arya, N., Kaur, J., Verma, A., & Dhanik, J. (2017). Chemical composition of leaf essential oil of wild and domestic genotypes of Murraya paniculata L. *Journal of Essential Oil Bearing Plants, 5026*(May). https://doi.org/10.1080/0972060X.2017.1312552

Ballester-Costa, C., Sendra, E., Fernández-López, J., Pérez-álvarez, J. A., & Viuda-Martos, M (2017). Assessment of antioxidant and antibacterial properties on meat homogenates of essential oils obtained from four thymus species achieved from organic growth. *Foods, 6*(8), 1–11. https://doi.org/10.3390/foods6080059

Ballester-Costa, C., Sendra, E., Fernández-López, J., Pérez-Álvarez, J. A., & Viuda-Martos, M. (2013). Chemical composition and in vitro antibacterial properties of essential oils of four Thymus species from organic growth. *Industrial Crops and Products, 50*, 304–311. https://doi.org/10.1016/j.indcrop.2013.07.052

Ballester-Costa, C., Sendra, E., Fernández-López, J., & Viuda-Martos, M. (2016). Evaluation of the antibacterial and antioxidant activities of chitosan edible films incorporated with organic essential oils obtained from four Thymus species. *Journal of Food Science and Technology, 53*(8), 3374–3379. https://doi.org/10.1007/s13197-016-2312-y

Bhagat, M., Sangral, M., Kumar, A., Rather, A., & Arya, K. (2020). *Heliyon Chemical, biological and in silico assessment of Ocimum viride essential oil.* 6(December 2019), 0–6. doi:10.1016/j.heliyon.2020.e04209.

Bora, H., Kamle, M., Mahato, D. K., & Tiwari, P. (2020). *Citrus essential oils (CEOs) and their applications in food : An overview* (pp. 1–25).

Bouyahya, A., Dakka, N., Talbaoui, A., Et-Touys, A., El-Boury, H., Abrini, J., & Bakri, Y. (2017). Correlation between phenological changes, chemical composition and biological activities of the essential oil from Moroccan endemic Oregano (Origanum compactum Benth). *Industrial Crops and Products, 108*(May), 729–737. https://doi.org/10.1016/j.indcrop.2017.07.033

Braga, A. L., da Cruz, R. P., Carneiro, J. N. P., dos Santos, A. T. L., Sales, D. L., Bezerra, C. F., Fonseca, V. J. A., Rocha, J. E., de Freitas, T. S., Campina, F. F., Costa, M.doS., Amaral, W.do, Rebelo, R. A., da Silva, L. E., Ribeiro-Filho, J., Coutinho, H. D. M., Rodrigues, F. F. G., & Morais-Braga, M. F. B (2021). Piper regnellii (Miq.) C. DC.: Chemical composition, antimicrobial effects, and modulation of antimicrobial resistance. *South African Journal of Botany, 142*, 495–501. https://doi.org/10.1016/j.sajb.2021.07.017

Carneiro, J. N. P., da Cruz, R. P., Campina, F. F., Costa, M.doS., dos Santos, A. T. L., Sales, D. L., Bezerra, C. F., da Silva, L. E., de Araujo, J. P., do Amaral, W., Rebelo, R. A., Begnini, I. M., de Lima, L. F., Melo Coutinho, H. D., & Bezerra Morais-Braga, M. F. (2020). GC/MS analysis and antimicrobial activity of the Piper mikanianum (Kunth) Steud. essential oil. *Food and Chemical Toxicology, 135*(October 2019), Article 110987. https://doi.org/10.1016/j.fct.2019.110987

Cesar, J., Luiz, R., Pereira, S., Sampaio, T., Freitas, D., Esmeraldo, J., Silva, N., Fatima, C. De, Nonato, A., Leite, M., Sampaio, D., Tavares, A., Assis, F., Douglas, H., Coutinho, M., Gonçalo, S., Lima, D., Pereira-junior, F.N., Paulo, F., … Neto, P. (2022). *Evaluation of antibacterial and toxicological activities of essential oil of Ocimum gratissimum L . and its major constituent eugenol*. Food Bioscience 50(October). doi:10.1016/j.fbio.2022.102128.

da Silva, J. K., da Trindade, R., Alves, N. S., Figueiredo, P. L., Maia, J. G. S., & Setzer, W. N. (2017). Essential Oils from Neotropical Piper Species and Their Biological Activities. *International Journal of Molecular Sciences, 18*(12). https://doi.org/10.3390/IJMS18122571

Da Silva, J. K. R., Pinto, L. C., Burbano, R. M. R., Montenegro, R. C., Andrade, E. H. A., & Maia, J. G. S (2016). Composition and cytotoxic and antioxidant activities of the oil of Piper aequale Vahl. *Lipids in Health and Disease, 15*(1), 1–6. https://doi.org/10.1186/s12944-016-0347-8

de Souza, M. T., de Souza, M. T., Bernardi, D., Krinski, D., de Melo, D. J., da Costa Oliveira, D., Rakes, M., Zarbin, P. H. G., de Noronha Sales Maia, B. H. L., & Zawadneak, M. A. C (2020). Chemical composition of essential oils of selected species of Piper and their insecticidal activity against Drosophila suzukii and Trichopria anastrephae. *Environmental Science and Pollution Research, 27*(12), 13056–13065. https://doi.org/10.1007/s11356-020-07871-9

do Nascimento Silveira Dorneles, L., Luís Duarte Goneli, A., Andrea Lima Cardoso, C., Bezerra da Silva, C., Rosemari Hauth, M., Cardoso Oba, G., & Schoeninger, V (2019). Effect of air temperature and velocity on drying kinetics and essential oil composition of Piper umbellatum L. leaves. *Industrial Crops and Products, 142*(July), Article 111846. https://doi.org/10.1016/j.indcrop.2019.111846

DorieJ. Yontz. (2016). *Fragrant formulations, methods of manufacture thereof and articles comprising the same* (Patent No. US9301910B2).

Faleiro, M. L. (2020). *The mode of antibacterial action of essential oils The mode of antibacterial action of essential oils. January 2011*.

Falleh, H., Ben Jemaa, M., Djebali, K., Abid, S., Saada, M., & Ksouri, R. (2019). Application of the mixture design for optimum antimicrobial activity: Combined treatment of Syzygium aromaticum, Cinnamomum zeylanicum, Myrtus communis, and Lavandula stoechas essential oils against Escherichia coli. *Journal of Food Processing and Preservation, 43*(12), 1–11. https://doi.org/10.1111/jfpp.14257

FDA | U.S. Food & Drug Administration. (n.d.). *FDA | U.S. Food & Drug Administration.* https://www.fda.gov/.

Gautam, M. K., Gangwar, M., Nath, G., Rao, C. V, & Goel, R. K. (2012). In-vitro antibacterial activity on human pathogens and total phenolic, flavonoid contents of Murraya paniculata Linn . leaves. *Asian Pacific Journal of Tropical Biomedicine, 2*(3), S1660–S1663. https://doi.org/10.1016/S2221-1691(12)60472-9

Ghabraie, M., Vu, K. D., Tata, L., Salmieri, S., & Lacroix, M. (2016). Antimicrobial effect of essential oils in combinations against five bacteria and their effect on sensorial quality of ground meat. *Lwt, 66*, 332–339. https://doi.org/10.1016/j.lwt.2015.10.055

Ghosh, S., Kumar, A., Sachan, N., & Chandra, P. (2021). Anxiolytic and antidepressant-like effects of essential oil from the fruits of Piper nigrum Linn. (Black pepper) in mice: Involvement of serotonergic but not GABAergic transmission system. *Heliyon, 7*(4), e06884. https://doi.org/10.1016/j.heliyon.2021.e06884

Guenther, E. (1948). *The essential oils: History, origin in plants, production, analysis - Volume one*.

Guimarães, E. F., Medeiros, E. V. S. S., & Queiroz, G. A. (2020). *Piper in Flora do Brasil 2020*. Jardim Botânico do Rio de Janeiro.

Hallagan, J. B., & Hall, R. L. (1995). *FEMA GRAS - A gras assessment program for flavor ingredients. pdf*.

Hallagan, J. B., Hall, R. L., & Drake, J. (2020). The GRAS provision - The FEMA GRAS program and the safety and regulation of fl avors in the United States. *Food and Chemical Toxicology, 138*, Article 111236. https://doi.org/10.1016/j.fct.2020.111236. March.

Hao Yongming. (2013). *Aromatic flavouring seasoning powder* (Patent No. CN104738509A).

Isu. (2006). Antibacterial effect of Aframomum meleguata, Xylopia aethiopicum and Ocimum viride. *Nigerian Journal of Natural Products and Medicine*.

Jack, L. (2011). *Acercamiento al género Murraya (Rutaceae) y a la especie Murraya paniculata Acercamiento al género Murraya (Rutaceae) y a la especie Murraya paniculata. L .) Jack . December*.

Jafarizadeh-malmiri, H., Anarjan, N., & Berenjian, A. (2022). Developing three-component ginger-cinnamon-cardamom composite essential oil nanoemulsion as natural food preservatives. *Environmental Research, 204*(PB), Article 112133. https://doi.org/10.1016/j.envres.2021.112133

Joji Yamahara, Taro Aoki, Kazuyuki Miyake, H. S. (1996). *Flavor and fragrance modifier for perfume and modifying method* (Patent No. JPH1077495A).

Karak, S., Bhattacharya, P., Nandy, A., Saha, A., & De, B. (2016). Metabolite profiling and chemometric study for varietal difference in piper betle L. leaf. *Current Metabolomics, 4*(2), 129–140. https://doi.org/10.2174/2213235X04666160216224035

Ki, I. K. J., & July, F. Q. F. (2004). Piper: A model genus for studies of phytochemistry, ecology, and evolution. *Piper: A Model Genus for Studies of Phytochemistry*. Ecology, and Evolution. https://doi.org/10.1007/978-0-387-30599-8

Kibar, B., & Temel, S. (2016). Evaluation of mineral composition of some wild edible plants growing in the Eastern anatolia region grasslands of Turkey and consumed as vegetable. *Journal of Food Processing and Preservation, 40*(1), 56–66. https://doi.org/10.1111/jfpp.12583

Kinupp, V. F., & Lorenzi, H. (2014). *Plantas alimentícias não convencionais (PANC) no Brasil: Guia de identificação, aspectos nutricionais e receitas. Instituto Plantarum de estudos da Flora*. São Paulo.

Lal, R. K., Gupta, P., Srivastva, S., Chanotiya, C. S., Mishra, A., Yadav, A., & Maurya, R. (2021). South African Journal of Botany Delineating photosynthesis, essential oil yield performance, and their component traits under genotype £ traits £ environments interactions in Ocimum genotypes. *South African Journal of Botany, 141*, 54–65. https://doi.org/10.1016/j.sajb.2021.03.039

Leal, M. L., Alves, R. P., & Hanazaki, N. (2018). Knowledge, use, and disuse of unconventional food plants. *Journal of Ethnobiology and Ethnomedicine, 14*(1), 1–9. https://doi.org/10.1186/s13002-018-0209-8

Letavernier, Jean Francois, J.M. 2007. (2007). *Process for stabilizing and aromating unsaturated substances and oils containing unsaturated and polyunsaturated fatty acids* (Patent No. FR2915350A1).

Li Xinshe. (2008). *Chili oil and preparation method thereof* (Patent No. CN101352227A).

Liang, H. Z., Du, Z. Y., Yuan, S., Lu, M. Q., Xing, J. Y., Ma, Q., Han, Z. Z., Tu, P. F., & Jiang, Y. (2021). Comparison of Murraya exotica and Murraya paniculata by fingerprint analysis coupled with chemometrics and network pharmacology methods. *Chinese Journal of Natural Medicines, 19*(9), 713–720. https://doi.org/10.1016/S1875-5364(21)60087-0

Liang Jian. (2016). *Simple condiment liquid* (Patent No. CN106213427A).

Mahanta, B. P., Bora, P. K., Kemprai, P., Borah, G., Lal, M., & Haldar, S. (2021). Thermolabile essential oils, aromas and flavours : Degradation pathways, effect of thermal processing and alteration of sensory quality. *Food Research International, 145* (May), Article 110404. https://doi.org/10.1016/j.foodres.2021.110404

Melo, R. S., Azevedo, Á. M. A., Pereira, A. M. G., Rocha, R. R., Cavalcante, R. M. B., Matos, M. N. C., Lopes, P. H. R., Gomes, G. A., Rodrigues, T. H. S., Dos Santos, H. S., Ponte, I. L., Costa, R. A., Brito, G. S., Catunda, 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). https://doi.org/10.3390/molecules24213864

Morais-Braga, M. F. B., Leal, A. L. A. B., de Oliveira, A. H., Carneiro, J. N. P., Lucas dos Santos, A. T., Sales, D. L., Fonseca, V. J. A., Rocha, J. E., de Freitas, T. S., Campina, F. F., do, Socorro, Costa, M., Pereira-Junior, F. N., do Amaral, W., Rebelo, R. A., da Silva, L. E., Ribeiro-Filho, J., & Coutinho, H. D. M. (2022). Chemical characterization and antimicrobial potential of the essential oil obtained from the leaves of Piper xylosteoides (Kunth) Steud. *South African Journal of Botany, 000*, 1–9. https://doi.org/10.1016/j.sajb.2022.03.017

Nair, V. (2012). *Dietary nutritional supplements for healthcare* (Patent No. US8227013B2).

Neuron Sub. (2018a). *A composition of feed additives for cattle* (Patent No. KR101940544B1).

Neuron Sub. (2018b). *A composition of feed additives for pig and poultry* (Patent No. KR101940539B1).

Neuron Sub. (2019). *A composition of encapsuled feed additives for animal* (Patent No. KR101950919B1).

Oyemitan, I. A., Olayera, O. A., Alabi, A., Abass, L. A., Elusiyan, C. A., Oyedeji, A. O., & Akanmu, M. A. (2015). Psychoneuropharmacological activities and chemical composition of essential oil of fresh fruits of Piper guineense (Piperaceae) in mice. *Journal of Ethnopharmacology, 166*, 240–249. https://doi.org/10.1016/j.jep.2015.03.004

Prakash, B., Kujur, A., Yadav, A., Kumar, A., Singh, P. P., & Dubey, N. K. (2018). Nanoencapsulation: An efficient technology to boost the antimicrobial potential of plant essential oils in food system. *Food Control, 89*, 1–11. https://doi.org/10.1016/j.foodcont.2018.01.018

P. Chidambaranath, J. Joseph, A. Wilson Santhoshkumar, P.S.. (2021). *A method of preparing ethno-herbal farm produce sanitizer* (Patent No. AU2021103471A4).

Properzi, A., Angelini, P., Bertuzzi, G., & Venanzoni, R. (2013). Some biological activities of essential oils. *Medicinal & Aromatic Plants, 2*(5), 2–5. https://doi.org/10.4172/2167-0412.1000136

Raina, A. P., & Gupta, V. (2018). Chemotypic characterization of diversity in essential oil composition of Ocimum species and varieties from India. *Journal of Essential Oil Research, 30*(6), 444–456. https://doi.org/10.1080/10412905.2018.1495109

Rehman, A., Qunyi, T., Rizwan, H., Korma, S. A., Karim, A., Faisal, M., Mehmood, A., Waheed, M., Raza, H., Ali, A., & Mehmood, T. (2021). Biopolymer based nanoemulsion delivery system : An effective approach to boost the antioxidant potential of essential oil in food products. *Carbohydrate Polymer Technologies and Applications, 2*(April), Article 100082. https://doi.org/10.1016/j.carpta.2021.100082

Rodrigues de Oliveira, M., Anjos da Silva, L., Santos Da Silva, R., Branco de Queiroz, C. C., & Takeara, R. (2021). Chemical composition and biological activities of essential oils of Piper species from the Amazon. *Journal of Essential Oil Research, 33* (6), 536–548. https://doi.org/10.1080/10412905.2021.1942250

Roersch, C. M. F. B. (2010). Piper umbellatum L.: A comparative cross-cultural analysis of its medicinal uses and an ethnopharmacological evaluation. *Journal of Ethnopharmacology, 131*(3), 522–537. https://doi.org/10.1016/j.jep.2010.07.045

Saikia, S., Tamuli, K. J., Narzary, B., Bordoloi, M., & Banik, D. (2022). Chemical composition, antimicrobial activity and cytotoxicity of Murraya paniculata (L .) Jack leaf essential oil from Assam, India : The effect of oil on cellular morphology of micro - organisms. *Archives of Microbiology, 204*(1), 1–13. https://doi.org/10.1007/s00203-021-02665-0

Saleem, S., Ahmed, B., Khan, M. S., Al-Shaeri, M., & Musarrat, J. (2017). Inhibition of growth and biofilm formation of clinical bacterial isolates by NiO nanoparticles synthesized from Eucalyptus globulus plants. *Microbial Pathogenesis, 111*, 375–387. https://doi.org/10.1016/j.micpath.2017.09.019

Salehi, B., Zakaria, Z. A., Gyawali, R., Ibrahim, S. A., Rajkovic, J., Shinwari, Z. K., Khan, T., Sharifi-Rad, J., Ozleyen, A., Turkdonmez, E., Valussi, M., Tumer, T. B., Fidalgo, L. M., Martorell, M., & Setzer, W. N. (2019). Piper species: A comprehensive review on their phytochemistry, biological activities and applications. *Molecules, 24* (7). https://doi.org/10.3390/molecules24071364

Salwe, K. J., Mirunalini, R., Mano, J., & Manimekalai, K (2017). Hepatoprotective and antioxidant activity of Murraya Koenigii leaves extract against paracetamol induced hepatotoxicity in Rats. *International Journal of Basic & Clinical Pharmacology, 6*(6), 1274. https://doi.org/10.18203/2319-2003.ijbcp20172044

Samanta, S. K., Kandimalla, R., Gogoi, B., Dutta, K. N., Choudhury, P., Deb, P. K., Devi, R., Pal, B. C., & Talukdar, N. C. (2018). Phytochemical portfolio and anticancer activity of Murraya koenigii and its primary active component, mahanine. *Pharmacological Research, 129*, 227–236. https://doi.org/10.1016/j.phrs.2017.11.024

Sand in the forest. (2011). *Flavoring for cooking lobster* (Patent No. CN103099169A).

Sanquetta, C. R., Fernandes, L. D. A. V., Miranda, D. L. C.de, & Mognon, F (2010). Inventário de plantas fornecedoras de produtos não madeireiros da floresta ombrófila mista no estado do paraná. *Scientia Agraria, 11*(5), 359. https://doi.org/10.5380/rsa.v11i5.20222

Saqib, F., Ahmed, M. G., Janbaz, K. H., Dewanjee, S., Jaafar, H. Z. E., & Zia-ul-haq, M. (2015). Validation of ethnopharmacological uses of Murraya paniculata in disorders of diarrhea, asthma and hypertension. *BMC Complementary and Alternative Medicine*, 1–8. https://doi.org/10.1186/s12906-015-0837-7

Srivastava, S., Lal, R. K., Maurya, R., Mishra, A., Yadav, A. K., Pandey, G., Rout, P. K., & Chanotiya, C. S. (2021). *Industrial Crops & Products Chemical diversity of essential oil among basil genotypes (Ocimum viride Willd .) across the years, 173*. October.

Subaharan, K., Senthoorraja, R., Manjunath, S., Thimmegowda, G. G., Pragadheesh, V. S., Bakthavatsalam, N., Mohan, M. G., Senthil-Nathan, S., David, K. J., Basavarajappa, S., & Ballal, C. (2021). Toxicity, behavioural and biochemical effect of Piper betle L. essential oil and its constituents against housefly, Musca domestica L. *Pesticide Biochemistry and Physiology, 174*(November 2020), Article 104804. https://doi.org/10.1016/j.pestbp.2021.104804

Tanko, Y., et al. (2012). Anti-nociceptive and anti-inflammatory activities of methanol leaves extract of ocimum gratissimum in mice and rats. *IOSR Journal of Pharmacy and Biological Sciences, 4*(5), 1–5. https://doi.org/10.9790/3008-0450105

Tripathi, Y., Anjum, N., & Rana, A. (2018). Chemical composition and in vitro antifungal and antioxidant activities of essential oil from Murraya Koenigii (L.) Spreng. Leaves. *Asian Journal of Biomedical and Pharmaceutical Sciences, 8*(65). https://doi.org/10.4066/2249-622x.65.18-729

Vr Ramanathan Siva Vallabhaneni, V.R. (2022). *A nutraceuticals formulation with an enhanced organoleptic properties used for skin care* (Patent No. WO2022153337A1).

Xia, Y.lian, Cao, Y., Tan, X.hang, Fang, Y., Dong, C.zhu, Wang, Z.kai, Yu, S.quan, Hou, Z. min, & Wu, X. F (2020). Chemical composition and fungicidal activity of murraya microphylla essential oil against colletotrichum gloeosporioides. *Journal of Essential Oil-Bearing Plants, 23*(4), 678–685. https://doi.org/10.1080/0972060X.2020.1829997

Xu Chaoqun. (2017). *A kind of spicy spareribs with chili face seasoning packet and preparation method thereof* (Patent No. CN109380676A).

Yin Jiaxuan. (2017). *Tasty and tasty fragrant tea for health and its method of preparation* (Patent No. CN108029808A).

You, C. X., Yang, K., Wang, C. F., Zhang, W. J., Wang, Y., Han, J., Fan, L., Du, S. S., Geng, Z. F., & Deng, Z. W. (2014). Cytotoxic compounds isolated from Murraya tetramera Huang. *Molecules, 19*(9), 13225–13234. https://doi.org/10.3390/molecules190913225

Zhang, C., Zhao, J., Famous, E., Pan, S., Peng, X., & Tian, J. (2021). Antioxidant, hepatoprotective and antifungal activities of black pepper (Piper nigrum L.) essential oil. *Food Chemistry, 346*(March 2020), Article 128845. https://doi.org/10.1016/j.foodchem.2020.128845

Zhang Xiaobo. (2011). *Butter hotpot condiment formula* (Patent No. CN105011085A).

Zhao, Pingjia, Chiihong, Mei Fengkim, M. (2016). *Natural preservatives, antimicrobial agents, and compositions thereof* (Patent No. JP6903656B2).