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Chemical Composition of the Essential Oil of *Piper guineense* Schum. & Thonn. Fruits from the Republic of Congo

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Abstract The fruits of *Piper guineense* Schum. & Thonn. are used in traditional medicine to treat several diseases and in African cuisine as a spice to flavor culinary preparations. The extraction of essential oil from the fruits of the Congolese plant species was done by hydrodistillation. The results of analysis of this oil by GC/MS and GC/FID showed a total of 53 compounds. Oxygenated monoterpenes (44%) and hydrocarbon sesquiterpenes (22.87%) are the most dominant in this essential oil. Linalool (39.28%) and Germacrene D (14.23%) are the majority in this oil. The presence in this oil of these compounds as well as *alpha-phellandrene* (2.65%), *para*-cymene (2.60%), *beta*-caryophyllene (2.55%), limonene (2.36%), caryophyllene oxide (1.98%) and piperitone (1.11%) is very important; because they have several applications in the food and pharmaceutical industry. This richness in compounds shows that *Piper guineense* fruits are plant organs to consume to ensure the health of the body.

Keywords *Piper guineense*, Essential oil, Fruits, Congo

1. Introduction

Since ancient times, plant materials with intense and varied flavors have been used for food and medicinal purposes. They are generally known for their flavor profile, particularly their aromatic properties. These plants are commonly used as seasonings (spices) in cooking due to their ability to enhance flavor, thus playing an important role in the food industry [1]. In addition to their nutritional and aromatic values, spices also constitute a good resource for use in medicine and cosmetic products [2]. Among the spices, Black pepper (*Piper nigrum* L.) is the most used spice in the world, which gives it the name "king of spices" [3]. At the origin of the aromatic character of spices are volatile compounds called essential oils [4]. Essential oils, consisting mainly of terpene and phenolic compounds, are widely used as flavorings in food as well as in medicine due to their antimicrobial, antioxidant, antibacterial, antifungal, antiviral, anticancer properties, etc. [5,6].

In certain African countries, in the Republic of Congo in particular, a species of the *piper genus* named *Piper guineense* Schum. & Thonn. is widely used by populations for their food and health needs. Indeed, *Piper guineense* is a climbing herbaceous plant in the Piperaceae family. It is commonly found in African tropical forest areas [7]. These seeds are used as spices by the Congolese population [8]. In traditional African medicine, these organs are used in the treatment of rheumatism, bronchitis, cough, gastric disorders, intestinal diseases, gonorrhea, obstetrics and improving fertility in women, weight control and obesity, mental illness [8-10]. Chemical metabolites, including proteins, carbohydrates, lipids, terpenes, polyphenols and alkaloids, present in the plant give it its flavoring character and are responsible for several biological properties (antioxidant, anti-inflammatory, antimicrobial, antifungal, etc.) [11-13].

Natural products, particularly spices, are increasingly renowned for their powerful beneficial effects on health, both nutritionally and medicinally; they can therefore play a role in reducing the use of synthetic seasonings (nutrients) and medicines [8]. With the aim of contributing to the valorization of natural nutrients (spices) used by the Congolese population, this present work was undertaken to determine the chemical composition of the essential oil of *Piper guineense fruits.*

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2. Material and Methods

2.1. Plant Material

Piper *guineense* fruits were collected in Zanaga district of the Lékoumou department (Republic of Congo) in August 2023. This plant was identified by botanists from the National Herbarium of Congo where the species is recorded under number 164. The harvested plant material was dried at room temperature in a ventilated room for 3 weeks then crushed.

2.2. Extraction of Essential Oil from *Piper guineense* Fruits

The extraction of the essential oil from this plant was done using a Clevenger extractor. Therefore, 250 g of crushed dry fruits of the plant were put in a 6l flask containing 3l of distilled water and subjected to hydrodistillation for 3 hours. The yield of essential oil obtained was determined by a mass ratio between the oil obtained and the dry plant material used.

2.3. Analysis of the Essential Oil of *Piper guineense* Fruits

The analysis of this essential oil was carried out by gas chromatography coupled with mass spectrometry (GC/MS), on the one hand, and by gas chromatography coupled with a flame ionization detector (GC/FID), on the other hand. The analytical conditions of the essential oil are summarized in Table 1.

Table 1. Analytical conditions of the essential oil by GC/MS and GC/FID

Devices	Device Features	Analysis parameters
GC-MS	Gas chromatography (Agilent 7890)	HP5 column (20 m x 0.18 mm x 0.18 μm)
		Temperature programming: 50°C (3 min) then 300°C at 8°C (min)
		Carrier gas: He; flow rate: 0.9 ml/min
		Injector: split/splitless, 100 ml/min (230°C)
	Mass spectrometry (Agilent 5975)	Ionization by electron impact (70 ev)
		Quadrupole analyzer
GC-FID	Gas chromatography (Agilent model 6890)	HP5 column (20 m x 0.18 mm x 0.18 μm)
		Temperature setting: 50°C (3.2 min) then 300°C at 10°C (min)
		Carrier gas: He, 1.6 ml/min
		Injector: split/splitless, 100 ml/min (300°C)
	Flame ionization detector	Detection temperature: 280°C
		H_2 rate: 1 ml/min

2.4. Identification of Compounds

Chemical compounds in this oil were identified using Adams 2012, LEXVA analytical, Wiley and NIST databases.

3. Results and Discussion

3.1. Extraction Yield of Essential Oil from *Piper guineense* Fruits

Piper *guineense* fruits provided an essential oil yield of 0.25%. This yield found is within the range of yields of species of the genus Piper. The value of 0.25% obtained is close to that (0.2%) obtained on the same organs of the Cameroonian species [14]. However, it is higher than the yield (0.09-0.17%) obtained with the fruits of the Ivory Coast species and lower than those produced (0.45% and 1.2%) respectively by the fruits of the Nigerian and Liberian species [12,15,16]. Furthermore, the extraction of essential oils from the different species of *Piper* cited in the literature gave variable yields; this is the case of essential oils obtained from *Piper nigrum* L. *(*1.11%), *Piper cubeba* L. *(*1.23%) and *Piper umbelatum* L. (0.02%).

The difference in yield, from the same species or botanical family and from one organ to another, in essential oil can be due to several factors such as the origin of harvest of the species, the harvest period, the species of the plant, the organ of the plant, the method of extraction, etc. [18,19].

3.2. Chemical Composition of the Essential Oil of *Piper guineense fruits*

The analysis results identified a total of 53 compounds representing 84.67% of the compounds in the essential oil of this Congolese plant species, divided into 5 chemical families, namely: hydrocarbon monoterpenes (11.81%), oxygenated monoterpenes (44%), hydrocarbon sesquiterpenes (22.87%), oxygenated sesquiterpenes (4.16%) and non-terpene compounds (1.83%) such as alkenes and aromatic hydrocarbons (Figure 1, Table 2). In terms of compound diversity, of the 53 compounds identified, there are 11 hydrocarbon monoterpenes (21%), 16 oxygenated monoterpenes (30%), 16 hydrocarbon sesquiterpenes (30%), 3 oxygenated sesquiterpenes (6%) and 7 non-terpene compounds (13%) (Table 2).

Among these identified compounds, linalool (39.28%) and germacrene D (14.23%) are the majority compounds in the oil of this Congolese species (Table 2).

Several works on the chemical composition of the essential oil of *Piper guineense* have been carried out in other countries and have shown diversity in terms of chemical compounds of its fruits. Nearly half of all the compounds identified in this Congolese species have not been cited by numerous authors who have studied this same organ in species from other countries [14,16,20].

In addition, the content of the dominant compound in the essential oil of this plant species varies depending on the country. We note that the essential oil obtained in this study has a Linalool content close to that of the fruits of the Cameroonian species (41.8%) and lower than that found on fruits of the Liberian species (70.2%) [14,15]. Unlike this Congolese species, the fruits of the Ivory Coast species are dominated by *beta*-phelllandrene (29.2%) out of the 54 compounds identified [17].

Table 2. Chemical composition of the essential oil of *Piper guinenese* fruits

No.	TR	KI	Compound	Content (%)	Chemical group
1	8.32	886	Ethylbenzene	0.07	Aromatic hydrocarbon
2	8.65	872	*Meta*-Xylene	0.27	Aromatic hydrocarbon
3	8.70	873	*Para*-Xylene	0.11	Aromatic hydrocarbon
4	9.47	895	*Ortho*-Xylene	0.18	Aromatic hydrocarbon
5	10.73	930	*Alpha*-Thujene	0.03	Hydrocarbon monoterpene
6	11.01	938	*Alpha*-Pinene	0.44	Hydrocarbon monoterpene
7	12.47	978	Sabinene	1.30	Hydrocarbon monoterpene
8	12.65	983	*Beta*-Pinene	0.93	Hydrocarbon monoterpene
9	13.04	993	Myrcene	0.25	Hydrocarbon monoterpene
10	13.69	1012	*Alpha*-Phellandrene	2.65	Hydrocarbon monoterpene
11	14.34	1031	*Para*-Cymene	2.60	Hydrocarbon monoterpene
12	14.50	1036	Limonene	2.36	Hydrocarbon monoterpene
13	14.56	1037	*Beta*-Phellandrene	0.74	Hydrocarbon monoterpene
14	14.62	1039	Eucalyptol	0.37	Oxygenated monoterpene
15	15.48	1064	*Gamma*-Terpinene	0.01	Hydrocarbon monoterpene
16	15.93	1077	*Cis*-Hydrate of Sabinene	0.50	Oxygenated monoterpene
17	16.40	1091	Terpinolene	0.05	Hydrocarbon monoterpene
18	17.05	1111	**Linalool**	**39.28**	Oxygenated monoterpene
19	17.12	1113	Sabinene *Trans*-Hydrate	0.06	Oxygenated monoterpene
20	17.76	1133	*Cis*-*Para*-Menth-2-en-1-ol	0.52	Oxygenated monoterpene
21	18.31	1150	*Trans*-*Para*-Menth-2-en-1-ol	0.14	Oxygenated monoterpene
22	18.51	1156	Camphor	0.50	Oxygenated monoterpene
23	19.01	1172	Isoborneol	0.11	Oxygenated monoterpene
24	19.51	1187	Terpinene-4-ol	0.50	Oxygenated monoterpene
25	19.72	1194	Cryptone	0.07	Oxygenated monoterpene
26	19.95	1201	*Alpha*-Terpineol	0.06	Oxygenated monoterpene
27	19.99	1202	Myrtenol	0.15	Oxygenated monoterpene
28	20.21	1210	*Cis*-Sabinol	0.32	Oxygenated monoterpene
29	21.73	1263	Piperitone	1.11	Oxygenated monoterpene
30	22.39	1286	Linalool *Trans Oxide* Acetate	0.24	Oxygenated monoterpene
31	22.92	1305	Carvacrol	0.07	Oxygenated monoterpene
32	23.99	1342	*Delta*-Elemene	0.12	Hydrocarbon sesquiterpene
33	24.32	1353	*Alpha*-Cubebene	0.03	Hydrocarbon sesquiterpene
34	25.14	1382	*Alpha*-Copaene	0.47	Hydrocarbon sesquiterpene
35	25.38	1390	*Beta*-Bourbonene	1.17	Hydrocarbon sesquiterpene
36	25.46	1393	*Beta*-Cubebene	0.50	Hydrocarbon sesquiterpene
37	25.48	1394	*Beta*-Elemene	0.93	Hydrocarbon sesquiterpene
38	25.65	1400	MethylEugenol	0.60	Aromatic hydrocarbon
39	26.30	1426	*Beta*-Ylangene	0.41	Hydrocarbon sesquiterpene
40	26.36	1428	*Beta*-Caryophyllene	2.55	Hydrocarbon sesquiterpene
41	26.52	1435	*Gamma*-Elemene	0.56	Hydrocarbon sesquiterpene
42	26.59	1437	*Beta*-Copaene	0.38	Hydrocarbon sesquiterpene
43	27.28	1465	*Alpha*-Humulene	0.66	Hydrocarbon sesquiterpene
44	27.98	1493	**Germacrene D**	**14.23**	Hydrocarbon sesquiterpene
45	28.28	1505	*Alpha*-Murolene	0.28	Hydrocarbon sesquiterpene
46	28.68	1521	*Gamma*-Cadinene	0.03	Hydrocarbon sesquiterpene
47	28.76	1524	*Delta*-Cadinene	0.34	Hydrocarbon sesquiterpene
48	29.53	1555	Elemol	0.85	Oxygenated sesquiterpene

No.	TR	KI	Compound	Content (%)	Chemical group
49	29.86	1568	Germacrene B	0.66	Hydrocarbon sesquiterpene
50	30.45	1592	Caryophyllene Oxide	1.98	Oxygenated sesquiterpene
51	30.72	1603	Guaiol	1.33	Oxygenated sesquiterpene
52	34.96	1793	1-Octadecene	0.31	Alkene
53	39.04	1992	1-Eicosene	0.29	Alkene
Total (%)				**84.67**	

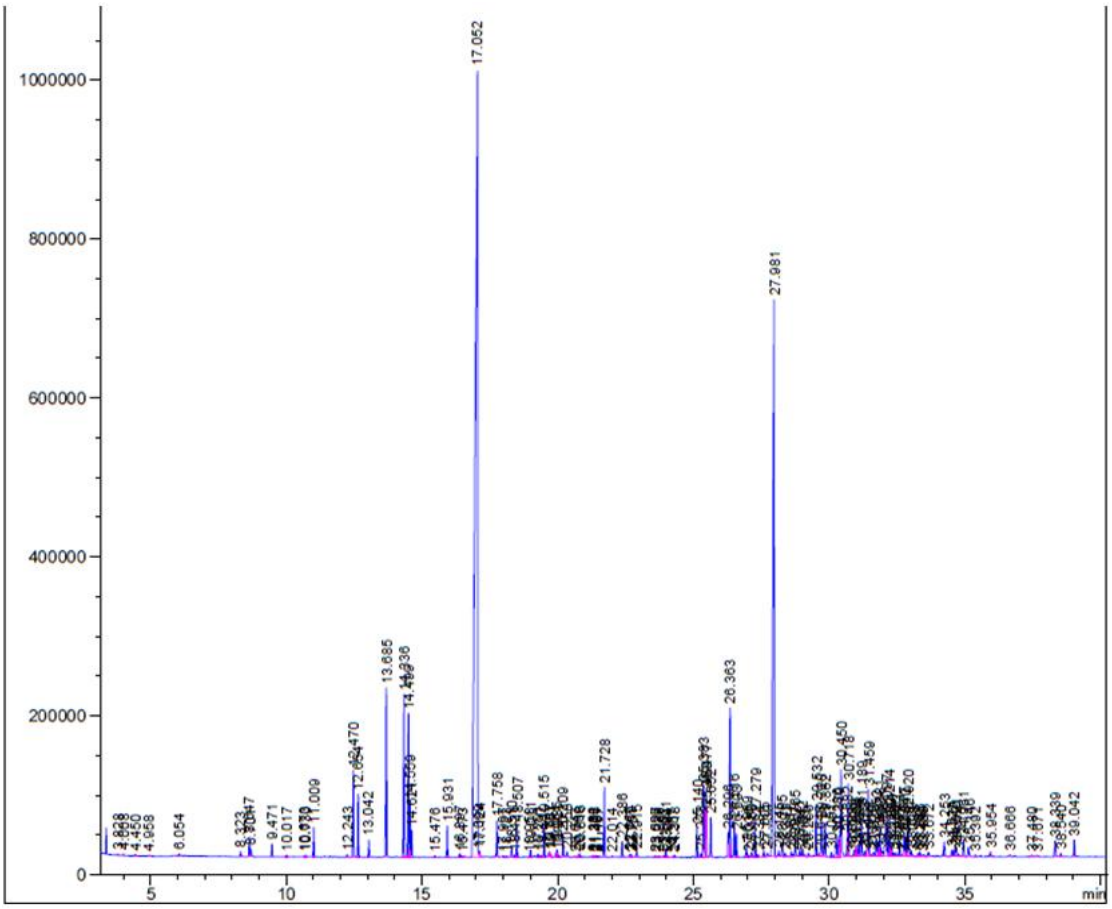

Figure 1. GC/FID chromatogram of the essential oil of *Piper guineense* fruits

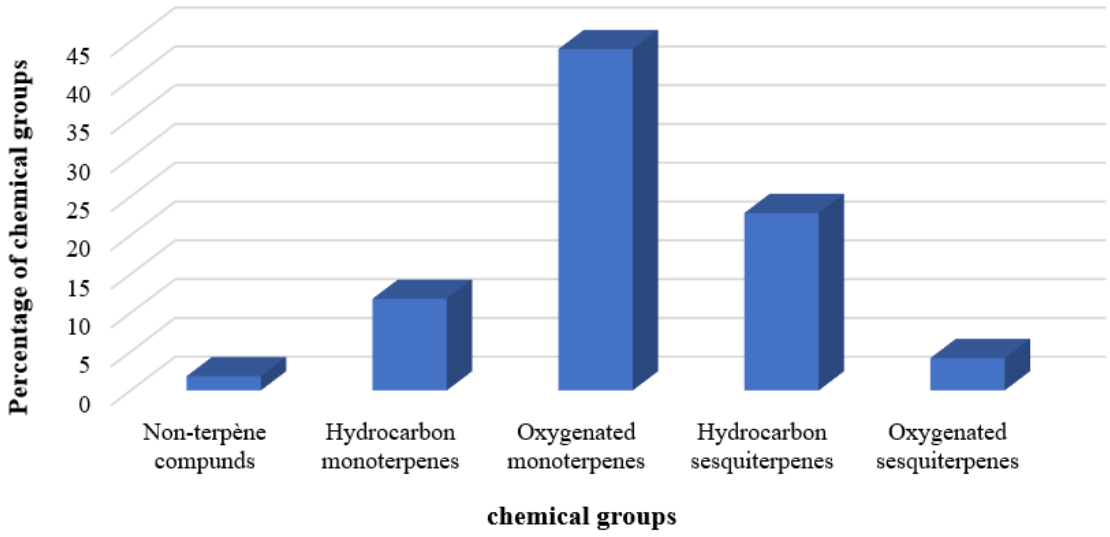

Figure 2. Distribution of the main classes of compounds in the essential oil of *Piper guineense* fruits

This variability in the chemical composition of the oil studied with those of other works may be due to several factors, such as ecological parameters, the species of the plant and its genetic heritage, the databases used, etc [21].

According to the work of Sruthi et *al*. in 2013, *Piper guineense* studied contains several compounds with different contents found in *Piper nigrum*, namely: *alpha*-Humulene (2.43%), *alpha*-Copaene (4.75%), *alpha*-Cubebene (0.49%), *alpha*-Pinene (3.88%), *alpha*-Thujène (2.65%), *beta*-Elemene (1.06%), *Delta*-Cadinene (2.43%), *Gamma*-Terpinene (0.28%), Caryophyllene Oxide (4.91), *Trans*-*Para*-Menth-2-en-1-ol (0.35%), *beta*-Pinene (13.26%), Sabinene (18.07%), Linalool (1.70%) and Germacrene D (0.52%). Indeed, *Piper nigrum* commonly called black pepper is the most consumed natural spice in the world which contains *β*-Pinene and Sabinene as main compounds [22,23].

The difference observed between the majority compounds of *Piper guineense* and those of *Piper nigrum* could explain the increased use of *Piper guineense* in traditional medicine than in the Congolese diet [8].

Linalool, called 3,7-dimethyl-1,6-octadiene-3-ol, is an acyclic monoterpene tertiary alcohol found in the essential oils of several plant species [24,25]. It is also present as the majority compound in certain natural spices and aromatic plants such as *Coriandrum sativum* L. (Coriander), *Ocimum basilicum* L. (Basil) and Origanum majorana L. (Marjoram) and these insecticidal properties probably explain why so many plants produce it. [25,26]. In food, linalool is used as a food additive added to drinks and foods for its pleasant odor [27]. This organic compound is designated today as a true ally for well-being and health, endowed with almost revolutionary therapeutic potential. It has antioxidant, anti-inflammatory, anticancer, anti-hyperlipidemic, antimicrobial, antinoceptive, analgesic, anxiolytic, antidepressant, and neuroprotective properties [28]. In the cosmetic industry, linalool is used to enrich numerous products such as beauty lotions, fine perfumes, shampoos, toilet soaps as well as in household cleaners and detergents thanks to its pleasant scent and beneficial effects on the skin [29].

Furthermore, germacrene D is a sesquiterpene which is found in various plants known for their antimicrobial and insecticidal properties. This compound is renowned for its powerful antifungal, antibacterial, Anti-inflammatory properties, etc [30-32].

In a world where food safety is a priority, several synthetic food additives such as buthylhydroxyanisole (BHA), butylated hydroxytoluene (BHT) and propylene glycol (PG) would present possible adverse effects in the body; Spices including *Piper guineense* can be used as food preservatives due to their antioxidant and antimicrobial potential [33].

Piper guineense species from Congo allows it, on the one hand, to be used in food as a flavoring agent for food dishes in the same way as other essential oils known and put on the market like that of *Piper nigrum* (black pepper), *Zingiber officinale* (Ginger), *Ocimomum basilicum* (Basil) and, on the other hand, to be the subject of medical or even cosmetic applications [34]. Knowledge of the phytochemical composition of the essential oil of the fruits of the *Piper guineense species* allows the latter to have the prospects of applying phytoproducts to the market and seeing its domestication.

4. Conclusions

The present work was devoted to the identification of the chemical compounds present in the essential oil of fruits of *Piper guineense* Schum. & Thonn. of the Republic of Congo. The extraction of this oil gave a yield of 0.25%, appreciable compared to certain results from other countries. The chemical analysis of this oil from the Congo species showed some profile rich in chemical compounds, almost half of the compounds identified were not identified by several works on the same species. Linalool and Germacrene D are the two major compounds and could be responsible for the biological and aromatic properties of this plant. The *Piper guineense* species from Congo, which is used all the more by the population in traditional medicine and in food, can also be valued as a spice given its richness in aromatic compounds to enhance the flavor of dishes.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest with any third party.

REFERENCES

[1] Huang, L., Ho, C., Wang, Y. (2020). Biosynthetic pathways and metabolic engineering of spice flavors. *Critical Reviews in Food Science and Nutrition*. 61(12): 1-14.

[2] Thien, T., Le, K., Chinh, D., Phat, D., Hong, L., Nguyen, D., Nguyen, T., Vo, D., Tran, Q., Bach, L. (2019). The Study on Extraction Process and Analysis of Components in Essential Oils of Black Pepper (Piper nigrum L.) Seeds Harvested in Gia Lai Province, Vietnam. *Processes*. 7(56): 1-15.

[3] Takooree, H., Aumeeruddy, M., Rengasamy, K., Venugopala, K., Jeewon, R., Zengin, G., Mahoomodally, M. (2019). A systematic review on Black pepper (Piper nigrum L.): from folk uses to pharmacological applications. *Critical Reviews in Food Science and Nutrition*. 59 (1): 1-34.

[4] Diniz, L., Moraes, A., Costa, K., Pereira, J., Taube, P., Costa, C., Faria, L. (2020). Bioactive Natural Compounds and Antioxidant Activity of Essential Oils from Spice Plants: New Findings and Potential Applications. *Biomolecules*, 10(988): 1-35.

[5] Srinivas, K. (2016). Spices and flavoring crops: uses and health effects. CSIR-Central food technological research

institute, Mysore, India. *Elsevier Ltd.*, 98-105.

[6] Jiang, T. (2019). Health Benefits of Culinary Herbs and Spices. *Journal of AOAC International*. 102(2): 395-411.

[7] Olonisakin, A., Oladimeji, M., Lajide, L. (2006). Chemical composition and antibacterial activity of steam distilled oil of ashanti pepper (*Piper guineense*) fruits (berries). *Electron. J. Environ. Agric. Food Chem*. 6(11): 1531-1535.

[8] Bonazaba Milandou, L. J. C., Madzou Mbani, B. F., Nkounkou Loumpangou, C., Bouka Dipelet, G. U., Ouamba, J-M. (2023). Inventaire des plantes alicamentaires utilisées comme assaisonnements en République du Congo. *International Journal of Biological and Chemical Sciences*. 17(3): 1098-1116.

[9] Mensah, J., Okoli, R., Ohaju-Obodo, J., Eifediyi, K. (2008). Phytochemical, nutritional and medical properties of some leafy vegetables consumed by Edo people of Nigeria. *African Journal of Biotechnology*. 7(14): 2304-2309.

[10] Uhegbu, F., Chinedou, I., Ugbogu, A. (2015). Effect of aqueous extract of Piper guineense seeds on some liver enzymes, antioxidant enzymes and some hematological parameters in Albino Rats. *International Journal of Plant Science and Ecology*. 1(4), 167-171.

[11] Agbor, G., Vinsonb, J., Sortino, J., Johnson, R. (2012). Antioxidant and anti-atherogenic activities of three Piper species on atherogenic diet fed hamsters. *Experimental and Toxicologic Pathology*. 64: 387-391 (2012).

[12] Oyedeji, O., Adeniyi, B., Ajayi, O., König W. (2005). Essential Oil Composition of Piper guineense and its Antimicrobial Activity. Another Chemotype from Nigeria. *Phytotherapy Research*. 19: 362-364.

[13] Ngono Ngane, A., Biyiti, L., Bouchet, P., Nkengfack, A., Amvam Zollo, P. (2003). Antifungal activity of Piper guineense of Cameroon. *Fitoterapia*, 74(5): 464-468.

[14] Tankam, J., Ito, M. (2013). Inhalation of the Essential Oil of Piper guineense from Cameroon Shows Sedative and Anxiolytic-Like Effects in Mice. *Biol. Pharm. Bull*. 36(10): 1608-1614.

[15] Juliani, H., Koroch, A., Giordano, L., Amekuse, L., Koffa, S., Asante-Dartey, J., Simon, J. (2013). Piper guineense (Piperaceae): Chemistry, Traditional Uses, and Functional Properties of West African Black Pepper. *American Chemical Society*. 1127: 35-48.

[16] Kambiré, D., Yapi, T., Boti, J., Garcia, G., Tomi, P., Bighelli, A., Tomi, F. (2019). Chemical Composition of Leaf Essential Oil of Piper umbellatum and Aerial Part Essential Oil of Piper guineense From Côte d'Ivoire. *Natural Product Communications.* 14(6): 1-8.

[17] Andriana, Y., Xuan, T., Qui, T., Tran, H., Le, Q. (2019). Biological Activities and Chemical Constituents of Essential Oils from Piper cubeba Bojer and Piper nigrum L. *Molecules*. 24(10): 1876, 1-16.

[18] Thompson, J., Chalchat, J-C., Michet, A., Linhart, Y., Ehlers, B. (2003). Qualitative and quantitative variation in monoterpene co-occurrence and composition in the essential oil of Thymus vulgaris chemotypes. *Journal of Chemical Ecology*. 29(4): 859-880.

[19] Karousou, R., Koureas, D., Kokkini, S. (2005). Essential oil composition is related to the natural habitats: Coridothymus capitatus and Satureja thymbra in NATURA 2000 sites of Crete. *Phytochemistry*. 66(22): 2668-2673.

[20] Ganiyu, O., Ayokunle, O., Oluwatoyin, V., Ifeoluwa, A. (2013). Antioxidative Properties and Inhibition of Key Enzymes Relevant to Type-2 Diabetes and Hypertension by Essential Oils from Black Pepper. *Advances in Pharmacological Sciences*. 2013: 1-6.

[21] Russo, M., Galletti, G., Bocchini, P., Carnacini, A. (1998). Essential Oil Chemical Composition of Wild Populations of Italian Oregano Spice (Origanumvulgaressp.hirtum (Link) Ietswaart): A Preliminary Evaluation of Their Use in Chemotaxonomy by Cluster Analysis. 1. Inflorescences. *Journal of Agricultural and Food Chemistry*. 46(9): 3741-3746.

[22] Sruthi, D., Zachariah, T., Leela, N., Jayarajan, K. (2013). Correlation between chemical profiles of Black pepper (Piper nigrum L.) var. Panniyur-1 collected from different locations. *Journal of Medicinal Plants Research*, 7(31), 2349-2357.

[23] Ashokkumar, K., Murugan, M., Dhanya, M., Pandian, A., Warkentin, T. (2021). Phytochemistry and therapeutic potential of Black pepper [Piper nigrum (L.)] essential oil and piperine: a review. *Clinical Phytoscience*. 7(52): 1-11.

[24] Raguso, R. (2016). More lessons from linalool: insights gained from a ubiquitous floral volatile. *Current Opinion in Plant Biology*. 32: 31-36.

[25] Aprotosoaie, A., Hăncianu, M., Costacheb, I.-I., Miron, A. (2014). Linalool: a review on a key odorant molecule with valuable biological properties. *Flavour and Fragrance Journal*. 29(4): 1-27.

[26] Bochra, L., Kouki, K., M'Hamdi, M., Bettaieb, T. (2015). Coriander (Coriandrum sativum L.) and its bioactive constituents. *Fitoterapia*. 103: 1-59.

[27] Kamatou, G., Viljoen, A. (2008). Linalool-A Review of a Biologically Active Compound of Commercial Importance. *Natural Product Communications*. 3(7): 1183-1192.

[28] Pereira, I., Severino, P., Santos, A., Silva, A., Souto, B. (2018). Linalool Bioactive Properties and Potential Applicability in Drug Delivery Systems. *Colloids and Surfaces B: Biointerfaces*, 171: 1-60 (2018).

[29] Letizia, C., Cocchiara, J., Lalko, J., Api, A. (2003). Fragrance material review on linalool. *Food and Chemical Toxicology*, 41(7), 943-964.

[30] Abhay, K., Pooja, S. (2017). Review The Genus Artemisia: A 2012–2017 Literature on Chemical Composition, Antimicrobial, Insecticidal and Antioxidant Activities of Essential Oils chemical. *Medicines*, 4(68): 1-15.

[31] Acimovic, M., Stankovic, J., Miljkovic, A., Rat, M., Loncar, B. (2023). Screening of Volatile Compounds, Traditional and Modern Phytotherapy Approaches of Selected Non-Aromatic Medicinal Plants (Lamiaceae, Lamioideae) from Rtanj Mountain, Eastern Serbia. *Molecules*. 28 (4611): 1-20.

[32] Fikru, S., Tolossa, K., Lindemann, P., Bucar, F., Asres, K. (2024). Larvicidal, Ovicidal, and Repellent Activities of Leucas stachydiformis (Hochst. ex Benth.) Briq Essential Oil against Anopheles arabiensis. Hindawi, *Journal of Tropical Medicine*. 1-9.

[33] Salehi, B., Zakaria, Z., Gyawali, R., Ibrahim, S., Rajkovic, J., Shinwari, Z., Khan, T., Sharifi-Rad, J., Ozleyen, A., Turkdonmez,

E., Valussi, M., Tumer, T., Fidalgo, L., Martorell, M., Setzer, W. (2019). Piper Species: A Comprehensive Review on Their Phytochemistry, Biological Activities and Applications. *Molecules*. 24(1364), 1-117.

[34] DGCCFR. (2019). Huiles essentielles: Recommandations sanitaires pour l'emploi d'huiles essentielles dans les compléments alimentaires. Nutrition et information des consommateurs Secteur «Compléments alimentaires». 9p.