

VALORIZATION OF LOCAL BIORESOURCES IN NORTHERN CÔTE D'IVOIRE: A Comparative Study of the Phytochemical Profiles of Orange Peel and Lemongrass Essential Oils

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Abstract:

Northern Côte d'Ivoire is home to a rich flora, the industrial and pharmaceutical potential of which remains largely untapped. Amid the search for alternatives to synthetic inputs, essential oils derived from local aromatic plants represent a high-potential bioresource. This study characterizes and compares the phytochemical profiles of essential oils extracted from the peel of *Citrus sinensis* (orange) and the aerial parts of *Cymbopogon citratus* (lemongrass) two resources abundant in the north of the country. The oils were obtained via hydrodistillation (Clevenger method), and their chemical composition was determined using gas chromatography-mass spectrometry (GC-MS). Results are expressed as the relative percentage of each constituent, calculated from the mean of three independent extractions. GC-MS analysis identified six (6) compounds in the orange peel oil and five (5) in the lemongrass oil. Orange oil is overwhelmingly dominated by d-limonene ($94.9 \pm 0.28\%$), whereas lemongrass oil exhibits a bimodal profile, with geranial ($57.8 \pm 0.46\%$) and β -myrcene ($34.2 \pm 0.93\%$) as the major constituents. These two oils thus offer distinct and complementary chemical profiles. The results confirm the potential for utilizing these two local bioresources, with possible applications in the food, cosmetic, and phytosanitary sectors. They provide a database for the sustainable exploitation of plant resources in northern Côte d'Ivoire.

Keywords: Essential oils; d-limonene; geranial; β -myrcene; Côte d'Ivoire; bioresources; GC-MS.

I. INTRODUCTION

Harnessing the value of local plants is a major challenge for developing African economies, particularly for Côte d'Ivoire, which boasts exceptional floral biodiversity. In the country's northern regions characterized by a Sudan-Sahelian climate both wild and cultivated flora harbor numerous species with significant bioactive potential that remain largely underexploited¹.

Essential oils, volatile secondary metabolites produced by aromatic plants, are attracting growing interest in the pharmaceutical, agri-food, and cosmetic fields owing to their well-documented biological properties: antimicrobial, antioxidant, insecticidal, and flavoring activities^{2,3}. These natural products offer a credible alternative to synthetic chemical inputs. The current climate is favorable: antibiotic resistance is on the rise, and environmental concerns are playing an increasingly significant role in decision-making.

Among the plant species most represented in northern Côte d'Ivoire, *Citrus sinensis* (L.) Osbeck (orange tree) and *Cymbopogon citratus* (DC.) Stapf (lemongrass) stand out for their wide availability, their use in traditional medicine, and their proven economic value. The orange tree is cultivated on a large scale in the orchards of Korhogo and its surroundings, while lemongrass, introduced and naturalized, is used as a condiment, repellent, and medicinal plant by rural communities⁴.

Despite their ethnobotanical and economic value, these two resources harvested in the ecological setting of northern Côte d'Ivoire have been the subject of few in-depth chemical studies. Indeed, the composition of the essential oils varies according to geographical origin, soil and climatic conditions, and harvesting practices. This study intends to fill this gap. For the first time, it is carrying out a systematic comparative analysis of essential oils of orange peel and lemongrass produced in the Korhogo region, by gas chromatography coupled with mass spectrometry (GC-MS). Three objectives structure it: identify and quantify the volatile compounds of each oil; compare their respective chemical profiles; examine their potential for application in a logic of sustainable valorization of local bioresources.

II. MATERIAL AND METHODS

2.1 Study area and collection of plant material

Plant material was collected in the Korhogo region (09°27'N, 05°37'W), the administrative center of the Poro department in northern Côte d'Ivoire. The climate is of the Sudanian type: the rainy season extends from May to October, and the dry season from November to April. Annual precipitation reaches approximately 1,200 mm, and average temperatures range between 24°C and 35°C. The soils, primarily ferrallitic, are suitable for the cultivation of fruit trees and aromatic plants.

Orange peels (*Citrus sinensis*) were obtained from ripe fruit harvested in village orchards within the Korhogo municipality. The aerial parts (leaves and stems) of lemongrass (*Cymbopogon citratus*) were gathered early in the morning from home gardens in the Sinématiali sub-prefecture. Collection took place between July and August 2024 during the peak of the rainy season a period when secondary metabolite production is optimal. Botanical identification was confirmed by the Department of Botany at Peleforo Gon Coulibaly University in Korhogo (herbarium samples No. UPGC-Bot-2024-018 and No. UPGC-Bot-2024-019).

2.2 Extraction of essential oils

The essential oils were extracted by hydrodistillation using the standardized Clevenger method. This technique is the standard procedure for extracting essential oils from citrus fruits and herbaceous plants. For each plant matrix, 200 g of finely ground fresh material was placed in a 2-liter flask containing 1 liter of distilled water. Distillation was carried out for 3 hours, starting from the appearance of the first oil droplets. The collected essential oils were dried over anhydrous sodium sulfate (Na₂SO₄) and then stored in amber glass vials at -20 °C until analysis. Each extraction was performed in triplicate to ensure the reproducibility of the results. The essential oil yield was calculated based on the fresh weight of the plant material.

2.3 Analysis by gas chromatography coupled with mass spectrometry (GC-MS)

Analyses were performed using an Agilent Technologies 7890B/5977A gas chromatograph coupled with a mass spectrometer, equipped with an HP-5MS capillary column (30 m × 0.25 mm × 0.25 µm). The oven temperature program was as follows: 60 °C for 2 min, then a ramp of 4 °C/min up to 250 °C, followed by a 10 min hold at 250 °C. The injector temperature was 250 °C and the ion source temperature was 230 °C. The carrier gas used was helium (flow rate: 1.2 mL/min). Mass spectra were recorded in electron impact mode (70 eV) over an *m/z* range of 40 to 350.

Compound identification was carried out by comparing calculated retention indices (RI), relative to a C7–C28 hydrocarbon series, with literature data⁶, and by matching mass spectra against the NIST 2020 library. Only compounds with a match factor above 90% were retained. Relative quantification of compounds was performed by integrating chromatographic peak areas, without the use of a correction factor. Results are expressed as relative percentages of total peak area, calculated from three independent extractions.

2.4 Statistical analysis

Quantitative data are presented as mean ± standard deviation. Variability between the three extraction replicates was assessed by calculating the coefficient of variation (CV). A CV below 5% was considered indicative of good analytical reproducibility. Comparisons between the two essential oils were made descriptively, sample sizes being insufficient for the application of parametric statistical tests.

III. RESULTS

3.1 Extraction yields

Hydrodistillation yielded essential oil contents of 0.82 ± 0.06% (w/w, wet basis) for orange peel and 0.47 ± 0.04% for lemongrass aerial parts. These values are consistent with those published for species harvested in West Africa^{7,8}. The slightly higher yield of orange oil is attributable to the numerous secretory glands in the citrus pericarp.

3.2 Chemical composition of orange peel essential oil

GC-MS analysis of the *Citrus sinensis* peel essential oil identified six constituents, representing the entire detected composition (100% of the total content). The results are presented in Table 1.

Table 1: Chemical composition of orange peel essential oil (*Citrus sinensis*) collected in the Korhogo region, Côte d'Ivoire.

Peak	RT (min)	Compound	Mean content (%)	SD (%)
1	8.073	<i>β-myrcene</i>	1.4	0.09
2	9.003	<i>p-cymene</i>	0.4	0.02
3	9.124	<i>d-limonene</i>	94.9	0.28
4	10.83	<i>p-α-dimethylstyrene</i>	1.1	0.02
5	11.101	<i>linalool</i>	1.8	0.19
6	13.705	<i>terpineol</i>	0.4	0.04
		TOTAL	100.0	—

RT: retention time. Compounds in bold represent the major constituents. Values are means of three independent extractions.

The chemical profile of orange oil is characterized by the very clear predominance of *d-limonene* (retention time: 9.124 min), which alone accounts for $94.9 \pm 0.28\%$ of the total composition. This monocyclic monoterpene hydrocarbon gives orange essential oil its characteristic odoriferous properties as well as its biological activity. The five other compounds identified are minor: linalool (1.8%), *β-myrcene* (1.4%), *p-α-dimethylstyrene* (1.1%), *p-cymene* (0.4%), and *terpineol* (0.4%). Together, these compounds represent only 5.1% of the total composition. The extremely low standard deviation of *d-limonene* (0.28) confirms the very good reproducibility of the extractions and the stability of the composition of the plant matrix analyzed.

3.3 Chemical composition of lemongrass essential oil

GC-MS analysis of the *Cymbopogon citratus* essential oil revealed the presence of five (5) identified compounds, totaling 100% of the composition. Results are presented in Table 2.

Table 2: Chemical composition of lemongrass essential oil (*Cymbopogon citratus*) collected in the Korhogo region, Côte d'Ivoire.

Peak	RT (min)	Compound	Mean content (%)	SD (%)
1	8.068	<i>β-myrcene</i>	34.2	0.93
2	10.83	<i>p-α-dimethylstyrene</i>	1.5	0.28
3	13.456	<i>verbenol</i>	4.6	0.36
4	15.439	<i>geraniol</i>	1.9	0.30
5	15.913	<i>geranial</i>	57.8	0.46
		TOTAL	100.0	—

RT: retention time. Compounds in bold represent the major constituents. Values are means of three independent extractions.

Lemongrass essential oil shows a bimodal chemical profile clearly different from that of orange. It is dominated by *geranial* (an acyclic monoterpene aldehyde, RT: 15.913 min), which accounts for $57.8 \pm 0.46\%$ of the total composition, and by *β-myrcene* (an acyclic monoterpene hydrocarbon, RT: 8.068 min) at $34.2 \pm 0.93\%$. Together, these two major compounds represent 92.0% of the oil's composition. Three minor compounds complete the profile: *verbenol* (4.6%), *geraniol* (1.9%), and *p-α-dimethylstyrene* (1.5%). The relatively higher standard deviation of *β-myrcene* (0.93) compared with *geranial* (0.46) suggests slight variability in the accumulation of this compound between individuals or harvests.

3.4 Comparative analysis of the two phytochemical profiles

Comparison of the two essential oils reveals contrasting chemical profiles, reflecting the diversity of the biosynthetic pathways involved. Table 3 summarizes the main differences between the two matrices.

Table 3: Comparison of the phytochemical profiles of the two essential oils.

Parameter	Orange EO (<i>Citrus sinensis</i>)	Lemongrass EO (<i>Cymbopogon citratus</i>)
Yield (%)	0.82 ± 0.06	0.47 ± 0.04
No. of compounds	6	5
Major compound	<i>d-limonene</i> (94.9%)	<i>Geranial</i> (57.8%)
2nd compound	<i>Linalool</i> (1.8%)	<i>β-myrcene</i> (34.2%)
Main chemical class	Monoterpene hydrocarbons	Aldehydes & monoterpene hydrocarbons
Profile type	Unimodal, dominant	Bimodal
Common compound(s)	<i>β-myrcene</i> (1.4%); <i>p-α-dimethylstyrene</i> (1.1%)	<i>β-myrcene</i> (34.2%); <i>p-α-dimethylstyrene</i> (1.5%)

EO: essential oil.

Despite their differences, both oils share the presence of β -myrcene and p- α -dimethylstyrene, reflecting partial biosynthetic proximity. β -myrcene, present in both orange (1.4%) and lemongrass (34.2%), is the only notable compound common to both matrices.

IV. DISCUSSION

4.1 Chemical profile of orange essential oil: dominance of d-limonene

The strong dominance of *d-limonene* (94.9%) in *Citrus sinensis* peel essential oil is fully consistent with data published in the literature. Indeed, this compound is recognized as the major chemotaxonomic marker of citrus essential oils⁹. Reported levels for oranges of various African origins generally range between 87 and 97%, depending on variety, pedoclimatic growing conditions, and fruit ripeness stage^{10,11}. The value obtained in the present study (94.9%) falls within the upper range of this interval, suggesting growing conditions favorable to the biosynthesis of this monoterpene in the Korhogo region.

d-Limonene is a monocyclic monoterpene with numerous documented biological properties: antimicrobial activity against pathogenic bacteria and fungi¹², antioxidant properties¹³, insecticidal potential¹⁴, and the ability to promote the cutaneous absorption of other active ingredients¹⁵. These properties give Korhogo orange essential oil strong potential for application in the agri-food (flavoring, preservation), cosmetic (perfumery, emulsifiers), and pharmaceutical (topical formulations) sectors. The high d-limonene content is also an argument in favor of valorizing by-products of the local citrus industry, particularly peels, which are generally discarded after fruit consumption.

4.2 Chemical profile of lemongrass essential oil: a bimodal aldehyde-hydrocarbon profile

The bimodal chemical profile of *Cymbopogon citratus* essential oil, dominated by geranial (57.8%) and β -myrcene (34.2%), shows some specific features compared with literature data. Indeed, *C. citratus* essential oils are generally characterized by a bimodal citral profile, with geranial (citral a) and neral (citral b) as the dominant compounds, together reaching 65–85% of the composition^{16,17}.

The originality of the profile obtained in the present study lies in the very high proportion of β -myrcene (34.2%), well above the values usually reported (5–15%). This particularity could be explained by several factors: the specific pedoclimatic conditions of the Korhogo region, the phenological stage at harvest, local cultivation practices, or the particular chemotype of the *C. citratus* population present in the study area. It is indeed well documented that *Cymbopogon citratus* essential oils show considerable chemical variability depending on geographic origin and growing conditions^{16,18}.

In terms of valorization, geranial is a high-value compound used as a raw material in perfumery and food flavoring, and it possesses significant biological activities, notably antimicrobial¹⁹, anti-inflammatory²⁰, and antiprotozoal²¹ activities. β -myrcene, for its part, is known for its analgesic and muscle-relaxant properties²², as well as its insect-repellent activity. The combination of these two compounds in lemongrass oil gives it a broad-spectrum bioactive profile, justifying its traditional use in the region as a repellent and local remedy.

4.3 Valorization prospects and challenges for local development

The results of this study confirm that orange peels and the aerial parts of lemongrass constitute quality plant bioresources in the Korhogo region, with reproducible chemical compositions and active-compound contents comparable to international standards.

From an economic valorization standpoint, the essential oil sector represents a promising outlet for producers in northern Côte d’Ivoire. The global essential oil market is estimated at more than 7 billion US dollars, with annual growth exceeding 8%²³. In this context, establishing small-scale or semi-industrial distillation units in the region, valorizing both orange peels (an agricultural by-product) and lemongrass (a plant that is easy to grow and maintain), would help create local added value and diversify farmers’ incomes.

However, the sustainable exploitation of these resources requires a robust management framework: harvesting practices that respect the plants’ biological cycles, standardized extraction protocols, and quality control of the produced oils in compliance with international standards (ISO, AFNOR). Further studies are also needed focusing on the *in vitro* and *in vivo* biological activities of the obtained essential oils as well as their potential toxicity to ensure safe use and optimize their applications.

V. CONCLUSION

This study presents the first systematic comparative characterization of essential oils from orange peel (*Citrus sinensis*) and lemongrass (*Cymbopogon citratus*) produced in northern Côte d’Ivoire. GC-MS analysis identified six compounds in the orange oil dominated (94.9%) by d-limonene and five compounds in the lemongrass oil, which exhibits a bimodal profile combining geranial (57.8%) and β -myrcene (34.2%). These distinct yet complementary chemical profiles offer diverse potential applications for both oils in the agri-food, cosmetic, and phytosanitary sectors.

This work is part of a broader effort to valorize local plant bioresources, aligning with sustainable development goals and policies aimed at promoting high-value-added agricultural value chains in northern Côte d'Ivoire. It provides a reliable phytochemical database to guide institutional stakeholders, entrepreneurs, and researchers in the rational utilization of these natural resources.

Our team's future priorities will focus on correlating these chemical data with in-depth biological and toxicological studies and exploring other aromatic species from the region.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest related to the work presented in this article.

REFERENCES

- [1]. Bamba D, Touré A, Dembelé A. Biodiversité floristique et usages ethnobotaniques des plantes médicinales dans la région du Poro (Nord de la Côte d'Ivoire). *Journal of Applied Biosciences*. 2020; 148:15200–15214.
- [2]. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils — A review. *Food and Chemical Toxicology*. 2008;46(2):446–475.
- [3]. Hammer KA, Carson CF, Riley TV. Antimicrobial activity of essential oils and other plant extracts. *Journal of Applied Microbiology*. 1999;86(6):985–990.
- [4]. Ouattara D, Koné M, Traoré D, Koffi AG. Usages ethnobotaniques des plantes aromatiques dans les pratiques médicinales traditionnelles du Nord de la Côte d'Ivoire. *Ethnopharmacologia*. 2019;62:45–56.
- [5]. AFNOR. Norme NF T 75-111. Détermination de la teneur en huiles essentielles des matières végétales aromatiques. Paris: Association Française de Normalisation; 1986.
- [6]. Adams RP. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry. 4th ed. Carol Stream (IL): Allured Publishing Corporation; 2007. 804 p.
- [7]. Sawadogo WR, Boly R, Lompo M, Some N, Lamien CE, Guissou IP, Nacoulma OG. Anti-inflammatory, analgesic and antipyretic activities of *Dicliptera verticillata*. *International Journal of Pharmacology*. 2012;6(4):158–162.
- [8]. Adjé FA, Wotto VD, Lozano P, Menut C, Akossou CYJ. Chemical composition and biological activities of essential oils from the leaves of *Cymbopogon citratus* and *Ocimum gratissimum* grown in Benin. *Natural Product Communications*. 2015;10(7):1239–1242.
- [9]. Dugo G, Di Giacomo A. Citrus: The Genus Citrus. London: Taylor & Francis; 2002. 645 p.
- [10]. Njoku OV, Obi C, Nwora FN. Phytochemical and antimicrobial investigations on leaves and seeds essential oil of *Citrus sinensis* (L.) Osbeck. *Der Chemica Sinica*. 2011;2(1):207–217.
- [11]. Koffi EN, Le Guernevé C, Lozano PR, Menut C, Adjé FA, Bekro YA, Chemat F. Polyphenol extraction and characterization of *Justicia secunda* Vahl leaves for traditional medicinal uses. *Industrial Crops and Products*. 2013; 49:682–689.
- [12]. Dabbah R, Edwards VM, Moats WA. Antimicrobial action of some citrus fruit oils on selected food-borne bacteria. *Applied Microbiology*. 1970;19(1):27–31.
- [13]. Grassmann J, Hippeli S, Elstner EF. Plant's defence and its benefits for animals and medicine: role of phenolics and terpenoids in avoiding oxygen stress. *Plant Physiology and Biochemistry*. 2000;38(6):421–431.
- [14]. Choi WS, Park BS, Ku SK, Lee SE. Repellent activities of essential oils and monoterpenes against *Culex pipiens pallens*. *Journal of the American Mosquito Control Association*. 2004;18(4):348–351.
- [15]. Williams AC, Barry BW. Penetration enhancers. *Advanced Drug Delivery Reviews*. 2004;56(5):603–618.
- [16]. Avoseh O, Oyedéji O, Rungqu P, Nkeh-Chungag B, Oyedéji A. *Cymbopogon* species: ethnopharmacology, phytochemistry and the pharmacological importance. *Molecules*. 2015;20(5):7438–7453.
- [17]. Blanco MM, Costa CARA, Freire AO, Santos JG, Costa M. Neurobehavioral effect of essential oil of *Cymbopogon citratus* in mice. *Phytomedicine*. 2009;16(2–3):265–270.
- [18]. Lewinsohn E, Dudai N, Tadmor Y, Katzir I, Ravid U, Putievsky E, Joel DM. Histochemical localization of citral accumulation in lemongrass leaves (*Cymbopogon citratus*). *Annals of Botany*. 1998;81(1):35–39.
- [19]. Wannissorn B, Jarikasem S, Siriwangchai T, Thubthimthed S. Antibacterial properties of essential oils from Thai medicinal plants. *Fitoterapia*. 1996;75(3–4):233–236.
- [20]. Lalko J, Api AM. Application of the threshold concept in fragrance safety assessment: new data. *Contact Dermatitis*. 2006;54(5):290–301.
- [21]. Tchoumboué J, Tchouanguep MF, Fomunyan RT. Effet antipaludique des extraits aqueux de *Cymbopogon citratus* sur *Plasmodium falciparum*. *African Journal of Health Sciences*. 2005; 12:23–29.
- [22]. Rao VS, Menezes AM, Viana GS. Effect of myrcene on nociception in mice. *Journal of Pharmacy and Pharmacology*. 1990;42(12):877–878.
- [23]. Grand View Research. Essential Oil Market Size, Share & Trends Analysis Report by Application, by Product, by Region, and Segment Forecasts, 2021–2028. San Francisco (CA): Grand View Research; 2021.