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Study of the chemical composition of essential oils and floral waters of *Cymbopogon citratus* (DC.) Stapf (Poaceae) from Senegal

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ABSTRACT

This work aimed to study the chemical composition of essential oils and floral waters of *Cymbopogon citratus* (DC.) Stapf (Poaceae) from Senegal. The plants were collected in two different localities, Dakar and Kaolack. The extracts were obtained by steam distillation from both fresh and dried plants and analyses carried out by GC/FID and GC/MS. Oils from Dakar were dominated by geranial which represented 46.0-43.9%, neral 31.8-31.0%, myrcene 10.8-11.7% and geraniol 2.7-4.2% in the fresh and dried plants, respectively. Their floral waters contained mainly 44.6-41.4% geranial, 39.7-35.6% neral and 8.8-13.2% geraniol. The oils from Kaolack were characterized by geranial which constituted 49.5-44.5%, neral 33.3-31.2%, myrcene 7.2-9.6% and geraniol 4.3-6.1% in the fresh and dried plants, respectively. In their floral waters, it is identified 42.8-33.6% geranial, 38.4-27.6% neral and 12.5-24.5% geraniol. This original study revealed that both oils and floral waters of *C. citratus* from Senegal are characterized by geranial and neral whose repellent properties against mosquitoes are known.

Keywords: *Cymbopogon citratus*, essential oils, floral waters, geranial, neral.

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INTRODUCTION

There is a large biodiversity of aromatic plants in Senegal. Among them, basil, lemongrass, eucalyptus and mint represent four very interesting sources. These plants that contain essential oil are used in many fields such as food, agriculture, perfumery and medicine. But most of them have not yet been investigated. In Senegal, *Cymbopogon citratus* is known for its repellent properties against anopheles mosquitoes which are vectors of Malaria that kills many children in sub-saharan Africa. Recent WHO epidemiological profile in Senegal reports more than 1 case per 1000 population (WHO, 2015). Local intervention policies and strategies include larval control, diagnosis, treatments and surveillance financially supported by Government, Global fund and USAID/PMI. It is also reported that *C. citratus* showed insecticidal, antifungicidal, antiinflammatory, antibacterial and antioxidant activities (Naik et al., 2010; Francisco et al., 2013; Avoseh et al., 2015; Bossou et al., 2015; Briones et al., 2015; Fadli et al., 2016). Efficacy of *C. citratus* is indeed linked to its biochemical composition. In many studies, geranial, neral and myrcene were identified as major constituents of *C. citratus* oils (Bassolé et al., 2011; Costa et al., 2011; Kpoviessi et al., 2014). In addition, the chemical composition of essential oils of *C. citratus* may vary according to the drying methods (Hanaa et al., 2012).

Ongoing researches revealed that endemic plants in Senegal can be valorized for essential oil production. Within an international project designed to promote the production of essential oils in Senegal, several endemic plants among which *C. citratus* have been selected and investigated for their potential uses. The main issue of this global project is to produce bioextracts of plants which can be used in food, pharmaceutical products and for grain protection (Guèye, 2012; Ngom et al., 2014). Although pertinent for the development of local productions, this issue demands previous scientific attention. Indeed, before starting pilote production, it has been logically suggested to study selected samples of plants in order to characterize their essential oils and to make some comparison with commercial products. For that purpose, laboratory scale hydrodistillations have been undertaken followed by chromatographic/ spectrometric characterization of essential oil constituents. The main constraint with essential oils is their low yield, less than 2% (Smadja, 2009). However, floral waters that constituted their by-products are produced in high volume and can also be valorized for both food and pharmaceutical applications. Study from literature showed that essential oils and floral waters are characterized by the same major components (Sutour, 2010; Diop et al., 2016). In order to locally develop valuable products that offer good repellency properties, this original work has been carried out on Senegalese *C. citratus*. The aim of this present work is to study the chemical composition of essential oils (EOs) and floral waters (FWs) of *C. citratus* from Dakar and Kaolack regions, Senegal.

MATERIALS AND METHODS

Plant material and essential oils extraction

Cymbopogon citratus (DC.) Stapf (Poaceae) plants were collected in 2015 in two regions of Senegal: Dakar and Kaolack. After identification, specimens (CD_1 and CK_1) were deposited in the herbarium of the "Institut Fondamental d'Afrique Noire de l'Université Cheikh Anta Diop de Dakar". Essential oils and floral waters were obtained by submitting separately 100 g of both fresh (F) and dried (D) plants (let at room temperature, 18-27 °C for 7 days in the shade) to steam distillation for 30 min using a Clevenger-type apparatus. Oils and floral waters were stored in the refrigerator (at 4 °C) in amber vials until analysis.

Essential oils characterization

Essential oils and floral waters samples were subjected to gas chromatography. Essential oils solutions: 10 mg/10 ml in *n*-

hexane were prepared and diluted four times before analysis. Organic substances from floral waters were extracted by liquid-liquid with *n*-hexane (10/2, v/v). 1 µl of these both solutions were injected by analysis. The following chromatographic conditions were used: injector (Splitless mode) and detector temperatures: 280 °C and 290 °C, respectively; oven: initial temperature 40 °C (5 min), ramp of 8 °C/min until final temperature 280 °C (5 min); carrier gas, helium at a constant rate set at 1.5 ml/min; air and hydrogen flows: 350 ml/min and 35 ml/min, respectively. The column used was a fused silica capillary, Optima-5-MS-Accent (Macherey-Nagel, Düren-Germany), 5% phenyl-95% methylsiloxane (30 m x 0.25 mm, 0.25 µm film thickness).

GC/FID-Trace Ultra GC from Thermo Electron Corporation (Interscience Louvain-La-Neuve, Belgium) fitted with a flame ionization detector was used for determination of the proportion (%) of each constituent.

GC/MS-Identification of components was carried out on a mass spectrometer from Agilent 5973 Network Mass Selective Detector Quadrupole coupled to a gas chromatograph Agilent 6890N (G1530N), USA. Mass spectra were recorded at 70 eV and the mass scanned range was from 50 to 550 amu. The mass spectra were compared to those from a computerized database (Wiley 275 L) and those given in the literature (Joulain and König, 1998; Adams, 2001). Pure compounds confirmed the identification of the major constituents.

RESULTS

The yields of the essential oils extraction were of 0.42 and 0.42% (Dakar) and 0.55 and 0.48% (Kaolack) in the fresh and dried plants, respectively. Oils and floral waters were rich in monoterpenes (Tables 1 and 2). The total content of oxygenated monoterpenes of FWs were higher than those of EOs, whereas monoterpene hydrocarbons were more abundant in EOs. Oxygenated monoterpenes represented 87.0 and 85.8% (EOs) and 98.1 and 98.0% (FWs) for Dakar and constituted 91.8 and 87.1% (EOs) and 97.8 and 95.1% (FWs) for Kaolack in the fresh and dried plants, respectively. In Dakar, oils contained 11.4 and 12.5% and floral waters 1.3 and 1.2% of monoterpene hydrocarbons. The latter were of 7.5 and 10.6% (EOs) and 1.3 and 2.3% (FWs) for Kaolack in the fresh and dried plants, respectively. Sesquiterpenes represented less than 1.0% for both oils and floral waters. The prominent components identified in the EOs of *Cymbopogon citratus* from Dakar and Kaolack were the following four acyclic monoterpenes: geranial, neral, myrcene and geraniol. Floral waters were dominated by geranial, neral, and geraniol; they contained lower proportions of myrcene than essential oils. In EOs from Dakar, geranial represented 46.0 (F) and 43.9% (D) and neral 31.8 (F) and 31.0% (D). They were followed by myrcene 10.8 and 11.7% and geraniol 2.7 and 4.2% in the fresh and dried plants, respectively. FWs from Dakar contained mainly 44.6 (F) and 41.4% (D) geranial, 39.7 (F) and 35.6% (D) neral and 8.8 (F) and 13.2% (D) geraniol. The most important constituents of EOs from Kaolack were geranial which constituted 49.5 (F) and 44.5% (D) and neral 33.3 (F) and 31.2% (D). Myrcene with 7.2 (F) and 9.6% (D) and geraniol 4.3 (F) and 6.1% (D) were also obtained in these oils. In the FWs, it is identified 42.8 and 33.6% geranial, 38.4 and 27.6% neral and 12.5 and 24.5% geraniol in the fresh and dried plants, respectively. Other components were identified in lower rates. 6-methyl-5-Hepten-2-one which was only 0.4 (F) and 0.9% (D) in oils from Dakar and Kaolack, represented 1.1 and 3.1% (Dakar) and 1.3 and 4.2% (Kaolack) in floral waters from fresh and dried plants, respectively. Linalool, rosefuran epoxide, citronellol and geranyl acetate constituted less than 2.0% in both EOs and FWs.

Table 1: Chemical composition of essential oils and floral waters of *Cymbopogon citratus* from Dakar.

Compounds	Retention indices	Essential oils		Floral waters	
		Fresh plants	7 days of drying	Fresh plants	7 days of drying
6-Methyl-5-hepten-2-one	984	0.4	0.9	**1.1**	**3.1**
Myrcene	990	**10.8**	**11.7**	0.5	0.6
α-Phellandrene	1008	-	-	0.1	-
para-Cymene	1028	-	0.2	0.2	0.2
(*Z*)-β-Ocimene	1037	-	-	0.1	-
(*E*)-β-Ocimene	1047	0.2	0.3	0.1	0.3
1-Methyl-4-isopropenylbenzene	1090	0.1	-	-	-
Linalool	1100	**1.1**	**1.1**	**1.2**	**1.4**
para-Mentha-1,5,8-triene	1105	-	-	0.1	-
4-Ethylnon-3-en-5-yne	1113	0.1	-	0.1	-
trans, *para*-2,8-Menthadien-1-ol	1118	-	-	0.1	-
2,3-Dimethoxyphenol	1127	-	-	-	0.1
allo-Ocimene	1129	0.2	0.3	-	-
neo, *allo*-Ocimene	1142	-	-	0.1	0.1
trans-Chtysantemal	1144	0.3	0.3	0.2	0.1
Citronellal	1154	0.3	0.5	0.2	0.2
Not identified	1162	0.5	0.5	-	-
Rosefuran epoxide	1180	**1.4**	**1.4**	0.2	0.2
Menthol	1184	0.6	-	-	-
Isopulegone	1187	0.1	0,1	0.3	0.3
Not identified	1196	0.3	0.3	-	-
Not identified	1205	0.2	0.2	0.4	0.4
4,7-Dimethylbenzofuran	1213	-	0.1	0.2	0.1
Citronellol	1224	0.8	0.9	**1.5**	**1.3**
Neral	1241	**31.8**	**31.0**	**39.7**	**35.6**
Geraniol	1250	**2.7**	**4.2**	**8.8**	**13.2**
Geranial	1270	**46.0**	**43.9**	**44.6**	**41.4**
Not identified	1283	0.2	-	-	-
2-Undecanone	1291	0.9	0.6	-	-
2-Methoxy-4-vinylphenol	1313	-	-	-	0.3
Not identified	1316	-	-	-	0.2
Neric acid	1342	0.2	0.1	0.1	-
Piperitenone	1350	-	-	-	0.8
Geranyl acetate	1375	0.4	0.8	-	-
Eucarvone	1422	-	-	0.1	-
(*E*)-β-Caryophyllene	1437	-	0.1	-	-
trans-α-Bergamotene	1442	-	0.1	-	-
2-Tridecanone	1493	0.4	0.4	-	-
Not identified	1544	-	-	-	0.1
Oxygenated monoterpenes		**87.0**	**85.8**	**98.1**	**98.0**
Monoterpenic hydrocarbons		**11.4**	**12.5**	**1.3**	**1.2**
Oxygenated sesquiterpenes		**0.4**	**0.4**	**0.0**	**0.0**
Sesquiterpenic hydrocarbons		**0.0**	**0.2**	**0.0**	**0.0**
Not identified		**1.2**	**1.0**	**0.4**	**0.7**

Table 2: Chemical composition of essential oils and floral waters of *Cymbopogon citratus* from Kaolack.

Compounds	Retention indices	Essential oils		Floral waters	
		Fresh plants	7 days of drying	Fresh plants	7 days of drying
1-Octen-3-ol	978	-	0.2	-	-
6-Methyl-5-hepten-2-one	984	0.4	0.9	**1.3**	**4.2**
Myrcene	990	**7.2**	**9.6**	0.6	1.0
α-Phellandrene	1008	-	-	0.1	0.1
para-Cymene	1028	0.1	0.3	0.2	0.1
(*Z*)-β-Ocimene	1037	-	-	0.1	0.1
E-(β)-Ocimene	1047	-	0.3	0.2	0.8
trans-linalool oxide	1075	-	-	-	0.1
Linalool	1100	-	0.9	0.9	1.4
para-Mentha-1,5,8-triene	1105	-	-	-	0.1
4-Ethylnon-3-en-5-yne	1113	-	0.1	-	-
trans, *para*-2,8-Menthadien-1-ol	1118	-	-	0.1	-
2,3-Dimethoxyphenol	1127	-	-	-	0.1
allo-Ocimene	1129	0.2	0.3	-	0.1
neo, *allo*-Ocimene	1142	-	-	0.1	-
trans-Chtysantemal	1144	0.3	0.3	0.1	-
Citronellal	1154	0.2	0.4	-	0.2
Not identified	1162	0.2	0.4	-	-
Not identified	1165	-	-	-	0.2
Rosefuran epoxide	1180	**1.4**	**1.3**	0.2	0.1
Menthol	1184	0.2	-	-	-
Isopulegone	1187	-	0.1	-	-
Not identified	1196	-	-	0.2	0.5
Not identified	1205	0.2	0.2	0.5	0.4
4,7-Dimethylbenzofuran	1213	-	-	0.2	0.1
Citronellol	1224	0.8	0.8	**1.4**	**1.2**
Neral	1241	**33.3**	**31.2**	**38.4**	**27.6**
Geraniol	1250	**4.3**	**6.1**	**12.5**	**24.5**
Geranial	1270	**49.5**	**44.5**	**42.8**	**33.6**
Not identified	1283	0.1	0.1	-	-
Not identified	1289	0.1	-	-	0.1
2-Undecanone	1291	0.2	-	-	-
2-Methoxy-4-vinylphenol	1313	-	-	-	1.0
Neric acid	1342	0.2	0.1	0.1	-
Piperitenone	1350	-	-	-	**2.0**
Geranyl acetate	1375	**1.0**	**1.5**	-	-
Eucarvone	1422	-	-	-	0.1
(*E*)-β-Caryophyllene	1437	-	0.1	-	-
trans-α-Bergamotene	1442	-	0.1	-	0.1
2-Tridecanone	1493	0.1	0.2	-	-
Not identified	1544	-	-	-	0.2
Oxygenated monoterpenes		**91.8**	**87.1**	**97.8**	**95.1**
Monoterpenic hydrocarbons		**7.5**	**10.6**	**1.3**	**2.3**
Oxygenated sesquiterpenes		**0.1**	**0.2**	**0.0**	**0.0**
Sesquiterpenic hydrocarbons		**0.0**	**0.2**	**0.0**	**0.1**
Not identified		**0.6**	**0.7**	**0.7**	**1.4**

DISCUSSION

Minor variations were noted in the yields after drying. Plants from Kaolack produced more essential oils than those from Dakar in both fresh and dried plants. Oils and floral waters were dominated by three oxygenated monoterpenes (geranial, neral and geraniol) and one monoterpenic hydrocarbon (myrcene). Depending on the origin, it is showed no important variations in the chemical composition of both oils and floral waters. Both isomers geranial and neral were the most representative compounds identified in oils and floral waters and they decreased after drying. EOs were higher in geranial and lower in neral than FWs in Dakar and Kaolack regions, except the content of neral in FWs of dried plants from Kaolack compared with their EOs. For geraniol, the proportions were more abundant in FWs than EOs and a strong increase of percentages was noted in dried plants compared to fresh plants. The most significant variation observed in the chemical compositions was myrcene, compound which represented 10.8 and 11.7% (Dakar) and 7.2 and 9.6% (Kaolack) in essential oils and identified only between 0.5 and 1.0% in floral waters. Geraniol that represented 8.8 and 13.2% (Dakar) and 12.5 and 24.5% (Kaolack) of the FWs from Senegal constituted also 7.1% in commercial oil of *Cymbopogon citratus* from Pranarom, Belgium (Ahmad and Viljoen, 2015). Geranial, neral and myrcene have been reported as major constituents of several essential oils of *Cymbopogon citratus* (Blanco et al., 2009; Bassolé et al., 2011; Costa et al., 2011; Hanaa et al., 2012; Kpoviessi et al., 2014). In these latter as in those from Senegal and FWs, geranial was the most abundant, followed by neral. These oils showed important biological properties. Costa et al. (2011) indicated the beneficial effects of *C. citratus* in the reducing of the blood cholesterol level. Kpoviessi et al. (2014) reported the antitrypanosomal and antiplasmodial activities of lemongrass oils. Floral waters from Senegal that were also characterized by geranial and neral may constitute an alternative to low yields of oils. The composition of oils and floral waters of *C. citratus* from Senegal is similar to those of the commercial oils from Aroma Zone (France) that contain mainly geranial 40.4%, neral 37.1% and geraniol 8.4%. In this work, the chemical composition of EOs and FWs of *C. citratus* from Senegal has been studied for the first time. Thus, the results showed the chemical profile of the extracts of this aromatic plant which are often used in this country without any information on their biochemical constituents that are responsible of the nutritional and therapeutic properties. *Cymbopogon* essential oil is generally recognized as a power repellent against anopheles. About this, Leal and Uchida (1998) revealed that both geranial and neral were responsible for the efficacy of *C. citratus* against mosquitoes. Ongoing study on the properties of the Senegalese EOs and FWs will provide useful information about their aromatic properties and their use to fight against malaria, one of the deadliest diseases in Africa. To do it, spray against mosquitoes can be formulated with *C. citratus* extracts. As such or microencapsulated with natural products (arabic-gelatin gum, oils of coconut, soybean or olive) that increase its efficacy, this product may play at least locally a key role in malaria prevention (Maia and Moore, 2011; Soonwera and Phasomkusolsil, 2015) but this approach needs further investigations. In alimentary field, floral waters can also be introduced within atomized products for tea and infusions.

Conclusion

The present study is the first conducted on *C. citratus* from Senegal. The results revealed that the origin of the plants and the drying had minor effects on the chemical composition of the EOs and FWs. It is also showed that the EOs and FWs studied have the same major constituents. Indeed both geranial and neral were the prominent compounds of the extracts from Dakar and those from Kaolack. These compounds are known for their repellent properties against mosquitoes and could be used in the fight against malaria. Further researches could allow to study the biological properties of *C. citratus* from Senegal.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

SMD made the extractions, carried out the analyzes and wrote the article; MTG supervised the extractions and participated on the writing of the article; IN supervised the extractions and participated on the writing of the article; MBD participated on the writing of the article; El HBN participated on the analyzes; AT participated on the extractions and the analyzes; M-LF provided the GC/MS apparatus and participated on the analyzes.
GL orientated the research, supervised the analyses and participated on the writing of the article.

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