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Chemical composition of essential oils and hydrosols of three Eucalyptus species from Senegal: *Eucalyptus alba* Renv, *Eucalyptus camaldulensis* Dehnh and *Eucalyptus tereticornis* Hook

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Abstract
The leaves of three eucalyptus species *Eucalyptus Alba*, *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* were collected in Kaolack (Senegal) and were extracted by steam distillation after 3, 7, 14 and 21 days of drying. The volatile components of aqueous distillates (hydrosols) were obtained by liquid–liquid extraction using n-hexane. The different extracts were analyzed by gas chromatography coupled to a flame ionization detector (GC-FID) and by gas chromatography coupled to a mass spectrometer (GC-MS). Essential oils yields obtained range from 0.3 to 1.6%. *E. camaldulensis* had the higher yield. Forty four compounds were characterized in *E. camaldulensis* essential oils. These lasts were dominated by 1.8-cineole (47.54 to 52.47%), limonene (16.5 to 19.1%), α-pinene (7.3 to 11.2%) and p-cymene (6.0 to 8.8%). Fifty compounds were identified in *E. Alba* oils with 1.8-cineole (36.0-38.3%) α-pinene (19.0-26.4%), limonene (5.7- 8.3%), trans-pinocarveol (3.5 -5.0%) β-pinene (1.9 to 4.6%) as major compounds. In *E. tereticornis* oils, fifty two compounds were identified. Their composition were dominated by p-cymene (42.49 to 48.51%) followed by 1.8-cineole (21.3- 24.5%), limonene (4.8- 5.9%) and α-pinene (1.9 to 6.7%). The analyzed hydrosols were composed by oxygenated molecules whose major part was found in oils. As essential oils, all corresponding hydrosols hade high rate of 1.8-cineole. *E. alba* hydrosol contains mainly 1.8-cineole (39.1%), trans-pinocarveol (19.3%), pinocarvone (6.8%). *E. camaldulensis* hydrosol was dominated by 1.8-cineole (52.6%), α-terpineol (6.6%), cis-p-mentha-1-(7)-8-dien-2ol (5.1%). The major compounds of *E. tereticornis* hydrolat were: 1.8-cineole (30.7%), α-terpineol (8.8%), trans-pinocarveol (7.6%), carvacrol (7.0%). The results showed that although 1.8-cineole was the main component of the hydrosols of all eucalyptus species, but its relative content was higher in *E. camaldulensis*.

Keywords: *Eucalyptus alba*, *Eucalyptus camaldulensis*, *Eucalyptus tereticornis*, 1.8-cineole, p-cymene, hydrosol

1. Introduction
Nowadays, essential oils are widely used in perfumery, medicine, pharmacy, as additives in the food industry and as antimicrobial [1]. According to the Senegalese Customs [2], Senegal imports all essential oils for its industries. Moreover, because of the difficulties of provisioning of quantity and quality which they are confronted, the importing Senegalese essential oil companies are in search of new sources. Thus, the biodiversity potential of Senegal can provide possibilities for using essential oils from local plants.
Belonging to the Myrtacea family, the eucalyptus genus has 700 species, most of which originated in Australia [3]. Several species have been recorded in the Senegalese flora, among them *Eucalyptus camaldulensis* is the most distributed in the country and which is widely cultivated species in tropical and subtropical areas of the world [4]. Introduced in Senegal for a long time [4], *E. tereticornis* competes with *E. camaldulensis* in term of resistance and fast-growing [5]. *E. alba* is one of the most known species of Eucalyptus in Senegal.
Eucalyptus essential oils are used in medicine to treat respiratory infections and certain skin diseases [6, 7]. They are also used in cosmetics and food industry as flavoring material [8, 9]. According to Pino *et al*. [10], eucalyptus oils rich in 1.8-cineole are widely used in the pharmaceutical industry. Several studies undertaken on essential oils of eucalyptus showed

antibacterial activities, antifungics, analgesics, anti-inflammatory and insecticide properties of these essential oils [11-14].

The biological activity depends exclusively on oil composition and doses. Knowledge of the composition of essential oils is a quality criterion highly sought by users. Several factors such as origin, variety, harvest season (i.e stage of the plants), storage of biomass can influence the chemical composition of essential oils [15]. Thus, a study undertaken by Cheng *et al*. [16] proved that *E. camaldulensis* oil from Taiwan were in majority composed by α-pinene (22.5%), α-phellandrene (20.1%), p-cymene (21.7%) and 1.8-cineole (9.4%) whereas *E. camaldulensis* essential oil from Morocco had 1.8-cineole (42.3%), α-pinene (28.3%), γ-terpinene (7.3%) and p-cymene (6.5%) as major compounds [17]. *E. alba* oil from Bangladesh contained β-pinene (24.0%), α-pinene (12.9%), β-caryophyllene (7.8%) and limonene (5.2%) as major compounds [18]. According to Bossou *et al*. [19] *E. tereticornis* essential oil from Benin had p-cymene (16.7%), cryptone (11.4%), spathulenol (13.5%), caryophyllene oxide (14.2%) as major compounds and a low content of 1.8-cineole (2.2%). Fresh leaves oil of *E. tereticornis* from India contained 28.5% of α-pinene, 19.5% of 1.8-cineole, 6.6% of γ-terpinene and 5.3% of β-pinene [20].

Aqueous distillate also called floral water or hydrosol is the co-products of hydro-distillation and steam distillation of plant material. Several studies on aqueous distillate have shown that oxygenated molecules [21, 22] accumulate in this by-product.

In order to investigate the potentialities of *Eucalyptus camaldulensis*, *Eucalyptus alba* and *Eucalyptus tereticornis* which are three of the four most known species in Senegalese flora [5], we report the results, the first time done on *E. camaldulensis*, *E. alba*, *E. tereticornis* leaves from Kaolack (Senegal). This work allowed highlighting the influence of factors such as the species used, the drying time and the extraction duration on the yield and chemical composition of essential oils and hydrosols of the same species.

2. Materials and Methods

2.1 Plant materials

The leaves of *Eucalyptus alba*, *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* were harvested in April 2014 in Kaolack (14°13'0" N et 16°12'0" W Senegal). Identification of species was confirmed in the Vegetable Biology Department of Cheikh Anta Diop University (Dakar). Botanicals specimens were deposited in the herbarium of "Institut Fondamental d'Afrique Noire" (IFAN) of Cheikh Anta Diop University (Dakar).

2.2 Essential oil extraction

Fresh leaves collected from field were washed with tap water and dried at room temperature for 03, 07, 14, and 21 days. For each sample, 100 g of leaves were submitted to steam distillation for 2 hours and 4 hours (with 1.5 L water) using a modified Clevenger-type apparatus. The oil yield was calculated relative to the fresh matter (in g of oi1/100 g of fresh leaves).

2.3 Extraction of the volatile constituents from hydrosols

A liquid-liquid extraction method was performed to isolate components of hydrosols which were recovered after essential oil hydrodistillation. In a separatory funnel, 20 mL of hydrosol and 4 mL n-hexane were mixed. After decantation, the extract was dried over anhydrous sodium sulphate and summited to analysis.

2.4 Quantitative and qualitative analysis

The oils and hydrosol extracts were analyzed by gas chromatography coupled with a flame ionization detector (GC-FID) and gas chromatography coupled to mass spectrometry (GC-MS).

2.5 GC-FID: The gas chromatograph coupled with a flame ionization detector (Thermo-Trace, Interscience, Belgium) was equipped with an optima-5-MS-Accent capillary column (30m long, 0.25mm diameter and 0.50 µm film thickness for a complete resolution of 1.8-cineole and limonene which co-eluted with thinner stationary phases). Helium (He) was used as carrier gas at a flow rate of 1.1ml/min. The oven temperature ranges from 40 to 250 °C according to the following program: 40 °C for 3 minutes and then a program rate of 5 °C / min until 250 °C with a final hold of 5 minutes at this temperature. The injector used in splitless mode was at 280 °C. The detector temperature was 280 °C; air and hydrogen flows were of 350 mL/min and 35 mL/min, respectively. A makeup gas (N_2) was used with a flow rate of 30 mL/min.

2.6 GC-MS: The gas chromatograph (Agilent 6890- USA) was equipped with MS (Agilent 5973 NETWORK mass selective detector) in the electron impact mode (70 eV). Scanned Mass range (m/z) was set from 35 to 350 amu. The column was a HP-5MS column (30 m×0.25 mm; film thickness, 0.50 µm). The oven temperature was programmed as follows: isotherm of 5 min at 40 °C then a progression of 8 °C/min up to 280 °C with a final hold of 5 minutes at 280 °C. The injector, used in splitless mode, was at 240 °C. The carrier gas was Helium (He) with a constant flow rate of 1.1 mL/min. The identification of the compounds was made using data of computer library (Wiley 275L) connected to the GC-MS and retention indices of components calculated using retention times of n-alkanes (that were injected after the oil with the same chromatographic conditions) compared with those of the literature [23, 24]. Whenever possible, the results were confirmed by injection of pure standard compounds**.**

3 Results

3.1.1 Extraction yield

Yields of leaves from *E. alba*, *E. camaldulensis* and *E. tereticornis* based on the fresh weight are presented in table1.

Table 1: Essential oil yields (%) of *E. alba*, *E. camaldulensis and E. tereticornis* leaves

Extraction duration	Drying time species	3 days	7 days	14 days	21days
02Hours	*E. alba*	0.6	0.8	0.8	0.8
	E. camaldulensis	1.5	1.5	1.5	1.4
	E. tereticornis	0.4	0.5	0.4	0.3
04Hours	*E. alba*	0.7	0.8	0.9	0.8
	E. camaldulensis	1.5	1.6	1.6	1.5
	E. tereticornis	0.4	0.5	0.5	0.4

The results show that *E. alba*, *E. camaldulensis* and *E. tereticornis* from Kaolack provide quantitatively different yields, which vary according to the time of drying and extraction duration. Yields range from 0.3 to 1.6%. *E. camaldulensis* is the species that provides more essential oil with a maximum of 1.6% on day 21 which are much higher than those of *E. alba* and *E. tereticornis*. The 4 hours extractions provide higher yields for each harvest and each drying day compared to 2 hours extractions. Taking into account the drying time, we noted an increase in yields with drying.

3.1.2 Chemical constituents of essential oils

Based upon total composition of the oils, fifty, forty four and fifty two compounds were identified in *E. alba*, *E. camaldulensis*, *E. tereticornis* accounting for 93.0 to 97.8%, 93.5 to 98.0% and 95.5 to 97.2% of identified constituents, respectively. Oils were mainly constituted of monoterpenes with 31.5 to 37.6% of hydrocarbon monoterpenes and 52.0 to 60.3% of oxygenated monoterpenes in *E. alba* oils and 33.3 to 39.1% of hydrocarbon monoterpenes and 56.1 to 63.5% of oxygenated monoterpenes in those of *E. camaldulensis*. *E. tereticornis* provided 50.7 to 61.8% of hydrocarbon monoterpenes and 30.5 to 41.0% of oxygenated monoterpenes. All oils show low sesquiterpenes content with 3.3 to 6.6% of total constituents in *E. alba*, 0.8 to 1.7% in *E. camaldulensis*; 2.1 to 4.9% of in *E. tereticornis* oils. Tables 2 and 3 show the chemical composition of eucalyptus essential oils.

Table 2: Chemical composition of oils from *E. alba*, *E. camaldulensis*, *E. tereticornis* after 2 hours of extraction

RI	Components	03 days			07 days			14 days			21 days		
		E. Alba	***E. camal***	**E. tere**	***E. Alba***	***E. camal***	**E. tere**	***E. Alba***	***E. camal***	**E. tere**	***E. Alba***	***E. camal***	**E. tere**
928	*α*-thujene	0.1	0.1	tr	0.1	0.1	0.1	tr	tr	0.1	tr	0.1	tr
936	*α*-pinene	20.5	10.6	1.9	20.0	7.3	6.7	19.0	11.1	4.5	20.0	10.8	4.5
954	Camphene	0.9	0.2	tr	0.8	0.1	tr	0.8	0.2	0.1	0.5	0.2	0.1
982	*β*-pinene	3.7	0.4	0.3	4.6	0.2	0.3	4.4	0.2	0.2	4.2	0.2	0.2
988	Myrcène	0.2	0.4	0.2	0.2	0.2	0.2	0.1	0.2	0.3	0.1	0.2	0.1
1008	*α*-phellandrene	0.3	0.5	0.7	0.6	1.2	1.0	0.5	0.5	1.1	0.1	0.6	0.9
1019	*α*-terpinene	-	tr	tr	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1
1026	p-cymene	1.5	8.8	42.5	2.0	7.1	46.2	1.7	6.0	45.3	1.8	5.6	42.5
1032	limonene	8.0	17.9	5.0	8.1	16.5	5.5	5.0	18.2	5.7	6.7	17.8	4.8
1036	1.8-cineole	37.6	47.6	24.1	37.8	52.5	24.5	38.3	51.0	24.1	37.4	50.5	22.7
1060	*γ*-terpinene	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	tr	0.1	0.2
1088	*α*-terpinolene	tr	0.1	tr	0.1	0.2	tr	tr	0.2	0.1	0.1	0.1	tr
1091	Trans-*β*-ocimene	0.1	0.1	-	0.1	0.1	-	0.1	0.2	-	0.1	0.2	-
1103	linalool	0.3	0.2	1.0	0.2	0.2	0.6	0.2	0.2	0.7	0.3	0.2	0.8
1125	fenchol « exo »	1.6	0.2	0.3	1.3	0.2	0.1	1.2	0.2	0.2	1.1	0.2	0.1
1128	*α*-campholenal	3.8	0.2	0.1	2.7	0.1	0.1	7.1	0.2	0.1	6.2	0.1	0.1
1144	terpinene-1ol	-	0.8	0.2	-	1.0	0.1	-	0.8	0.1	-	0.9	0.2
1149	trans-pinocarveol	4.0	-	2.2	4.1	-	1.5	4.2	-	1.7	4.8	-	1.9
1169	pinocarvone	2.5	0.3	1.3	2.5	0.4	0.9	2.4	0.3	1.0	2.1	0.3	1.1
1179	borneol	1.5	0.3	-	1.5	0.4	-	1.5	0.3	-	1.5	0.3	-
1183	terpinene-4ol	0.1	0.5	0.4	0.1	0.7	0.2	0.1	0.5	0.3	0.1	0.5	0.4
1186	P-cymen-8ol	0.1	0.9	1.9	0.1	1.0	1.1	0.1	0.7	1.3	0.1	0.8	1.9
1189	cryptone	tr	0.2	0.4	0.1	0.2	0.3	0.1	0.1	0.3	0.1	0.2	0.5
1192	*α*-terpineol	0.4	1.0	1.0	0.5	1.3	0.6	0.5	1.0	0.7	0.8	1.1	1.1
1199	trans-p-mentha-1-(7)-8-dien-2ol	1.4	1.2	0.6	1.4	1.5	0.3	1.5	1.2	0.4	1.2	1.3	0.6
1202	myrtenol	0.6	-	0.2	0.6	-	0.1	0.6	-	0.1	1.0	-	0.1
1209	trans-piperitol	tr	0.2	1.1	tr	0.3	0.8	tr	0.1	0.9	Tr	0.2	1.3
1222	trans-carveol	0.2	0.3	0.4	0.2	0.3	0.2	0.3	0.2	0.3	0.4	0.3	0.3
1233	Cis-carveol	0.4	1.3	0.9	0.5	1.8	0.5	0.6	1.4	0.6	0.9	1.6	0.7
1235	cis-p-mentha-1-(7)-8-dien-2ol	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1245	cuminal	tr	0.1	0.5	tr	0.1	0.3	tr	0.1	0.4	tr	0.1	0.7
1249	carvone	0.2	0.4	0.4	0.2	0.4	0.3	0.2	0.3	0.3	0.2	0.4	0.3
1254	carvotanacetone	-	0.2	0.9	-	0.2	0.5	-	0.1	0.6	-	0.2	0.8
1261	piperitone	-	0.5	1.4	-	0.5	0.8	-	0.3	0.9	-	0.4	1.5
1285	phellandral	-	-	0.1	-	-	0.1	-	-	tr	-	-	0.1
1292	thymol	1.5	0.4	0.1	2.4	0.2	0.1	1.4	0.1	0.1	1.7	0.2	0.1
1297	carvacrol	-	0.2	1.6	-	0.2	1.0	-	0.1	1.5	-	0.2	1.5
1339	bicycloelemene	0.3	-	-	0.2	-	-	0.2	-	-	0.3	-	-
1364	ni	-	0.2	-	-	0.2	-	-	0.2	-	-	0.2	-
1380	*α*-copaene	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.2
1385	*α*-elemene	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1
1396	*β*-elemene	0.1	0.1	0.2	0.1	tr	0.1	0.1	tr	0.2	0.1	tr	0.3
1433	*β*-caryophyllene	0.9	-	-	0.6	-	-	0.5	-	-	0.8	-	-
1445	calarene	0.1	-	-	0.1	-	-	0.1	-	-	0.05	-	-
1452	Aromadendrene	0.3	0.3	0.7	0.2	0.2	0.4	0.2	0.2	0.5	0.3	0.2	0.7
1458	α-humulene	0.5	-	-	0.9	-	-	0.9	-	-	0.8	-	-
1469	alloaromadendrene	0.1	-	0.2	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1
1474	*γ*-gurjunene	0.1	0.1	0.2	0.1	tr	0.1	0.1	0.1	0.2	0.1	0.1	0.3
1487	germacrene D	0.1	-	-	0.1	-	-	tr	-	-	0.1	-	-
1493	ledène	0.1	0.2	tr	0.1	0.1	0.1	tr	0.1	-	tr	0.1	0.1
1503	bicyclogermacrene	0.1	0.1	0.1	0.1	tr	0.1	0.1	0.1	0.1	0.1	tr	0.1
1508	*γ*-cadinene	0.2	-	-	0.1	-	-	0.2	-	-	0.2	-	-
1523	*δ*-cadinene	tr	-	-	tr	-	-	tr	-	-	tr	-	-
1576	spathunelol	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2

1586	globulol	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1
1590	epiglobulol	0.2	-	0.1	0.2	-	0.1	0.2	-	0.1	0.3	-	0.1
1600	viridiflorol	0.6	0.6	1.3	0.4	0.4	0.7	0.3	0.3	1.0	0.5	0.3	0.7
1621	10-epi-*γ*-eudesmol	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1
1638	*γ*-eudesmol	0.1	0.1	-	0.1	tr	-	0.1	tr	-	0.1	tr	-
1645	hinesol	-	-	0.1	-	-	tr	-	-	0.1	-	-	0.1
1668	*α*-eudesmol	0.3	0.1	0.5	0.2	tr	0.2	0.2	tr	0.4	0.4	tr	0.6
Hydrocarbon Monoterpenes		35.1	39.1	50.7	36.5	33.3	60.2	31.5	36.8	57.4	33.3	36.0	53.4
Oxygenated Monoterpenes		56.2	57.0	41.0	56.3	63.5	34.9	60.3	59.6	36.4	60.1	60.2	38.8
Hydrocarbon sesquiterpenes		2.8	0.6	1.6	2.5	0.3	0.9	2.4	0.4	1.1	2.9	0.4	1.7
Oxygenated sesquiterpenes		1.4	0.9	2.3	1.0	0.5	1.2	0.9	0.4	1.8	1.5	0.4	1.9
Total identified (%)		95.5	97.6	95.6	96.3	97.6	97.2	95.1	97.2	96.7	97.8	97.0	95.8

RI= Rétention Index tr= trace < 0.05%

Table 3: Chemical composition of oils from *E. alba*, *E. camaldulensis*, *E. tereticornis* after 04 hours extraction

RI	Compounds names	3 days			7 days			14 days			21 days		
		E. Alba	***E. camal***	***E. tere***	***E. Alba***	***E. camal***	***E. tere***	***E. Alba***	***E. camal***	***E. tere***	***E. Alba***	***E. camal***	***E. tere***
928	*α*-thujene	0.1	0.1	0.1	0.1	0.1	0.1	tr	0.1	0.1	tr	0.1	0.1
936	*α*-pinene	20.3	10.8	3.4	23.8	10.8	6.5	26.4	11.2	6.0	22.8	10.2	2.3
954	camphene	0.8	0.1	tr	1.0	0.2	0.1	1.0	0.2	0.1	0.9	0.2	tr
982	*β*-pinène	3.1	0.4	0.3	2.8	0.4	0.2	1.9	0.4	0.2	2.3	0.2	0.3
988	myrcene	0.2	0.3	0.3	0.2	0.3	0.2	0.1	0.3	0.2	0.1	0.2	0.2
1008	*α*-phellandrene	0.3	1.0	1.4	0.3	0.9	1.3	0.2	0.4	1.3	0.2	0.6	1.2
1019	*α*-terpinene	tr	0.1	0.1	0.1	0.1	0.1	tr	tr	0.1	tr	0.1	0.1
1026	p-cymene	1.5	6.0	48.5	1.5	6.2	48.2	0.7	6.1	45.5	1.2	6.3	43.0
1032	limonene	8.3	16.7	5.9	7.8	17.6	5.1	5.6	19.1	5.4	6.0	18.0	5.2
1036	1,8-cineole	36.0	47.5	21.3	36.7	48.5	21.6	36.9	49.6	23.0	36.0	50.1	22.2
1060	*γ*-terpinene	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2
1088	*α*-terpinolene	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	tr	0.1	0.2	0.1
1091	trans-*β*-ocimene	0.1	0.1	-	0.1	0.2		0.1	0.2	-	0.1	0.2	-
1103	linalool	0.3	0.2	0.8	0.3	0.2	0.5	0.3	0.2	0.7	0.3	0.2	0.9
1125	fenchol exo	1.6	0.1	0.1	1.4	0.2	0.1	1.5	0.2	0.1	1.4	0.2	0.1
1128	α-campholenal	1.9	0.1	tr	1.8	0.1	0.1	0.2	0.2	0.1	1.6	0.1	0.1
1131	ni	0.3	-	-	0.2	-	-	0.2	-	-	0.3	-	-
1144	terpinene-1ol	-	-	0.2	-	-	0.2	-	-	0.1	-	-	0.2
1149	trans-pinocarveol	3.8	0.7	0.9	3.5	0.8	1.0	4.2	0.7	1.4	4.1	0.8	1.8
1169	pinocarvone	2.5	0.3	0.7	2.2	0.3	0.7	2.5	0.3	0.9	2.5	0.3	1.1
1179	bornéol	1.6	0.3	-	1.4	0.3	-	1.5	0.3	-	1.6	0.3	-
1183	terpinene-4ol	0.1	0.4	0.1	tr	0.5	0.2	0.1	0.5	0.2	tr	0.6	0.3
1186	P-cymen-8ol	0.1	0.7	1.0	0.1	0.8	1.0	0.1	0.7	1.1	0.1	0.8	1.6
1189	cryptone	0.1	tr	0.2	tr	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.4
1192	*α*-terpineol	0.5	0.8	0.4	0.4	1.0	0.4	0.4	0.9	0.6	0.5	1.1	0.9
1199	trans-p-mentha-1-(7)-8-dien-2ol	1.5	1.2	0.3	1.3	1.3	0.3	1.6	1.4	0.4	1.4	1.5	0.6
1202	myrtenol	0.6	-	0.1	0.6	-	0.1	0.6	-	0.1	0.7	-	0.1
1209	trans-piperitol	0.1	0.2	0.8	tr	0.2	0.7	0.1	0.2	0.9	0.1	0.2	1.4
1222	trans-carveol	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.3
1233	cis-carveol	0.5	1.3	0.3	0.5	1.5	0.5	0.5	1.4	0.5	0.6	1.6	0.8
1235	cis-p-mentha-1-(7)-8-dien-2ol	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1245	cuminal	0.1	0.1	0.4	0.1	0.1	0.3	0.1	0.1	0.4	0.1	0.1	0.6
1249	carvone	0.1	0.4	0.2	0.1	0.4	0.3	0.2	0.4	0.3	0.2	0.4	0.4
1255	carvotanacetone	-	0.2	0.6	-	0.2	0.4	-	0.2	0.7	-	0.2	1.0
1260	piperitone	-	0.3	0.5	-	0.4	0.7	-	0.4	0.7	-	0.5	1.2
1285	phellandral	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1
1292	thymol	1.5	1.0		1.5	0.2	tr	1.7	0.2	0.1	2.6	0.2	0.1
1297	carvacrol	-	0.2	1.3	-	0.3	1.3	-	0.2	1.3	-	0.2	1.9
1339	bicycloelemene	0.5	-	-	0.4	-	-	0.4	-	-	0.2	-	-
1364	ni	-	0.1	-	-	0.2	-	-	0.2	-	-	0.2	-
1380	*α*-copaene	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1
1385	*α*-elemene	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1
1396	*β*-elemène	0.1	0.1	0.2	0.1	tr	0.1	0.1	tr	0.1	0.1	tr	0.2
1433	*β*-caryophyllene	1.5	-	-	1.3	-	-	1.3	-	-	1.0	-	-
1452	aromadendrene	0.5	0.3	1.1	0.5	0.4	0.8	0.5	0.3	0.9	0.4	0.3	1.0
1458	*α*-humulene	0.8	-	-	1.3	-	-	1.5	-	-	1.1	-	-
1469	allo-aromadendrene	0.2	-	0.2	0.2	-	0.2	0.2	-	0.2	0.1	-	0.2
1474	*γ*-gurjunene	0.2	0.1	0.3	0.2	0.1	0.2	0.2	0.1	0.3	0.2	0.1	0.3
1484	*α*-amorphene	-	-	0.1	-	-	0.1	-	-	tr	-	-	0.1
1487	germacrene D	0.1	-	0.1	0.1	-	0.1	0.1	-	tr	0.1	-	0.1
1493	ledene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	tr	0.1	0.1	tr
1503	bicyclogermacrene	0.3	0.1	0.1	0.3	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1
1508	*γ*-cadinene	0.3	-	-	0.3	-	-	0.2	-	-	0.2	-	-
1523	*δ*-cadinene	tr	-	tr	tr	-	tr	tr	-	0.1	0.1	-	0.1
1573	ni	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1	-
1576	spathunelol	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
1586	globulol	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1
1590	epiglobulol	0.3	-	0.1	0.2	-	0.1	0.3	-	0.1	0.3	-	0.1
1600	viridiflorol	0.7	0.6	1.5	0.8	0.7	1.3	0.7	0.5	1.1	0.6	0.6	1.5

1621	10-epi-γ-eudesmol	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1	-	0.1	0.1
1638	γ-eudesmol	0.2	0.1	-	0.2	0.1	-	0.2	0.1	-	0.1	0.1	-
1645	hinesol	-	-	0.1	-	-	0.1	-	-	0.1	-	-	0.1
1668	α-eudesmol	0.4	0.2	0.6	0.4	0.1	0.4	0.4	0.1	0.5	0.5	0.1	0.7
Hydrocarbon Monoterpenes		34.8	35.8	60.2	37.6	37.0	61.8	36.3	38.1	58.9	33.7	36.3	52.5
Oxygenated Monoterpenes		53.1	56.1	30.5	52.0	58.1	30.6	53.0	58.4	33.8	54.0	60.1	37.9
Hydrocarbon sesquiterpenes		4.5	0.5	2.2	4.7	0.7	1.7	4.7	0.6	1.7	3.6	0.6	2.1
Oxygenated sesquiterpenes		1.7	1.0	2.7	1.7	1.0	2.2	1.9	0.8	2.0	1.7	0.9	2.8
Total identified (%)		94.1	93.5	95.6	96.0	96.8	96.3	95.9	97.9	96.4	93.0	97.9	95.3

RI= Rétention Index tr= trace < 0.05%

E. alba oils had as major compounds 1.8-cineole (40.0 to 38.3%) followed by α-pinene (19.0 to 26.4%), limonene (5.7 to 8.3%), trans -pinocarveol (3.5 to 5.0%) and β-pinene (1.9 to 4.6%). In *E. camaldulensis* oils, 1.8-cineole (47.5 to 52.5%), limonene (16.5 to 19.1%), α-pinene (7.3 to 11.2%) and p-cymene (6.0 to 8.8%) were the major compounds. *E. tereticornis* oils were dominated by p-cymene (42.5 to 48.5%) followed by 1.8-cineole (21.3 to 24.5%), limonene (4.8 to 5.9%) and α-pinene (1.9 to 6.7%). Other compounds were present in the oils with low percentages. 1.8-cineole, major compound of samples from *E. Alba* and *E. camaldulensis* increases with drying in all oils.

Contrary to 1.8-cineole, the major compounds of *E. tereticornis*, p-cymene did not vary following drying. In all oils, 1.8-cineole rates are higher in the extractions of 2 hours than in those of 4 hours. The contrary was noted with p-cymene and sesquiterpenes. Rates of 1.8-cineole were higher in the *E. camaldulensis* oils than in those of *E. alba*. It was also noted a qualitative difference in chemical composition between oils of three species.

3.1.3 Chemical constituents of hydrosols

Hydrosols analysis showed a composition dominated by oxygenated compounds. The chemical composition of hydrosols of the three species of Eucalyptus is presented in Table 4.

Table 4: Chemical composition of hydrosols from *E. alba*, *E. camaldulensis* and *E. tereticornis*

RI	Compound names	*E. Alba*	*E. camaldulensis*	*E. tereticornis*
958	5-methylfurfural	-	0.1	0.1
988	6-methyl-5-hepten-2-one	-	0.1	-
1009	2.4-heptadienal	-	0.1	0.08
1035	1.8-cineole	39.1	52.6	30.7
1044	benzene acetaldehyde	0.1	0.1	0.2
1091	p-cresol	0.1	0.1	0.4
1093	cis-linalool oxid furanoide	0.1	0.3	0.2
1101	linalool	0.1	-	0.1
1123	fenchol	2.7	0.4	0.6
1128	cis-p-menth-2en-1ol	0.3	0.1	0.1
1138	Trans-p-mentha-2,8-dien-1-ol	-	0.1	0.3
1140	α-campholenal	0.1	-	0.1
1148	trans-pinocarveol	19.3	2.8	7.6
1153	cis-β-terpineol	0.2	0.1	0.1
1158	camphene hydrate	0.1	0.2	0.1
1168	pinocarvone	6.8	1.0	3.0
1173	δ-terpineneol	-	0.3	0.3
1175	borneol	6.1	1.0	0.5
1181	terpinene-4ol	0.2	2.7	1.6
1184	p-cymen-8ol	0.3	2.1	3.9
1190	α-terpineol	3.4	6.6	8.8
1198	trans-p-mentha-1-(7)-8-dien-2ol	6.0	4.8	1.8
1201	myrtenol	2.9	0.1	0.6
1207	α-phellandrene epoxide	-	1.0	5.8
1212	verbenone	0.8	0.8	1.1
1221	trans-carveol	1.5	1.5	1.8
1230	cis-carveol	3.7	3.4	5.0
1233	cis-p-mentha-1-(7)-8-dien-2ol	0.4	5.1	0.6
1240	cuminal	-	0.2	1.4
1247	carvone	0.9	1.1	1.2
1251	carvotanacetone	-	0.5	2.1
1257	Piperitone	-	2.6	6.1
1277	peryl aldehyde	-	0.1	0.2
1286	phellandral	-	0.1	0.6
1288	Thymol	-	0.1	0.3
1292	p-cymen-7ol	0.1	0.1	0.5
1295	carvacrol	0.1	1.2	7.0
1339	exo-2-hydroxycineole acetate	0.1	0.3	-
1394	cis-jasmone	0.1	0.1	0.2
1597	globulol	0.2	0.2	0.3
1634	10-epe-γ-eudesmol	-	0.1	0.1
1641	γ-eudesmol	-	0.1	0.1
1662	β-eudesmol	0.1	0.1	-
1667	α-eudesmol	0.2	0.1	0.3
Total identified (%)		95.6	93.9	95.5

RI= Rétention Index

Relatively to the total composition, twenty nine compounds were identified in the hydrosol from *E. alba* representing 95.6%. As for *E. camaldulensis*, forty two compounds in floral water were present accounting for 93.9%, and forty one compounds were found in *E. tereticornis* floral water representing 95.5%. *E. alba* hydrosol contained mostly 1.8-cineole (39.1%), trans-pinocarveol (19.3%), pinocarvone (6.8%), borneol (6.1%), trans-p-mentha-1-(7)-8-dien-2ol (6.0%) and cis-carveol (3.7%). *E. camaldulensis* floral water was dominated by 1.8-cineole (52.6%), α-terpineol (6.6%), cis-p-mentha-1-(7)-8-dien-2ol (5.1%), trans -p-mentha-1-(7)-8-dien-2ol (4.8%), cis-carveol (3.4%). The major compounds of *E. tereticornis* hydrosol were: 1.8-cineole (30.7%), α-terpineol (8.8%), trans-pinocarveol (7.6%), carvacrol (7.0%), piperitone (6.1%), α-phellandrene epoxide (5.8%), cis-carveol (5.0%).

4. Discussion

The results revealed that the three species of Eucalyptus from Kaolack (Senegal) had different essential oils yields. *E. camaldulensis* provided much higher yields. Although lows, *E. alba* and *E. tereticornis* yields were comparable to those found on Eucalyptus leaves by Marzoug *et al*. [11], Alain *et al*. [25], Chalchat *et al*. [26] with 0.5%, 0.2% and 0.5%, respectively. Yields increase with drying. The most interesting were obtained after 7, and 14. According to Bourkhiss *et al*. [27], increased essential oil content of plants with drying is related to the biosynthesis of essential oils which continues and accelerates after harvest. According to these same authors, the decrease yield after seven days of drying would be due to the reduction or discontinuation of enzymatic activity causing cell death due to severe dehydration.

1.8-cineole is the major compound in *E. alba* and *E. camaldulensis* essential oils with 36.0 to 38.3% and 47.5 to 52.5%, respectively. These rates of 1.8-cineole were very close to those found by Panahi *et al*. [28] and Lima *et al*. [29] in *E. amaldulensis* oils (54.4% and 46.7%, respectively) and significantly higher than those found by Mondello *et al*. [18] in *E. alba* oil from Bangladesh (1.4%). α-pinene rates were higher in *E. alba* oils than in those of *E. camaldulensis* and *E. tereticornis*. The results reported by Mondello *et al*. [18] on *E. Alba* from Bangladesh also show a high content of α-pinene. *E. tereticornis* oils had p-cymene and 1.8-cineole as major compounds; they had lower rates of 1.8-cineole than those contained in the *E. alba* and *E. camaldulensis* oils. This composition dominated by p-cymene and 1.8-cineole is in accordance with the results of Cimanga *et al*. [30] conducted on *E. tereticornis* which obtained oils with p-cymene as major compound and a low percentage of 1.8-cineole. Oils of the three species, *E. alba*, *E. camaldulensis* and *E. tereticornis* studied showed quantitative and qualitative differences of composition. Thus, trans-β-ocimene, borneol, thymol, bicycloelemène, β-caryophyllene, α-humulene, and γ-eudesmol were present in *E. alba* and *E. camaldulensis* oils and not in *E. tereticornis* oils. On the other hand, myrtenol, carvotanacetone, piperitone, phellandral, carvacrol, α-copaene, α-elemene were present only in *E. camaldulensis* and *E. tereticornis* oils. This qualitative difference in composition confirms the works of Sefidkon *et al*.[7] who found a qualitative difference in the composition of oils from four eucalyptus species (*E. microtheca*, *E. spathulata*, *E. torquata* and *E largiflorens*) of Iran. 1.8-cineole and α-pinene increases with drying in all oils. Zrira *et al*. [31] following studies undertaken on *E. camaldulensis* from Morocco noted that α-pinene and 1.8-cineole increase with drying.

The rates of some monoterpenes such as 1.8-cineole are higher in the extractions of 2 hours than in those of 4 hours. The contrary was noted for α-pinene, p-cymene and sesquiterpenes. This could be explained by the extraction order of compounds. According Medjdoub and Katsiotus [32], the sesquiterpenoids components need longer extension of distillation to reach their higher yields.

Analysis of hydrosols showed a composition strongly dominated by oxygenated molecules. This confirmed previous studies of hydrosol by Collin *et al*. [22]. Essential oils and hydrosols from *E. alba* and *E. camaldulensis* had 1.8-cineole as major compound. This result confirms those of Śmigielski *et al*. [20] who found the same major compound in essential oils and hydrosol from *Lavandula angustifolia*. The rate of some compounds such as 1.8-cineole, trans-pinocarveol, α-terpineol, trans-p-mentha-1-(7)-8-dien-2ol, cis-carveol were higher in hydrosols than in essential oils. Other compounds were present in hydrosol and not in the essential oils. This suggests that during extraction hydrophilic oxygeneted molecules pass in the hydrosol.

5. Conclusion

Based on their chemical composition, *E. Alba*, *E. camaldulensis* and *E. tereticornis* leaves harvested in Kaolack (Senegal) provided essential oils qualitatively and quantitatively different. This could be related to genetic or abiotic factors. All essential oils show chemotypes with acceptable rate of 1.8-cineole with a maximum in *E. camaldulensis* oil. It is also noted that the percentages of major compounds vary with drying and extraction duration. Analyzed aqueous distillates that had shown a high content of oxygenated molecules especially 1.8-cineole opens a track towards the valorization of Senegalese essential oil bearing plants.

This first study on essential oils and floral water chemical characterization of *E. alba*, *E. camaldulensis* and *E. tereticornis* from Senegal could contribute to the valorization of eucalyptus through a local essential oil production.

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