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RESEARCH ARTICLE

HEMI-SYNTHESIS AND UV-VISIBLE SPECTROPHOTOMETRIC CHARACTERIZATION OF 2,4-DINITROPHENYLHYDRAZONES DERIVED FROM CITRAL AND CITRONELLAL ESSENTIAL OILS OF TWO AROMATIC PLANTS ACCLIMATIZED IN CONGO-BRAZZAVILLE

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Abstract

The orange-yellow and colorless essential oils with respective yields of 1.54% and 3.59% were extracted from the dry leaves of *Cymbopogoncitratus* (DC.) Stapf and *Eucalyptus citriodora* Hook. collected south of Brazzaville. Analysis by gas chromatography (GC) and by gas chromatography coupled with mass spectrometry (GC/MS) allowed the identification of fifteen (15) and eight (8) constituents representing (96.25%) and (98.46%) of total essential oils respectively. *Cymbopogoncitratus* oil consists mainly of geranial (51.99%) and neral (32.94%), two geometric isomers constituting citral which occupies a rate of 84.93%. While citronellal with a high level of (80.72%) and citronellol (10.48%) are the major compounds of the essential oil of *Eucalyptus citriodora*. Geranial (citral a) and citronellal 2,4-dinitrophenylhydrazones were hemi-synthesized by a simple, easy method, respectively from essential oils of *Cymbopogoncitratus* and *Eucalyptus citriodora* with respective conversion rate (yields) of 20%. and 37%, in a short time (three to five minutes). Analysis of geranial and citronellal 2,4-dinitrophenylhydrazones by UV-visible spectrophotometry showed maximum absorption wavelengths of 390 nm and 370 nm respectively. The UV-visible spectrophotometric method employed for the determination of these hydrazones is convenient, fast and simple. The hemi-synthesized hydrazones could be useful in the pharmaceutical industry, in perfumery, cosmetic and in biomedicine.

Introduction:-

Among the organic compounds contained in the essential oils of certain aromatic plants are carbonyl compounds (aldehydes and ketones) with high proportions reaching 85%. This is the case of citral (geranial and neral) and citronellal in the essential oils of *Cymbopogoncitratus* and *Eucalyptus citriodora* respectively (Ndzeli et al., 2019a; Ndzeli et *al*., 2019b). These are chemical compounds which have a remarkable interest, intervening in a wide field of application (cosmetics, perfumery, pharmaceuticals, food industry, chemical industry). They are endowed with various chemical properties due to the presence of the C=O double bond giving rise to several nucleophilic and electrophilic addition reactions (Vollhard, 1995). However, the main disadvantage or disadvantage of these

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compounds is their instability which often results in oxidations, hence the need to convert them into hydrazones, crystalline compounds more stable than their precursors (carbonyls) (Quédraogo et *al*, 2009; Adjeroud, 2017).

Hydrazones are organic compounds of the general formula:
RR'C=N-N-R''R ''. 2,4-Dinitrophenylhydrazones are substituted hydrazones, derived from the condensation of an aldehyde or a ketone with 2,4-dinitrophenylhydrazine (Hany et *al*, 2015) (Figure 1); a reversible reaction subjected to acid catalysis (Rauk, 2001). They play an important role in the protection of carbonyl compounds (Greene et *al*.; 1999). They are also used for the isolation, purification and characterization of the carbonyl group (Shriner et *al.*, 1980) and as an intermediate in organic synthesis (Armbruster et *al*., 2006). Furthermore, hydrazones are used for the extraction or determination of transition metals such as iron (Shobha, 2011), molybdenum (Battula et *al*., 2012) by formation of hydrazonic metal complexes.

Regarding pharmacology, many studies affirm that hydrazones have various biological properties: antimicrobial, (Maldovan et *al*., 2012, Alberta Ade et *al*., 2020), antibacterial (Azim et *al*., 2014), (Ümmühan et *al*., 2008); antioxidant (Belkheire et *al*., 2010); analgesic, anti-inflammatory (Mohammad and Asif, 2013); antitoxoplasma, antimalarial, anticoagulant, anticonvulsant, antihypertensive, antitumor (Singh and Raghv, 2011). In addition, hydrazones are endowed with pesticide activities (Ali et *al*., 2009), antiviral, protozoan and antifungal activities (Sevim et *al*, 2007; Mehan et *al*., 2019; Ortiz et *al*., 2016).

It should be noted that the metal complexes derived from hydrazones are used in the treatment of tuberculosis (Srimam et *al.*, 2005).

To these biological properties are added electrochemical properties (Torje et *al*., 2012).

Several syntheses of 2,4-dinitrophenylhydrazones from marketed aldehydes and ketones have been reported in the literature (Monfared et *al*, 2007; Al-Rekabi, 2011; Anwar and Nour, 2016; Dinore et *al*., 2016; Iqbal et *al*., 2019). Very few studies on the hemi-synthesis of hydrazones derived from aldehydes and ketones of essential oils are described in the literature. We can cite the hemi-synthesized hydrazones of essential oils with an aldehyde chemotype (cuminaldehyde and perillalaldehyde) recently carried out in Algeria (Bouchachia and Ameur, 2019).

To our knowledge, the hemi-synthesis of 2,4-dinitrophenylhydrazones from the aldehydes (citral and citronellal) of essential oils is not known.

Various analytical techniques including GC-MS (Tai-sheng et *al*., 2013); LC-MS (Akdo et *al*., 2011), HPLC (Jianrong et *al*., 2007) are used for the determination of 2,4-dinitrophenylhydrazones. However, these analytical methods involve long analysis time, tedious sample pretreatment, and high product cost.

The aim of this present work is to extract essential oils, to hemi-synthesize and to characterize 2,4-dinitrophenylhydrazones derived from citral and citronellal by UV-Visible spectrophotometry, a simple and rapid method.

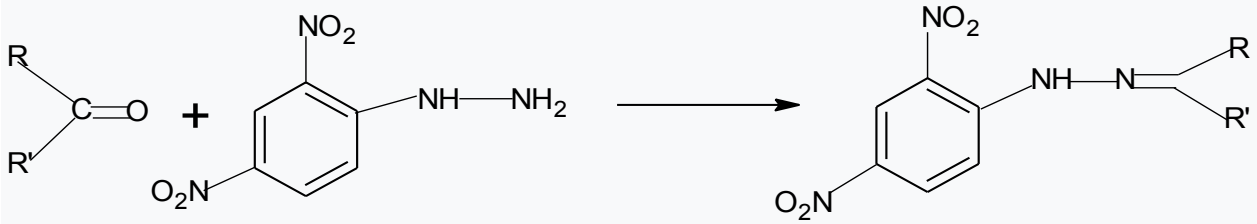

Figure 1:-Reaction of a carbonyl compound with 2,4-dinitrophenylhydrazine.

Materials and Methods:-

Plant material:
Samples of *Cymbopogoncitratus* (DC.)Stapf and *Eucalyptus citriodora* Hook. (Figure 2 and 3) were collected in January 2019 in the southern districts of Brazzaville (Makelekelé), respectively in the garden of the Library of the

University Marien NGOUABI and in the garden of the General Directorate of Examinations and Competitions.They were identified by botanists from the National Herbarium of the Congo. Only leaves were selected for the study.

Figure 2:- *Cymbopogoncitratus*(DC.) Stapf species

Figure 3: Leaves of the species *Eucalyptus citriodora* Hook.

Extraction of essential oils:

After eight (8) days of drying at room temperature, in a ventilated room, the samples of *Cymbopogoncitratus* and *Eucalyptus citriodora* made up of the leaves are subjected to hydrodistillation for four (4) hours using an extractor. Clevenger type (Clavenger, 1928), fitted with a two (2) liter balloon. The condensate loaded with essential oil and hydrolate is collected. The essential oil is separated from the hydrolate by decantation. The extraction with diethyl ether is carried out to isolate the aqueous phase of the essential oil followed by drying of the ether phase with anhydrous sodium sulfate. Twenty-four (24) hours after evaporation of the diethyl ether in air, the essential oil is recovered. These operating conditions are summarized in Table I. The yield R in essential oil is calculated according to the following formula.

Tableau I :- Operating conditions for hydrodistillation of leaves of *Cymbopogoncitratus* (DC.) Stapf and *Eucalyptus citriodora* Hook.

Vegetable matter	***Cymbopogoncitratus***	***Eucalyptus citriodora***
organs	Leaves	Leaves
Quantity of matter dry (g)	183	155
Quantity of water (L)	1	1
Execution time of the operation (h)	4	4

Analysis of essential oils:

Analysis by gas chromatography:

The quantification of the constituents was carried out using a Hewlett Packard HP 5890 type chromatograph equipped with a flame ionization detector equipped with HP ChemStation data acquisition software. The different constituents are separated using a DB5 capillary column (30 mx 0.25 mm), (film thickness 0.25 µm) under the following operating conditions: helium carrier gas (1 $mL.min^{-1}$), temperature injector temperature: 280 °C, detector temperature: 280 °C. The oven is programmed at 50 °C for 5 minutes with a gradient of 5 ° $C.min^{-1}$ from 50 to 300 °C, 5 minutes at 300 °C with a split mode injection of 1-20.

Analysis by gas chromatography-mass spectrometry:

Analysis by gas chromatography-mass spectrometry was carried out using a Hewlett Packard HP 6890 brand chromatograph coupled to an HP 5973 mass spectrometer. The various constituents are separated using a DB5 capillary column (30 mx 0.25 mm), (film thickness 0.25 µm) under the following experimental conditions: carrier

gas: (helium: 1 mL.min^{-1}), ionization energy (70 eV), temperature of injector (280 °C), detector temperature (280 °C). The oven is programmed at 50 °C for 5 minutes with a gradient of 5 °C. min^{-1} from 50 to 300 °C, 5 min at 300 °C with a 1-10 split mode injection.

Identification of constituents:
The various constituents of essential oil have been identified on the basis of their retention indices and their mass spectra by comparison with data from the literature (Adams, 2001; Joulain et *al*., 1998; Davies, 1990).

Hemi-synthesis of 2,4-dinitrophenylhydrazones:
The 2,4-dinitrophenylhydrazine reagent and essential oils from the species *Cymbopogoncitratus* and *Eucalyptus citriodora* are used for the preparation of hydrazones.

The method used has been reported by (Leclercq, 2008). It consists of dissolving 0.25 g of 2,4-dinitrophenylhydrazine in 5 mL of methanol, followed by addition of 0.5 mL of concentrated sulfuric acid, then filtration of the lukewarm solution. To this solution are added 0.2 g of essential oil previously solubilized in a small volume of methanol. After about three (3) to five (5) minutes, the solid formed is filtered off and washed in a little methanol. If there is no solid, the solution is acidified with sulfuric acid. The precipitate is then recrystallized from ethanol and then dried. These conditions are summarized in (Table II).

Tableau II:- Operating conditions for the synthesis of 2,4-dinitrophenylhydrazones.

Essential oils	Quantity of reagent (g)	Quantityof EO (g)	Quantity of MeOH (mL)	Quantityof H_2SO_4 (mL)
Cymbopogon.citratus	0.25	0.2	5	0.5
Eucalyptus. citriodora	0.25	0.2	5	0.5

Characterization of 2,4-dinitrophenylhydrazones:
Determination of melting points:
The measurement of the melting temperatures of the prepared hydrazones is carried out using the kofler bench.
The method consists of calibrating the device with benzoic acid which has a melting point of 122.35 °C. The carriage is moved horizontally until the cursor is at the border between solid and liquid. Then the movable index is moved vertically until it indicates the melting point of the standard. The hydrazone's melting point is then taken by depositing it at the cold end of the kofler bench and moving it towards the hot zone until the first drops of liquid appear. The carriage is then moved horizontally until the cursor is at the border between solid and liquid. The moving index then indicates the melting point. Three tests are carried out.

UV-visible spectrophotometric analysis:
The analysis of 2,4-dinitrophenylhydrazones is done by a UV-visible WPA Lightwawe II spectrophotometer, connected to an HP computer.

Preparation of solutions:
2,4-Dinitrophenylhydrazine solution:
A solution of 2,4-dinitrophenylhydrazine is prepared by dissolving 0.3 g of 2,4-dinitrophenylhydrazine in 100 mL of a 0.05 M sulfuric acid solution.

Essential oil solution:
The essential oil (10 to 20 mg) is placed in a 10 mL vial in which methanol is added to the mark.

Spectral scan:
2.4-dinitrophenylhydrazones scan:
0.5 mL of the 2,4-dinitrophenylhydrazine solution is added to 0.5 mL of the essential oil solution. An orange or brown precipitate forms depending on the essential oil used. The precipitate is left to stand for 10 minutes at room temperature and 5 ml of methanol are added to it: This is the solution of 2,4-dinitrophenylhydrazone**.**
We put in the reference tank
• 1 mL of the 30% (V/V) water/ethanol solvent
and in the measuring tank:

• 1 mL of the 2,4-dinitrophenylhydrazone solution

Results and discussion:-

Extraction and yield of essential oils:

Hydrodistillation extraction from the dry leaves of *Cymbopogoncitratus* from *Eucalyptus citriodora* provides orange-yellow and colorless essential oils with yields of 1.54% and 3.59% respectively (Table III). The yield of *Eucalyptus citriodora* essential oil (3.59%) is higher than that of *Cymbopogoncitratus* essential oil (1.54%). *Eucalyptus citriodora*essential oil can be produced in high yields of up to 4-6% (Mapola, 2004). The result of the extraction yield of the essential oil of *Eucalyptus citriodora*agrees with that described in Congo indicating a yield of 3.57% (Silou, et *al*., 2013), while that of the oil of *Cymbopogoncitratus* (DC.) Stapf (1.54%) is similar to that of essential oil of Togolese origin, which has a value of 1.60% (Koba et *al*., 2009).

Tableau III :- Extraction yield of essential oils from the leaves of *Cymbopogoncitratus* (DC.) Stapf and *Eucalyptus citrodora* Hook.

species	**yield (%)**	
	Our study	**Previous studies / origin**
Cymbopogoncitratus(DC.) Stapf	1.54	1.60 (Koba et *al*., 2009)/Togo
*Eucalyptus citriodora*Hook.	3.59	3,57 (Silou et *al*., 2013) /Congo

Chemical composition of essential oils:

Cymbopogoncitratus:

The results of the chemical analysis of the essential oil extracted from the leaves of *Cymbopogoncitratus* are shown in (table VI). In total, fifteen (15) constituents were identified representing (96.25%) of the chemical composition of the total essential oil. The essential oil is rich in monoterpenes (95.87%) with a dominance of oxygenates (90.24%) of which the most remarkable are géranial (51.99%) and neral (32.94%), two geometric isomers constituting the citral which occupies a rate of 84.93%. Hydrocarbon monoterpenes represent a rate of 5.63% with mainly myrcene (5.52%) and (Z) -ocimene (0.11%) as components.

In the group of sesquiterpenes, the hydrocarbon compounds are represented by a single constituent, β caryophyllene, which occupies a very low level of (0.07%). We note the absence of oxygenates.

These results are qualitatively in agreement with those of the literature which describe samples containing citral proportions of 79.28% and 100% respectively (Silou et *al*., 2017; Barreira et *al*., 2004).

Tableau VI:- Chemical composition of the essential oil of *Cymbopogoncitratus* (DC.) Stapf.

N°	**Compounds**	**Tr**	**%**
1	6-Methyl-5-Heptene one	6.09	0.31
2	**Myrcene**	6.13	**5.52**
3	(Z)-β-Ocimene	7.03	0.11
4	Linalool	8.16	0.68
5	Isopulegol	8.95	0.16
6	Citronellal	9.01	0.53
7	Terpinene-4-ol	9.45	0.48
8	Nerol	10.13	0.07
9	Citronellol	10.16	0.45
10	**Neral**	10.34	**32.94**
11	**Lynalyl acetate**	10.50	**2.34**
12	**Geranial**	10.78	**51.99**
13	Citronellyl acetate	11.87	0.29
14	Geranyl acetate	12.24	0.31
15	β-Caryophyllene	12.78	0.07
Total compounds identified **Oxygenated monoterpenes** **Hydrocarbonsmonoterpenes**			**96.25** **90.24** **5.63**

Hydrocarbonssesquiterpenes	**0.07**
Aliphatic compounds	**0.31**

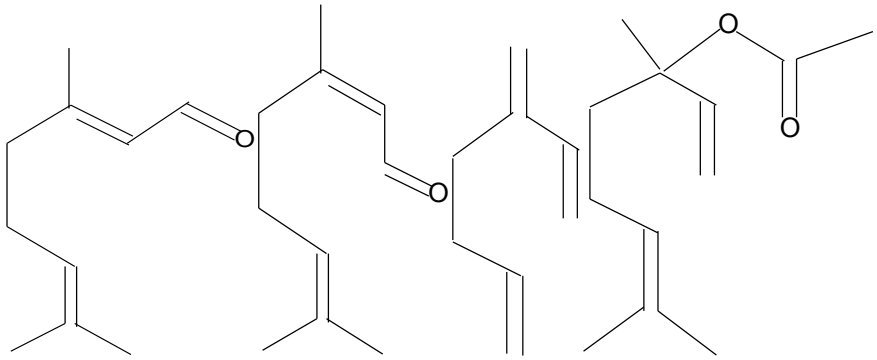

Figure 4:- Chemical structures of the main constituents of essential oil of *Cymbopogoncitratus* (DC.) Stapf.

Eucalyptus citriodora:

Table V collates the results of the chemical analysis of the essential oil extracted from the leaves of *Eucalyptus citriodora*. In total, eight (8) constituents were identified representing (98.46%) of the chemical composition of the total essential oil. The essential oil is characterized by a large amount of monoterpenes (97.96%) dominated by oxygenated monoterpenes (97.20%) of which the major compounds are citronellal with a high rate of (80.72%), citronellol (10.48%), lisopulegol (3.91%). We note the presence of a single hydrocarbon compound, β-pinene, which occupies a low level of (0.76%). The sesquiterpenes group remains marked by a single hydrocarbon compound, E caryophyllene, the level of which is low, amounting to (0.13%). Aliphatic compounds are characterized by ethylenic aldehyde 2,6 dimethyl hept-5-en-1-al in such a low proportion (0.37%).

These results agree qualitatively with those of *Eucalyptus citriodora* of Algerian origin, with citronellal (69.77%), citronellol (10.63%) and isopulegol (4.66%) as major compounds (Tolba et *al*, 2015). Also the sample of Ethiopian origin shows a chemical composition dominated by citronellal (73.86%) and citronellol (14.13%) (BekriMelka, 2019).

N°	Compounds	IK	%
1	β-Pinene	977	0.76
2	1,8 Cineole	1033	-
3	Melonal	1052	-
4	Linalol	1100	-
5	2,4 Dimethylhept-5-en-1-al	1150	0.37
6	**Isopulegol**	1152	**3.91**
7	**Citronellal**	1154	**80.72**
8	**(iso) isopulegol**	1161	0.24
9	**Citronellol**	1230	**10.48**
10	**Citronellyl format**	1276	-
11	Thymol	1296	-
12	Thymyl acetate	1355	-
13	Eugenol	1362	-
14	Methyleugenol	1404	1 .85
15	E-Caryophyllene	1426	0.13
16	a-Gurjunene	1430	-
Total compounds identified			**98.46**
Oxygenated monoterpenes			**97.20**
Hydrocarbonsmonoterpenes			**0.76**
Hydrocarbonssesquiterpenes			**0.13**
Aliphatic compounds			**0.37**

Tableau V:- Chemical composition of *Eucalyptus citriodora* Hook. essential oil.

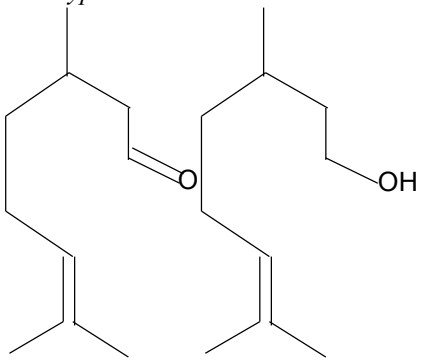

Figure 5:- Chemical structures of the main constituents of *Eucalyptus citriodora* Hook. essential oils.

Hemisynthesis of 2,4-dinitrophenylhydrazones:

Physical characterization:

Table VI shows the results of the hemi-synthesis of 2,4-dinitrophenylhydrazones and their measured melting points. The reaction of 2,4-dinitrophenylhydrazine in the presence of sulfuric acid on the essential oils of *Cymbopbogoncitratus* and *Eucalyptus citriodora* gives rise to precipitates of orange and brown colors respectively. These colors are characteristic of 2,4-dinitrophenylhydrazone derivatives.

The essential oils of *Cymbobogoncitratus* and *Eucalyptus citriodora* contain a varied range of constituents, 2,4-dinitrophenylhydrazones are formed after three (3) to five(5) minutes, the kinetics are slow so the extraction is also slow. Moreover, the yields of the hemi-synthesis of 2,4-dinitrophenylhydrazones obtained from these essential oils are low and respectively 20% and 37%. These low yields can be explained by the influence of the different constituents of essential oils during the reaction. In fact, the presence of the different constituents in essential oils changes the speed of extraction, resulting in slow kinetics. This slowing down means that there is competition or hindrance between the compound to be extracted and the other constituents of the mixture. This Competition is linked to steric and electronic effects.

Furthermore, the melting points of the hydrazones of the essential oils of *Cymbopogoncitratus* and *Eucayptuscitriodora* are 114 °C and 79 °C, respectively. These melting points are approximate to those in the literature (Rappoport, 1967) and correspond respectively to those of geranial and citronellal.

Tableau VI:- Yields and physical properties of the various 2,4-dinitrophenylhydrazones synthesized.

Compounds of essential oils converted to 2,4-dinitrophenylhydrazones	**Aspect**	**Colour**	**yield (%)**	**Pf measured (°C)**	**Pfof literature (°C)**
Cymbopogoncitratus (citral)	Precipitate	Orange	20	114	96-116
Eucalyptus citriodora(Citronellal)	Precipitate	Brown	37	79	78

Characterization by UV-visible spectrophotometry:

The maximum wavelengths of géranial and citronellal 2,4-dinitrophenylhydrazones derived from essential oils of *Cymbopogoncitratus* and *Eucalyptus citriodora*respectively of 390 nm and 370 nm were recorded (Table VII). These values are characteristic of the C=N chromophore of 2,4-dinitrophenylhydrazones, the wavelength of which at absorption maximum is (λmax = 360-370 nm) (Zhou &Mopper, 1990; Pötter et *al*., 1997; Levart&Veber, 2001).

Tableau VII:- Maximum absorption wavelengths of geranial and citronellal 2,4-dinitrophenylhydrazones.

2,4-Dinitrophenylhydrazone derivatives	**λmax(nm)**
	390

Géranial 2,4-dinitrophénylhydrazone	
Citronellal 2,4-dinitrophenylhydrazone	370

***Cymbopogoncitratus*(Géranial 2,4-dinitrophénylhydrazone):**

The UV-visible absorption spectrum of geranial 2,4-dinitrophenylhydrazone from the essential oil of *Cymbopogoncitratus* plotted in (Figure 6) shows three main bands:

1. A low intensity band at 247 nm. This band is attributable to the π→π* transition of the C=C group of the ethylenic group;
2. A low intensity band at 298 nm. This band corresponds to the transition→σ * relating to the aniline aromatic system;
3. Another not very intense band at 390 nm relating to the n→π* transition characteristic of the C=N group of hydrazone.

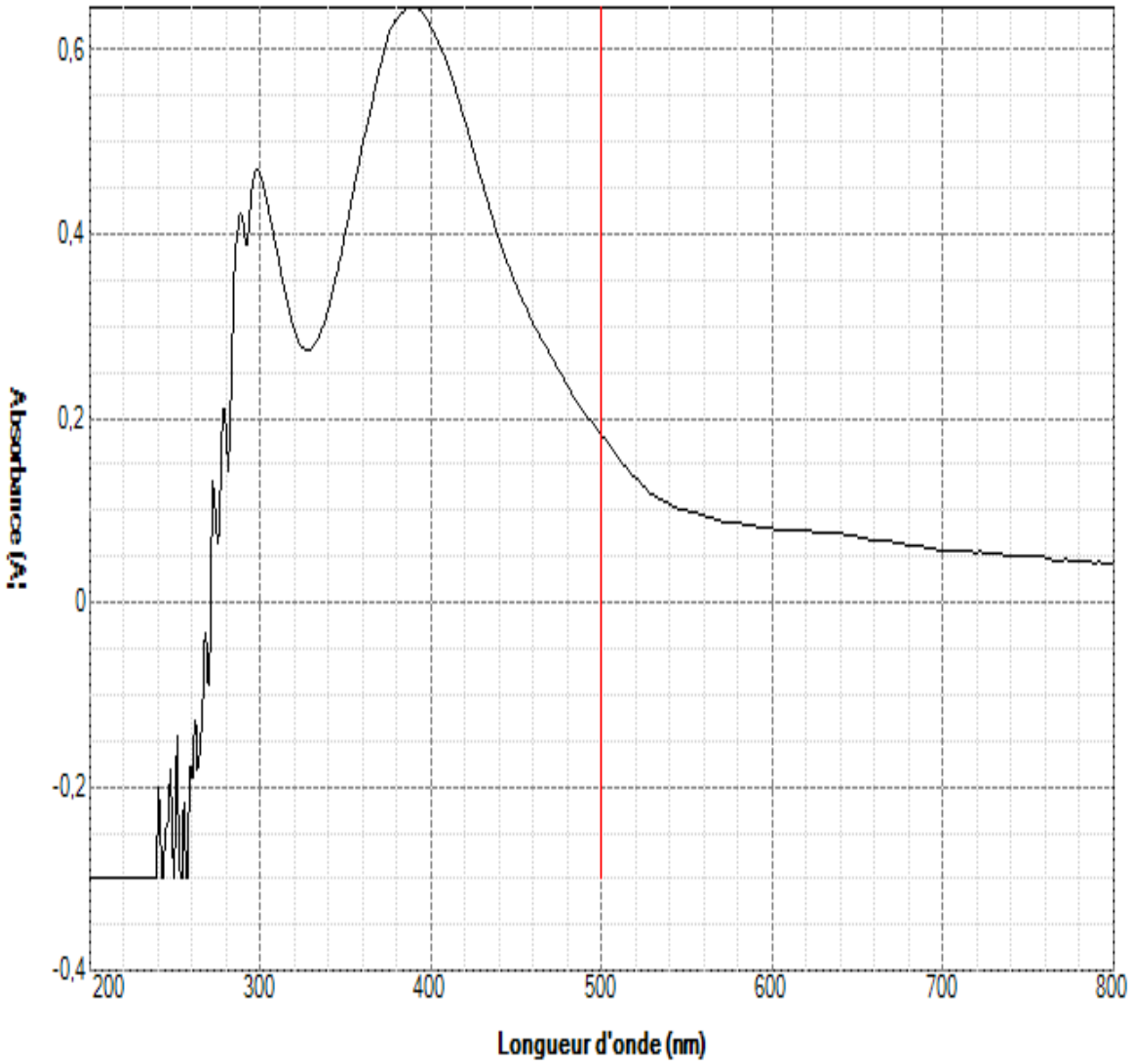

Figure 6:- UV-visible spectrum of geranial 2,4-dinitrophenylhydrazone from the essential oil of *Cymbopogoncitratus* (DC.) Stapf.

A bathochromic effect (increase in the absorption band) is observed in the spectrum of the 2,4-dinitrophenylhydrazone geranial for the 390 nm band, a band which would be between 360-370 nm (Zhou

&Mopper, 1990; Pötter and *al*., 1997; Levart&Veber, 2001) corresponding to the maximum absorption wavelength of the C=N group of 2,4-dinitrophenylhydrazone. This bathochromic effect could be explained by the steric and electronic effects observed within this molecule.

***Eucalyptus citriodora* (citronellal 2,4-dinitrophénylhydrazone):**

Le spectre UV-visible du citronellal 2,4-dinitrophénylhydrazone issu de l'huile essentielle d'*Eucalyptus citriodora*montre trois bandes essentielles (figure 7) :

1. Une bande fine d'intensité moyenne à 259 nm correspondant à la transition $\pi \rightarrow \pi^*$ du groupement (C=C) du système éthylénique ;
2. Une autre bande d'intensité moyenne à 287 nm attribuable à la transition $n \rightarrow \sigma^*$ relative au système aromatique anilinique ;
3. Une bande très intense à 370 nm. Cette bande est caractéristique de la transition $n \rightarrow \pi^*$ du groupement C=N de l'hydrazone.

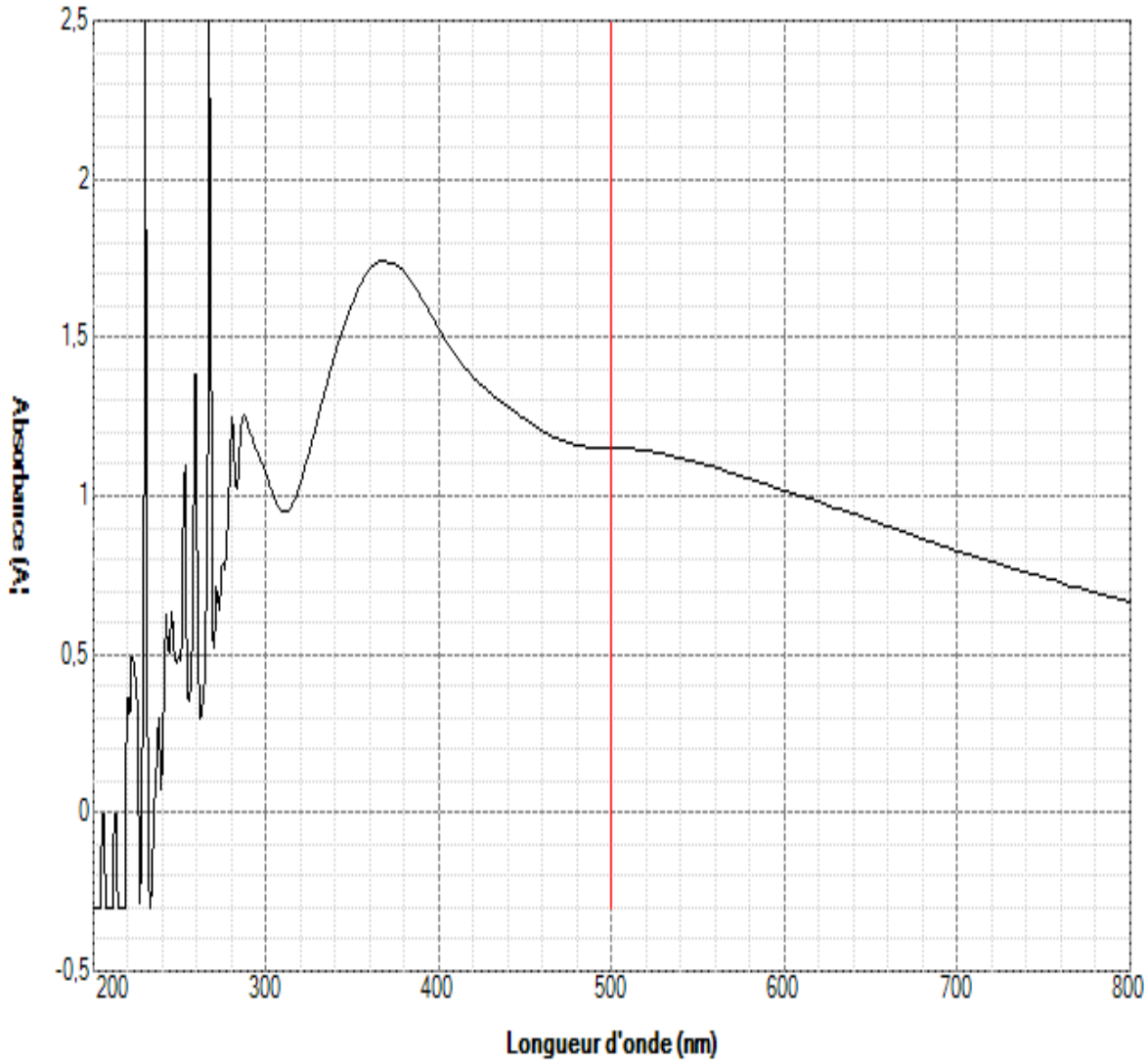

Figure 7:- UV-visible spectrum of citronellal 2,4-dinitrophenylhydrazone from the essential oil of *Eucalyptus citriodora* Hook.

The different absorption bands for geranial and citronellal 2,4-dinitrophenylhydrazones, as well as their chromophores, are shown in Table VIII.

Tableau VIII:- Bandes d'absorption UV-visibles du géranial et du citronellal 2,4-dinitrophénylhydrazones.

2,4 Dinitrophénylhydrazonesderivatives	**Bande d'absorptionλ(nm)**	**Transition et Chromophore**	**Groupement**
Géranial 2,4-dinitrophénylhydrazone	**247** Very low intensity	π→π* (C=C)	Ethylenique System
	298 Little intense	n→σ* (C-NH-)	Aromatic system aniline
	390 Little intense	n→π* (C=N)	Hydrazone
Citronellal 2,4-dinitrophénylhydrazone	**259** Thin,medium intensity	π→π* (C=C)	Ethylenique System
	287 Medium intensity	n→σ* (C-NH-)	Aromatic system aniline
	0 Very intense	n→π* (C=N)	Hydrazone

Dinitrophenylhydrazine:

The UV-visible spectrum of 2,4-dinitrophenylhydrazine shown in (Figure. 8) shows three main bands at 346 nm, 360 nm and at 377 nm due to the chromophoric groups C-N and NO_2 substituted at the aromatic nucleus.

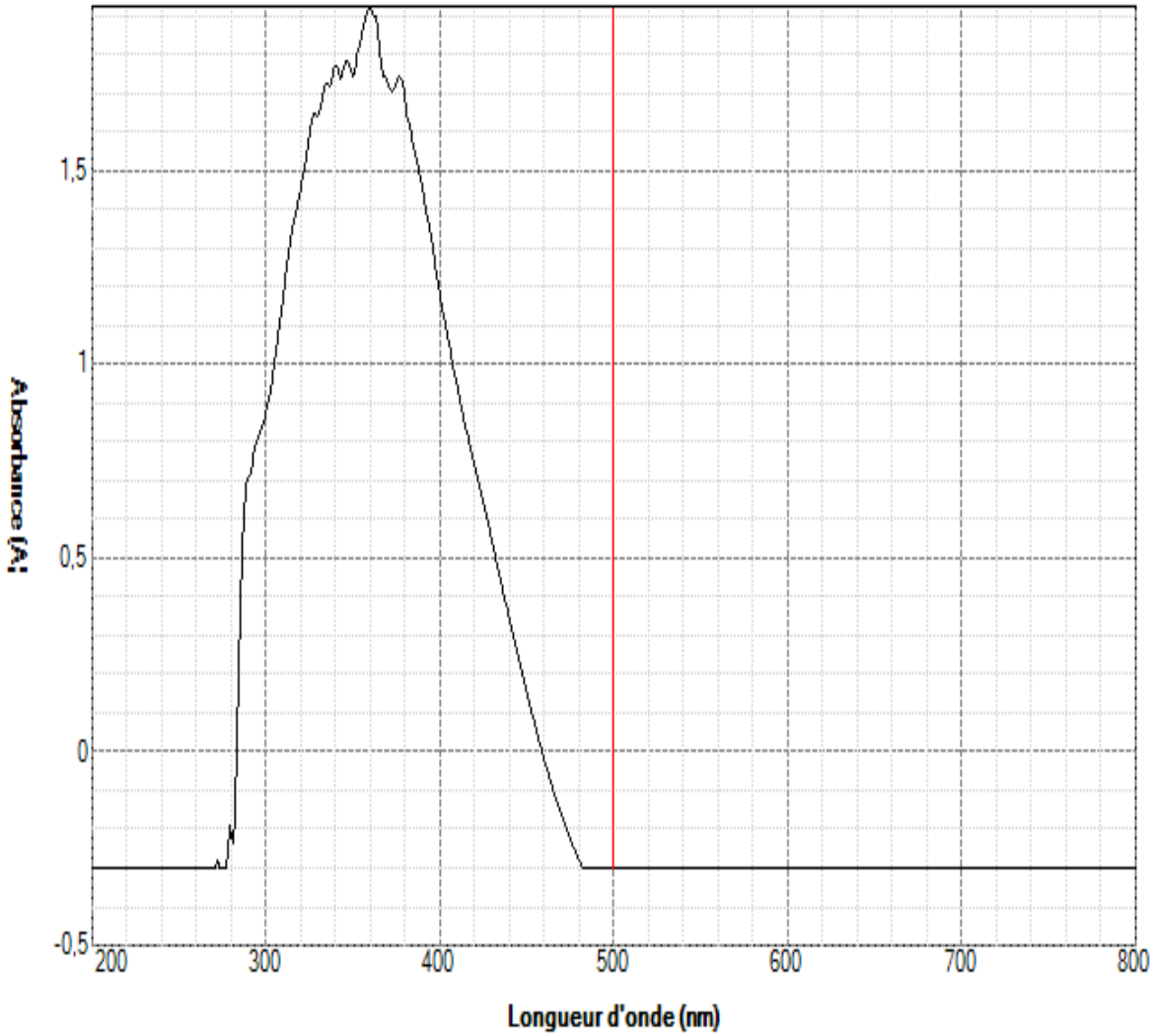

Figure 8:- UV-visible spectrum of 2,4-dinitrophenylhydrazine.

Conclusion:-

Geranial (citral a) and citronellal 2,4-dinitrophenylhydrazones were hemi-synthesized by a simple, easy method from the essential oils of *Cymbopogoncitratus* (DC.) Stapf and *Eucalyptus citriodora* (Hook.) Respectively with conversion rate (yields) of 20% and 37 % respectively, in a short time (three to five minutes). Analysis of geranial and citronellal 2,4-dinitrophenylhydrazones by UV-visible spectrophotometry showed maximum absorption wavelengths of 390 nm and 370, respectively. The UV-visible spectrophotometric method employed for the determination of these hydrazones is convenient, fast and simple. The hemi-synthesized hydrazones could be useful in the pharmaceutical, perfume and cosmetic industries. Indeed, citral and citronellal hydrazones are known for their olfactory functions (Kaushik et *al*., 2016) which orient their uses in cosmetics and perfumery as hydrogels and in biomedicine (Kölmel and Kool, 2017; Xu and Liu, 2019).

References:-

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