



# Phytochemical Study and Evaluation of the Antioxidant Activity of Extracts of the Roots of *Chrysopogon nigritanus*

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

In this work, we were interested in a medicinal plant named *Chrysopogon nigritanus*, belonging to the Poaceae family. In order to carry out this study, we were interested first in the phytochemical screening test, after having carried out the extraction with two solvents (water and isopropanol), to characterize the different families of metabolites present in the extracts. Then, the assays of polyphenols and flavonoids were carried out in order to quantify the contents of these two compounds in each extract. Finally, the antioxidant activity of the extracts was evaluated by three methods: the CUPRAC method, the trapping of the 2,2-diphenyl-1-picryl-hydrazyl radical (DPPH<sup>•</sup>) and the trapping of the ABTS<sup>•+</sup> radical-cation (2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid)). The best antioxidant activities were obtained with the ABTS<sup>•+</sup> radical scavenging with IC<sub>50</sub> of 0.13 mg/mL for the aqueous extract and 0.19 mg/mL for the isopropanol extract. Based on these first results, an in-depth study is underway for various biological tests and the isolation of bioactive molecules.

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## 1. INTRODUCTION

In a broader sense, a medicinal plant is a plant endowed with a therapeutic effect on the organism, without being toxic as an antioxidant, antibacterial, anti-inflammatory, enzymatic inhibitor due to its active molecules and compounds (polyphenols, flavonoids, alkaloids, terpenes, etc.).

Among the recognized biological potentialities of plants, antioxidant activity is of increasing interest because of the important roles that antioxidant compounds, found in plants, play in the treatment and prevention of oxidative stress-mediated diseases [1].

In this context, our choice is based on a medicinal plant which is named *Chrysopogon nigritanus*, belonging to the Poaceae family. *C. nigritanus* is a medicinal plant widely used because of its considerable therapeutic virtues [1-4].

They are generally herbaceous plants, more rarely woody (bamboos), which share morphological characteristics that clearly distinguish them from other plant families.

*C. nigritanus* is a large, erect perennial herb in cespitose clumps, entirely glabrous, reaching 3 m in height. The leaves are rough, linear, tip-terminated, often folded, with scabrous margins. The sheath is compressed, carinated, the ligule reduced to a line of hairs. The inflorescence is a large pyramidal panicle composed of numerous

purple racemes arranged in whorls. The spikelets are paired, one sessile, hermaphrodite, the other pedicellate and only male [2].

*C. nigritanus* also called vetiver in French is a plant generally used in India, Pakistan, Malaysia and in many African countries for its numerous therapeutic virtues especially in traditional medicine. In India and Pakistan, vetiver is used to treat mouth ulcers, boils, burns, epilepsy, snake bites, fever, headaches, infections, etc. In Malaysia, the wet powder is applied to the abdomen after the delivery of women. In Senegal, vetiver roots are used to purify water. Young girls use the infusion of roots to relieve cramps caused by menstruation or for intimate cleansing. The maceration or infusion of the root is also used to calm stress and as an aphrodisiac. The root of the plant is given to new brides as an infusion or mixed with rice porridge during the seven days of her stay in the bridal chamber. In Casamance, the root powder is used to accelerate the wound healing [3].

Vetiver is grown for many purposes. The plant helps to stabilize the soil and protects it from erosion, but it can also protect fields from pests and weeds. Vetiver has favorable qualities for animal feed. Vetiver leaves are a tasty fodder easily eaten by cattle, goats and sheep. In the East, the root has been used since ancient times in the manufacture of baskets and brooms. Rural communities in Thailand, Indonesia, the Philippines, Latin America, and Africa use vetiver leaves to produce a high-quality craft, an important income-generating activity.



**Fig. 1. Representation of *C. nigritanus* plant**

From the roots, oil is extracted and used for cosmetics, aromatherapy, herbal skin care and Ayurvedic soap. Vetiver is also used as a flavoring agent, usually in the form of khus syrup.

Vetiver is primarily grown for the fragrant essential oil distilled from its roots. It is a more common ingredient in men's fragrances.

The objectives are to explore the phytochemical composition and the antioxidant activity of *C. nigrifolius* root extracts, in order to valorize and rationalize its traditional use and to identify potential compounds of therapeutic interest.

## 2. MATERIALS AND METHODS

### 2.1 Plant Material

The roots of *C. nigrifolius* were collected in Thiès, more precisely in Nguint (latitude: 14.8035° north and longitude: 16.92586° west). They were dried at the Organic Chemistry and Therapeutics Research Team (ECOT) in Ngoundiane. After drying in the absence of sunlight, the roots were ground and recovered in powder form.

### 2.2 Extraction

Extraction is a process that involves the recovery of chemicals from a given organ. There are several extraction methods. In our study, we proceeded by solid-liquid extraction, which is one of the most used processes in phytochemistry by maceration.

### 2.3 Solid-liquid Extraction by Maceration

Maceration is an infusion in a cold solvent. The operation, although generally long and with often poor yield, is the only method that can be used in

the case of extraction of a set of fragile molecules.

We put down twice 15 grams (15 g) of powdered roots of *C. nigrifolius* to make two extractions with two solvents (water and isopropanol). The two 15 g of the obtained powder were each immersed in a 250 mL flask with 150 mL of distilled water in one and 150 mL of isopropanol in the other. After shaking, the mixtures were put under cover and left to macerate for 24 h with a 50 mL renewal of solvents.

### 2.4 Phytochemicals Screening

After extraction, we were interested in the phytochemical study of the extracts. This study is based on staining and precipitation reactions in order to characterize the different families of secondary metabolites present in the two extracts [4,5].

### 2.5 Determination of Polyphenols and Flavonoids Contents

The polyphenols content is determined using the Folin-Ciocalteu procedure [6-8]. A volume of 40  $\mu\text{L}$  of the isopropanol extract was taken and evaporated to dryness, after which 200  $\mu\text{L}$  of distilled water was added. For the aqueous extract, 200  $\mu\text{L}$  of extract was taken and evaporated to dryness. Then, 150  $\mu\text{L}$  of Folin-Ciocalteu reagent, 600  $\mu\text{L}$  of 20%  $\text{Na}_2\text{CO}_3$  solution and 2.32 mL of distilled water were added successively. In parallel, a gallic acid range (0.1 mg/mL) is prepared from a stock solution of 0.1 mg/mL. After 30 minutes of incubation in the dark, the absorbance is read at 760 nm using a UV-visible spectrophotometer. The amount of polyphenols is deduced from the equation of the calibration line and results are expressed as mg of gallic acid equivalents (GAE)/g of plant material.



Fig. 2. Dry and crushed roots of *C. nigrifolius*

**Table 1. Protocols for phytochemical tests and expected results**

Compounds tested	Protocol	Expected results
alkaloids	Wagner and Dragendorff	Yellowish white precipitate
Terpenes and sterols	Liebermann-Buchard reaction	Brownish red or purple ring
Saponosides	Addition of water and shaking	Persistent foam
Polyphenols	Alcoholic solution of ferric chloride 2%	More or less dark blue-black or green colouring
Flavonoids	Reaction with cyanidin	Orange or purplish colour
Tannins	Catechics Tiasny reagent and 2% ferric chloride (FeCl <sub>3</sub> )	Large flakes
	Gallic Saturated with sodium acetate of catechic tannin solution and drops of 2% ferric chloride (FeCl <sub>3</sub> )	Blackish blue colouration
Coumarins	25% ammonium hydroxide solution (NH <sub>4</sub> OH)	Fluorescence under UV lamp at 366 nm

The determination of flavonoids in extracts is based on the formation of a complex between aluminum trichloride (AlCl<sub>3</sub>) and flavonoids [8]. The aluminum trichloride (AlCl<sub>3</sub>) method is used to quantify flavonoids in our two extracts. 1.25 mL of extract is taken and made up to 2.5 mL with the extraction solvents. A volume of 2.5 mL of a 2% ethanolic solution of AlCl<sub>3</sub> is added. In parallel, a quercetin (0.1 mg/mL) line is prepared. After 60 min of incubation, the absorbance is read at 425 nm. The quantity of flavonoids is deduced from the calibration range established with quercetin and results are expressed in milligram of quercetin equivalents (QE) per gram of dry matter (mg QE/g of Ms).

## 2.6 Study of the Antioxidant Activity of the Extracts

The antioxidant activity was determined with three methods: DPPH<sup>•</sup> free radical scavenging, CUPRAC method and ABTS<sup>•+</sup> scavenging assays [9-12].

## 2.7 Determination of Antioxidant Activity by the CUPRAC Method

The CUPRAC method (cupric ion reducing antioxidant capacity) is based on the monitoring of the decrease of the increased absorption of the Neocuproin complex (NC). Indeed, in the presence of an antioxidant compound, the copper-neocuproin complex is reduced and this reduction is quantified spectrophotometrically at a wavelength of 450 nm.

For the determination of the antioxidant capacity with the CUPRAC method, three solutions are

prepared, namely a solution of copper chloride CuCl<sub>2</sub> at 10<sup>-2</sup> M, a solution of ammonium acetate at pH 7 and a solution of neocuproin at 7.5 mM.

For this purpose, a volume of 1.25 mL of extract was taken and supplemented to 2.5 mL with distilled water. Then, 1 mL of each of the three prepared solutions is added into the 2.5 mL. A range of Trolox (503 μmol/L) is prepared in parallel. The whole is incubated for one hour in the dark (60 min) and the absorbance is read at 450 nm. The result is determined thanks to the equation of the Trolox calibration line (mg TE/g of Ms).

## 2.8 Determination of Antioxidant Activity Using DPPH<sup>•</sup>

The principle of this method is the reduction of the purple DPPH (2,2-diphenyl-1-picrylhydrazyl) to the yellow 2,2 diphenyl-1-picrylhydrazine. DPPH absorbs at 517 nm, but upon reduction by an antioxidant its absorption decreases.

To determine the antioxidant capacity, 40 μL of each extract was taken and completed to 200 μL with distilled water. Then, 3.8 mL of a 0.1014 mM DPPH<sup>•</sup> solution is added into the diluted extracts. A Trolox line (503 μmol/L) is prepared in parallel. After 30 minutes of incubation in the dark, the absorbance is read at 517 nm.

After the determination of the antioxidant capacity, we were interested in the reaction kinetics of the DPPH<sup>•</sup> radical. The study was done over 180 minutes to see the evolution of the antioxidant activity of our extracts over time.

To do this, 200  $\mu\text{L}$  of each extract was taken and 3.8 mL of the DPPH solution was added. The absorbance is read every 5 minutes at 517 nm. The inhibition is calculated with the following formula:

$$\% \text{Inhibition} = \frac{\text{Abs control} - \text{Abs sample}}{\text{Abs control}} \times 100 \quad (1)$$

Abs control = absorbance of DPPH

Abs sample = absorbance after addition

## 2.9 Determination of Antioxidant Activity with ABTS<sup>•+</sup>

The antioxidant activity with the ABTS<sup>•+</sup> radical is determined by the method of [12]. The total activity of a molecule is deduced by its ability to inhibit the ABTS<sup>•+</sup> radical. Thus, by reacting with potassium persulfate ( $\text{K}_2\text{S}_2\text{O}_8$ ), ABTS forms the turquoise blue radical ABTS<sup>•+</sup>, the addition of an antioxidant reduces this radical and causes the discoloration of the mixture.

The antioxidant capacity is determined with the ABTS<sup>•+</sup> radical by the method of Thaipong et al. with some modifications.

For this purpose, a stock solution is prepared by mixing a 2 mM solution of potassium persulfate and a 7 mM solution of ABTS<sup>•+</sup> in equal volume. The mixture is incubated for 16 hours before use. A working solution (WS) is prepared by diluting the stock solution to the 25% with phosphate buffer (0.2 M; pH 7.4; 150 mM NaCl) to have a maximum absorbance of 0.750 at 734 nm.

For the determination of antioxidant capacity, a volume of 25  $\mu\text{L}$  is taken for each extract and supplemented to 100  $\mu\text{L}$  with distilled water. Then, 2.9 mL of the ST solution of ABTS is added to the extracts completed to 100  $\mu\text{L}$  with distilled water. A Trolox (503  $\mu\text{mol/L}$ ) line is prepared in parallel. After 30 minutes of incubation in the dark, the absorbance is read at 734 nm.

The  $\text{IC}_{50}$  is determined by making six dilutions and determining the percentage of inhibition using equation (1).

## 3. RESULTS AND DISCUSSION

### 3.1 Yields of Extracts

To calculate the yield, it is first necessary to determine the mass of the macerates. The mass of each macerate is determined by the difference

in the mass of the tube containing the extract and the mass of the same tube under vacuum. Once these different masses were obtained, the yield was determined.

The yield of each extract is obtained by making the ratio of the dry extract (macerate) to the mass of the plant material (root powder), all multiplied by one hundred (100).

$$\text{Extraction yield\%} = \frac{\text{Mass of dry extract}}{\text{Mass of plant powder}} \times 100 \quad (2)$$

**Table 2. Extraction rates obtained for aqueous and isopropanol extracts of *C. nigritanus***

Extracts	Aqueous extract	Isopropanol extract
Extraction rate %	3.16	2.21

Table 1 reveals that the aqueous extract has the highest yield compared to that of the isopropanol extract. These results can be explained by the polarity of the extraction solvents. Indeed, water being more polar than isopropanol, it tends to extract more polar molecules. More polar molecules are extracted with the aqueous extract than with isopropanol [3,4].

### 3.2 Phytochemicals Screening

Phytochemicals screening of secondary metabolites in the extracts was performed using the methods mentioned above and according to the availability of reagents. Table 2 presents the results obtained.

Phytochemical tests performed on both extracts revealed:

- The presence of terpenes, polyphenols, flavonoids and coumarins in both extracts,
- The presence of alkaloids, condensed and gallotannins in the aqueous extract,
- The absence of saponins in both extracts,
- The absence of condensed and gallotannins in the isopropanol extract.

From these results, we can say that the aqueous extract is richer in secondary metabolites than the isopropanol extract. Due to the high polarity of water, it is easier to extract polar molecules from the plant than isopropanol. Therefore, it is more likely that the aqueous extract contains more polar compounds than the isopropanol extract.

**Table 3. Results of phytochemical tests**

Compounds	Aqueous extract	Isopropanol extract
Terpenes	+	+
Polyphenols	+	+
Flavonoids	+	+
Alkaloids with Dragendorft	+	-
Alkaloids with Wagner	+	+
Saponins	-	-
Condensed tannins	+	-
Gallotannins	+	-
Coumarins	+	+

+: presence; -: Absence.

### 3.3 Determination of Polyphenols and Flavonoids Contents

#### 3.3.1 Polyphenols content

The polyphenols content is determined using the Folin-Ciocalteu reagent. Gallic acid is used as a standard, the result obtained is presented in a calibration curve whose equation:

$$Y = 0.0343x + 0.0762 \text{ with } R^2 = 0.9988$$

According to the results of Table 3, we notice that the two extracts have almost the same contents of polyphenols. These results are in correlation with the results of the phytochemicals screening concerning the polyphenols which showed the same aspect in the two extracts.

#### 3.3.2 Determination of flavonoids

The determination of flavonoids in extracts is based on the formation of a complex between  $AlCl_3$  and flavonoids. The absorbance is read at 425 nm.

Quercetin was used as standard, the calibration curve having the equation:

$$Y = 0.0203x + 0.0732 \text{ with } R^2 = 0.9953$$

The results of the flavonoid assay show that the aqueous extract has the highest amount of

flavonoids with 0.1584 QE/g of Ms, while that of the isopropanol extract is 0.0966 QE/g of Ms.

According to these different results obtained, it has been disputed that the quantity of polyphenols is not proportional with that of flavonoids in both extracts.

### 3.4 Evaluation of the Antioxidant Activity of the Extracts

The antioxidant activity of the extracts was determined by three methods, namely CUPRAC, DPPH<sup>•</sup> and ABTS<sup>•+</sup> methods.

#### 3.4.1 Determination of the antioxidant capacity by the CUPRAC method

The CUPRAC method is based on the capacity of antioxidants to reduce  $Cu^{2+}$  ions to  $Cu^+$ . Therefore, neocuproin is used as a chelating agent. The  $Cu^+$  ions will therefore form a complex with neocuproin.

This method thus allows the mobilization of antioxidants, having one or more thiol groups and lipophilic and hydrophilic antioxidants. Trolox was used as standard and the calibration line of Trolox has the equation:

$$Y = 0.0116 + 0.2745 \text{ with } R^2 = 0.9917$$

Table 5 summarizes the antioxidant capacities obtained with the CUPRAC method of extracts.

**Table 4. Polyphenols content of extracts**

Extracts	Polyphenols content (mg GAE/g of Ms)
Isopropanol	1.171 ± 0.0108
Aqueous	1.170 ± 0.0082

**Table 5. Flavonoids contents of extracts**

Extracts	Flavonoids content (mg QE/g of Ms)
Isopropanol	0.0966 ± 0.00035
Aqueous	0.1584 ± 0.00093

**Table 6. Antioxidant capacity of extracts by the CUPRAC method**

Extracts	Antioxidant capacity (mg TE/g of Ms)
Isopropanol	0.925 ± 0.0139
Aqueous	2.914 ± 0.0116

The results with the CUPRAC method revealed that the aqueous extract has the highest antioxidant capacity with 2.914 mg TE/g Ms, while that of the isopropanol extract is 0.925 mg TE/g Ms.

Comparing these results, it appears that even if the isopropanol extract is a little rich in polyphenols than the aqueous extract, the antioxidant capacity is better in the aqueous extract. It appears that the two extracts do not contain the same types of polyphenols or the same proportions for polyphenols of the same category.

#### 3.4.2 Determination of antioxidant activity by the DPPH' method

Table 8 summarizes the results of the antioxidant capacity of each of the extracts determined using the Trolox equation line with the DPPH method.

According to Table 6, the two extracts show a small difference in antioxidant capacity. Indeed, the isopropanol extract presents an antioxidant capacity of 0.5964 mg TE/g of Ms, while that of the aqueous extract is 0.5945 mg TE/g of Ms. These results are in correlation with the contents of polyphenols in the two extracts which presented the same tendencies.

### 3.5 Reaction Kinetics

After having determined the antioxidant capacity for the DPPH radical, we were interested in the reaction kinetics. The study was done over 180 minutes to see the evolution of the antioxidant activity of our extracts over time. The antioxidant capacity is measured every 5 minutes over the 180 minutes. Fig. 1 shows the evolution of the antioxidant activity of our two extracts.

Fig. 1 shows that during the first 15 minutes, the antioxidant activity of the isopropanol extract is slightly higher than that of the aqueous extract, with an inhibition of 21.36% for the isopropanol extract against 20.33% for the aqueous extract after 15 minutes.

After 20 minutes until the end of the reaction, a progressive evolution of the oxidative activity of the two extracts is noticed. In this part of the evolution, the inhibitions of the aqueous extract are more important than those of the isopropanol extract with a maximum inhibition of 46.99% for the aqueous extract and 41.59% for the isopropanol extract. This makes a difference in inhibition of 5.4% in favor of the aqueous extract.

### 3.6 Evaluation of the Antioxidant Activity by the ABTS<sup>•+</sup> Method

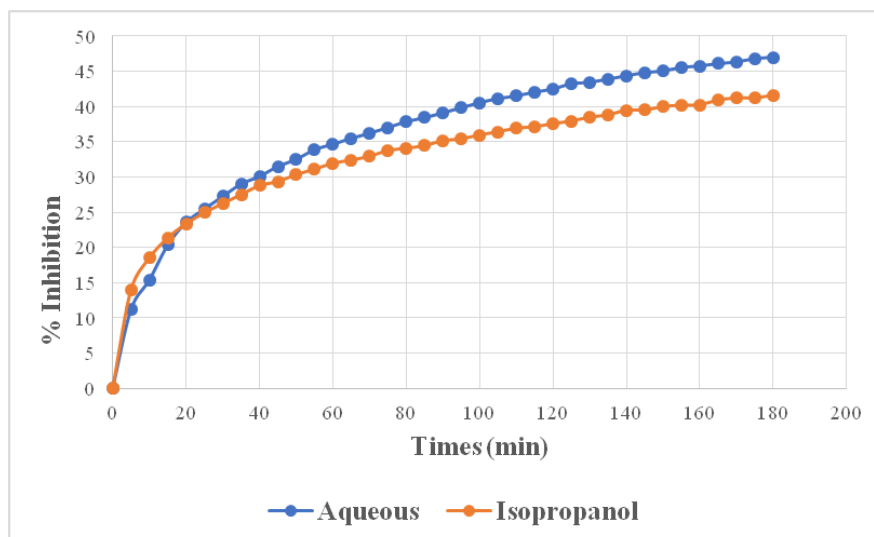
The antioxidant capacity of each of the extracts is deduced from the equation line of Trolox which has the equation:  $Y = -0.0347 + 0.6428$  with  $R^2 = 0.9901$  and the results are given in Table 7.

The results confined in Table 7 show that the antioxidant capacity of the isopropanol extract is a little higher than that of the aqueous extract. The antioxidant capacity of the two extracts is  $6.975 \pm 0.031$  mg/g for the isopropanol extract and  $6.324 \pm 0.068$  mg/g for the aqueous extract respectively. These results can be correlated with those of the polyphenol contents: 1.171 mg EAG/g of Ms for the isopropanol extract and 1.170 mg EAG/g of Ms for the aqueous extract. So, we can say that it is partly due to the difference of the polyphenol content in the extracts, since there are other compounds playing the role of antioxidant.



**Table 7. Antioxidant capacity of extracts by the DPPH<sup>•</sup> method**

Extracts	Antioxidant capacity (mg TE/g extract)
Aqueous	0.5945 ± 0.0019
Isopropanol	0.5964 ± 0.0071



**Fig. 3. Evolution of the antioxidant activity of the two extracts**

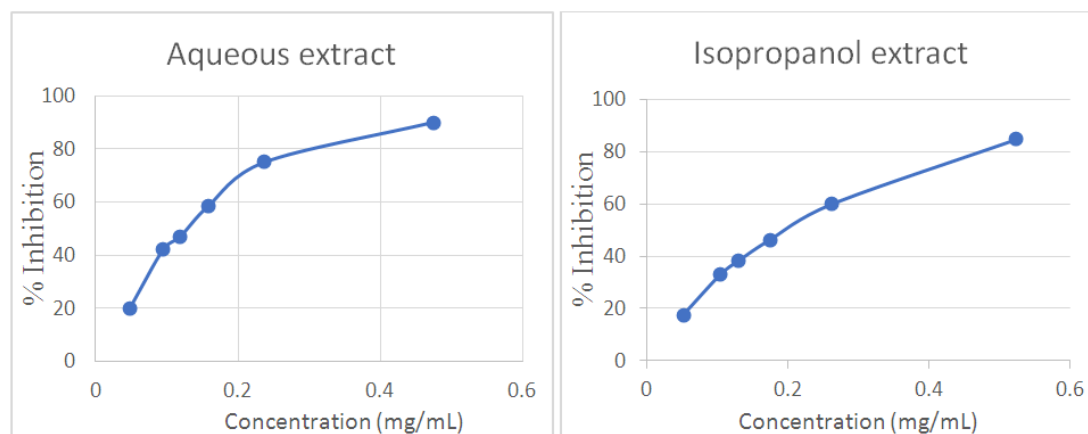
**Table 8. Antioxidant capacity by ABTS<sup>•+</sup> method**

Extracts	Antioxidant capacity (mg TE/g of Ms)
Aqueous	6.324 ± 0.068
Isopropanol	6.975 ± 0.031

### 3.7 Determination of the IC<sub>50</sub> of Extracts

After determining the antioxidant capacity, the evolution of the antioxidant activity of different concentrations of extract was evaluated. From Fig. 2, it can be seen that the antioxidant activity increases with the concentration. Both extracts

are able to inhibit at least 50% of the radical activity induced by ABTS<sup>•+</sup>. We also notice that the aqueous extract is able to inhibit 90% of this activity with a concentration of 0.474 mg/mL; for the isopropanol extract, we need a higher concentration of 0.523 mg/mL to inhibit about 84.96% of this activity by the ABTS<sup>•+</sup> radical.



**Fig. 4. Curves of % inhibitions as a function of different concentrations**



**Table 9. IC<sub>50</sub> of extracts by ABTS<sup>•+</sup> radicals scavenging assay**

Extracts	IC <sub>50</sub> (mg/mL)
Aqueous	0.13
Isopropanol	0.194

Thanks to this experiment, we can say that the antiradical capacity is dependent on the dose and the nature of the compounds contained in the extract. We will then determine the concentration causing 50% of the inhibition of each extract (Table 8).

Table 8 shows that the aqueous extract has the best IC<sub>50</sub> which is 0.13 mg/mL, while that of the isopropanol extract is 0.194 mg/mL. These results are not comparable with the polyphenol contents in the extracts. This can be explained by the presence of other compounds in the extracts acting as antioxidants [9].

According to the three methods to test the antioxidant activity, the test with ABTS<sup>•+</sup> shows the best activity. It can be said that the activity also depends on the type of radical used to measure the activity.

Finally, we can say that the study of the antioxidant activity of *C. nigritanus* showed the potential of the free radicals of the roots of this plant which could be considered as a source of natural antioxidants. The observed antioxidant activity would be due to their content of polyphenols and flavonoids which are the main components of plant with antioxidant activity.

#### 4. CONCLUSION

In the present work, we were interested in the phytochemicals screening, the determination of polyphenols and flavonoids and the evaluation of the antioxidant activity of two different extracts of the roots of *C. nigritanus* plant.

From the phytochemical point of view, we performed the solid-liquid extraction by maceration. The phytochemicals screening showed the richness of our plant in secondary metabolites in the aqueous extract (the presence of alkaloids, steroids, polyphenols, flavonoids, condensed and gallic tannins and coumarin).

It appears from the study of the antioxidant activity evaluated by three different methods, namely the CUPRAC method, the DPPH method and the ABTS<sup>•+</sup> method, that all the extracts of the plant exhibit antioxidant activity. However,

the ABTS method gives the best activity with IC<sub>50</sub> for each extract.

In the near future, we plan to deepen this study by trying to isolate the bioactive molecules responsible for the observed antioxidant activities. An evaluation of other activities such as antibacterial activity as well as a toxicological study would allow to enlarge the virtues and would favor a better safety of use of the plant by the population.

#### CONSENT AND ETHICAL APPROVAL

It is not applicable.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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