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Biological activity of leaves and stems extracts of *Artemisia herba-alba* from the Oriental region of Morocco and extraction of Cellulose from this plant (isolation, modification and applications)

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Abstract

Biopolymers are polymers that originate from biological sources. Due to their renewable biodegradability and abundance, they present themselves as a high potential source of innovation for several industrial applications. Polysaccharides, and in particular cellulose, today arouse great interest due to its high abundance, wide distribution, and low cost. It is considered one of the most popular organic polymers and an almost eternal source of raw materials for the growing demand for environmentally eco-friendly materials. First, we evaluated the biological activity (Antioxidant and Antimicrobial) of aqueous and organic extracts of *Artemisia herba-alba*. Second, we extracted and isolated cellulose from the stems and leaves of this plant. Third, the cellulose was modified to improve its solubility and activity using an acrylamide compound. Finally, we investigated the ability of cellulose acrylate to trap copper(II) ions in water. The objective of the study is to promote and maintain an eco-friendly environment with emphasis on water as a vital source.

Keywords: *Biological activity, Cellulose, Cellulose acrylate, Cu (II) ions, Artemisia herba alba.*

1. Introduction

The Moroccan flora have a considerable biodiversity, it has many aromatic and medicinal plants rich in secondary metabolites with significant therapeutic and pharmacological characteristics and has a considerable importance in term of its great important medicinal and aromatic value [1-8]. For over a thousand years, cellulose has been known as a polysaccharide that is readily available in nature. It is branded as a main constituent of the cell wall [9]. Since the cell wall is produced by all plants, it is probably the amplest organic compound on Earth. The extraction of cellulose from aromatic and medicinal plants is becoming a topic of interest because compounds extracted from aromatic and medicinal plants, including cellulose, are used as additives in pharmaceutical, neutraceutical, toxicology, and other chemical industries, for treating syphilis, kidney disorders, wound healing, ulcers, skin rash, gonorrhoea, and piles [10, 11]. *Artemisia herba-alba* is a greenish-silver perennial herb growing in semiarid and arid climates, 30 to 50 cm in height and belongs to the daisy family Asteraceae [12]. The vegetative growth of this plant takes place in the autumn; the flowering starts from September to December and basically develops at the end of the summer with many basal, erect and leafy stems covered by woolly hairs [12-15]. This plant commonly known as the white wormwood in Arabic as "Chih" and in French as "Armoise blanche", is one of five spontaneous Artemisia species that were identified and was used as aromatisant for tea [16]. In folk medicine, was known for its therapeutic and medicinal properties, was used for treatment of colds, coughing, intestinal disturbances, as antidiabetic agent, for bronchitis, diarrhea, neuralgias and hyper-tension [17]. This study focused on the isolation and modification of the cellulose extracted from the stems and leaves of *A. herba-alba* by acrylamide grafting and also on the study of its ability to scavenge divalent metal ion such as copper (II) ions. The further purpose in this work is evaluate the antioxidant and antibacterial activities of aqueous and organic extracts of this plant and precisely in the town of Sidi Ali Belkacem – Debdou.

2. Materials and methods

2.1. Collection and Preparation of Plant Materials

Artemisia herba-alba was collected from the city of Taourirt of the oriental of Morocco and precisely in the town of Sidi Ali Belkacem –Debdou. The plant was harvested at the beginning of its flowering period. Leaves and stems of *Artemisia herba-alba* were washed, dried in oven at 60°C and ground separately using an electric grinder and then sieved until a fine powder was obtained.

2.1.1. Preparation of aqueous extract

20g of the fine powder (leaves or stems) obtained was introduced into a flask containing distilled water. The mixture was heated in a reflux assembly for 5 hours at T=100 °C with stirring, after filtration on Büchner, the mixture was washed with distilled water and the liquid residue was evaporated to obtain the aqueous extract.

2.1.2. Preparation of organic extract

We add V=60ml of (THF/EtOH) (1/1) to the powder resulting from above and the mixture was heated for 24 hours at T=60 °C with continuous stirring. After a Büchner filtration, the mixture is washed with ethanol and the liquid residue was evaporated to obtain the organic extract.

2.2. Phytochemical screening

The qualitative phytochemical screening of the extracts was performed to identify the main groups of chemical constituents (Flavonoids, Anthocyanins, Tannins, and Quinones, Reducing compounds, Alkaloids, Terpenoids,

Steroids, and Polyterpenes). The detection of these compounds confirmed by the formation of a precipitate, change of color or turbidity. [18,19].

2.2.1. Flavonoids test

5 ml of hydrochloric alcohol (4 ml ethanol + 1 ml concentrated HCl), 1ml of Isoamyl alcohol and 2-3 small pieces of magnesium or zinc was added to 1ml of extract. The release of heat then the appearance of a pink, orange or red color indicates the presence of flavonoids [20, 21].

2.2.2. Anthocyanin test

To 5 ml of extract, 5 ml of hydrochloric alcohol and 1 ml of isoamyl alcohol are added, then the mixture is heated for 10 min in a water bath [22-24]. A purplish cherry-red color indicates the presence of leucoanthocyanins. A brown-red color indicates the presence of catechols.

2.2.3. Tannins test

The reaction carried out from 1 ml of extract placed in a tube in which the addition of $FeCl_3$ at 1% makes it possible to detect the presence or absence of tannins [25, 26]. The color changes to black blue in the presence of gallic tannins and dark green in the presence of catechin tannins.

2.2.4. Quinones test

The presence of Quinones is confirmed by the addition of a few drops of 1/10 NaOH, when the aqueous phase turns yellow, red or purple [27-29].

2.2.5. Test for Reducing Compounds

Their detection consists of introducing 2ml of the extract into a test tube, then 2ml of Fehling's liquor is added. Then, the whole is brought to a boiling water bath for 8 min. Obtaining a brick red precipitate indicates the presence of reducing compounds [30-32].

2.2.6. Alkaloids test

The alkaloids are demonstrated by Mayer's reagent (10 g of KI and 2.70 g of $HgCl_2$ dissolved in 20 ml of water). Adding a few drops of this reagent to 2 ml of the extract solution causes the formation of a white or yellow-white precipitate in the presence of alkaloid [33-35].

2.2.7. Steroids Test

To 5 ml of extracts, 5 ml of acetic anhydride and 3 ml of concentrated H_2SO_4 are added. Steroids give with this reaction a red coloring [36-38].

2.2.8. Polyterpenes test

To 5 ml of extracts, 5 ml of acetic anhydride and a few drops of concentrated H_2SO_4 are added. Polyterpenes give a green color [25, 28].

2.2.9. Terpenoids test

Development of a reddish brown coloration at the interface after addition 1ml of chloroform followed by 1,5 ml concentrated sulfuric acid to 2.5 ml of the extract indicates the presence of terpenoids [39-41].

2.3. Biological Studies

2.3.1. Antioxidant activity

The DPPH solution is obtained by dissolving DPPH$^{\bullet}$ powder in MeOH with a concentration of 4mg/100ml.

The samples were prepared by dissolution extracts in MeOH at a rate of 1000µg/1ml. This solution, called stock solution, and then diluted to have the following concentrations: 200, 150, 100, 70 and 30µg/ml. The negative control is a mixture of 750µl of methanol and 2250µl of the DPPH• solution. The test is carried out by mixing 2250µl (75%) of the previous DPPH$^{\bullet}$ solution with 750µl (25%) of the extract to be tested at different concentrations. The measurement of the change in absorbance was made 30 min after placing the tube containing this mixture (DPPH$^{\bullet}$ + samples) in the dark. The effect of the antioxidant is proportional to the disappearance of the DPPH$^{\bullet}$ radical and the discoloration of the solution, which changes from violet to yellow. The values obtained are then converted into percentage inhibition ($IP_{\%}$) using the following formula:

$$\mathbf{IP_{\%} = (A_{NC} - A_S)/A_{NC} \times 100}$$

$IP_{\%}$: The percentage of inhibition.

A_{NC}: The absorbance of the negative control.

A_S: The absorbance of the sample.

The graph of variation of the percentage of inhibition as a function of different concentrations makes it possible to determine the IC_{50}. This value is compared with that found for the reference compound; Ascorbic acid whose absorbance was measured under the same conditions as our samples [42-44].

2.3.2. Antimicrobial activity

The antimicrobial activity of aqueous and organic extracts was determined by diffusion method. The used bacteria were Bacillus subtilis, Micrococcus luteus, Escherichia coli, Pseudomonas aeruginosa as well as yeast Candida albicans. Sterile disks of Whatman paper 6 mm in diameter were impregnated with 20 µl of the extracts, then left to dry for 40 minutes. Then, for each Petri dish previously inoculated, 5 discs were placed on the surface of the agar, the latter having been soaked beforehand and the negative control (sterile Whatman paper). Two petri dishes were prepared by a microbial strain (bacteria and yeasts) The dishes were incubated at 4°C for 4 hours then at 37°C for 18 hours for the bacteria and at 28°C for 48 hours for the yeasts.

2.4. Extraction of cellulose from the leaves and stems of A. herba-alba

2.4.1. Treatment in alkaline medium

The powder arising from extraction of leaves and stems of *Artemisia herba-alba* has been dried and treated with 150ml of sodium hydroxide solution (1M) for 2 hours at T=100 °C in a reflux assembly. The mixture filtered, washed abundantly with water and ethanol. NaOH eliminates hemicelluloses and leads fiber swelling. These are transformed into individualized microfibers after bleaching.

2.4.2. Bleaching:

Bleaching was done using bleach Javel water 8°, with continuous stirring and repeated several times until the cellulose fibers are discolored. The bleached fibers are then washed abundantly with distilled water until neutral pH then with EtOH and dried in an oven at 60°C until the weight stabilizes.

2.5. Cellulose modification by acrylamide grafting

NaOH (6g) and Urea (4g) were dissolved in distilled water (90 ml) and 2g of cellulose was added to the mixture under stirring. Then, to avoid cellulose gel formation, a freeze (-12°C) – thaw cycle was carried out, where the cellulose slurry was frozen before thawed under stirring to obtain a homogenous and transparent cellulosic solution. Then 2,6g of acrylamide was added. Then, the mixture was stirred for 2 hours at 60°C. The obtained solution was precipitated in ethanol, filtered under vacuum, laved with ethanol and dried to obtain Cellulose-acrylamide.

2.6. Cu (II) removal capacity

The aqueous Cu (II) solution was prepared by dissolving $CuSO_4.5H_2O$ in powder form in distilled water. We have adopted an approach which consists in preparing first a stock solution of given concentration, from which we prepare, by successive dilutions, a series of solutions of well-defined concentrations (100, 200, 300, … 1000mg/L).

The flocculation capacity of Cellulose-acrylamide samples for the removal of Cu (II) metal ion was studied using $1cm^3$ of aqueous solution at 0.05g/10ml of Cellulose-acrylamide and $5cm^3$ of Cu (II) solution at different concentrations ranging between 100 and $1000mg.L^{-1}$, After 24 hours of adsorption process, the supernatant liquids were filtered. Then the samples will be analyzed by UV-visible spectrophotometry. The values of the adsorbate concentrations in the equilibrium solution Ce are calculated from the calibration curve and they correspond to the concentrations of copper (II) in the solutions at a given absorbance. Then the adsorption capacity Qe ($mg.g^{-1}$) is calculated using the following equation:

$$\mathbf{Qe= (C_0-Ce)\times V/m}$$

Where, C_0 is the initial concentration of metal ion ($mg.L^{-1}$), **Ce** is the metal ion equilibrium concentration of metal ion ($mg.\ L^{-1}$), **m** is the mass of Cellulose-acrylamide (g) and **V** is the volume of the solution (L).

3. Results and discussions

3.1. Calculation of Yields

3.1.1. Extract Yields

From the results shown in Table 1,

Table 1: ***Yields of aqueous and organic extracts***

Part of the plant	Extraction Types	Extracts	Yields (%)
Stems	Water extraction	Aqueous	25
	EtOH/THF extraction	Organic	5
Leaves	Water extraction	Aqueous	45.38
	EtOH/THF extraction	Organic	17.61

we concluded that yields of water extraction are higher than EtOH/THF extraction. There is a reason that could have an impact on the extraction yield, it is the extraction time which is generally very long in the case of the second

method (extraction with ethanol) 24 hours compared to the first method (extraction with water) 5 hours. The progression of extraction time can decrease the yield of the extract and this can be due to the degradation of some natural substances. In view of these data, it appears that the yields obtained from leaves are greater than yields obtained by stems, which means that the leaves contain a very large quantity of metabolites.

3.1.2. Yields of cellulose extracted from the stems and leaves of Artemisia herba-alba

As clearly shown in Table 2 below, the best cellulose yield is obtained from the stems with a yield of 30.75%, which is higher than that obtained from the leaves (9.23%).

Table 2: ***Yields and masses of the extracted Celluloses***

Part of the plant	Masses des celluloses (g)	Yields (%)
Stems	6.15	30.75
Leaves	1.20	9.23

3.2. Phytochemical screening

From the results of Table 3, it can be deduced that the qualitative phytochemical screening of stems and leaves of *A. herba-alba* revealed that Quinones, Steroids and Polyterpenes were present in both aqueous and organic extracts of the stems and leaves of this plant, while Reducing compounds, Terpènoïdes, tannins, Flavonoids and Anthocyanins were strongly present only in the leaves extracts. The results are summarized in the table 3 below.

Table 3: ***Phytochemical test results***

Secondary metabolites	Aqueous extracts		Organic extracts	
	Leaves	Stems	Leaves	Stems
Flavonoids	+++	-	+++	-
Anthocyanins	+++	++	-	-
Tannins	+++	++	+++	++
Quinones	+	+	+	+
Reducing compounds	++	-	-	-
Alkaloids	-	-	-	-
Terpènoïdes	+++	+++	-	+++
Steroids	+++	+++	+++	+++
Polyterpenes	+++	+++	+++	+++

3.3. Biological Studies

3.3.1. Antioxidant activity

According to the results obtained and presented in Figure 1 and Table 4. It is observed that percentage of inhibition of the free radical DPPH increases with the concentration of the aqueous and the organic extracts. The median inhibitory concentration is inversely proportional to the antioxidant capacity of a compound, because it expresses the amount of antioxidant required to decrease the free radical concentration by 50%. The lower IC_{50}value, means the better the antioxidant activity. In this case, the IC_{50} of the aqueous extract of the leaves shows a good DPPH radical scavenging activity which is less than 30µg/ml in comparison with the standard antioxidant (ascorbic acid) which has an IC_{50} of less than 50µg/ml, whereas with the organic leaves extract (76.1µg/ml) close to that of the reference.

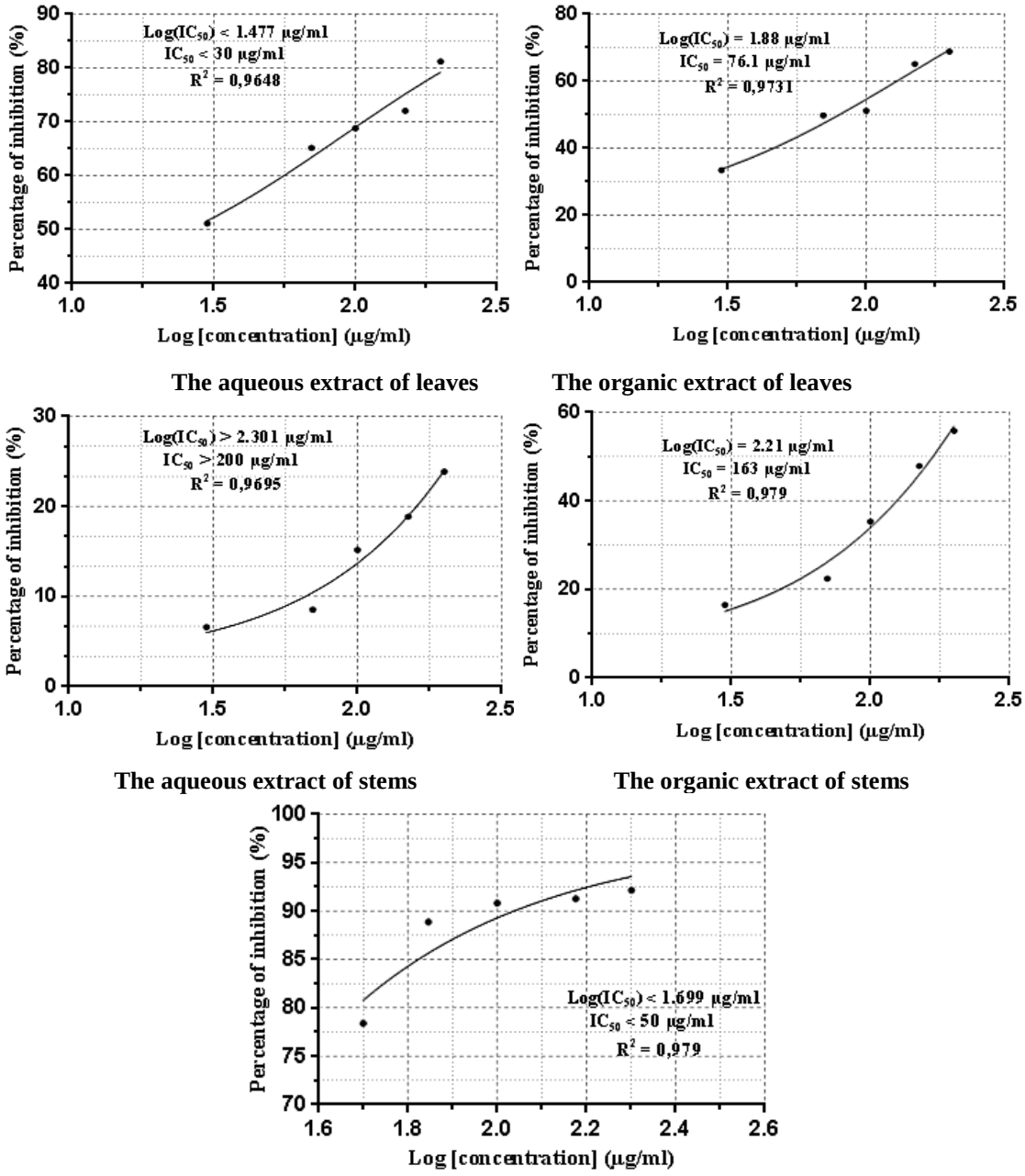


Figure 1: Variation in $IP_{\%}$ as a function of Log concentration of the extracts

Table 4: ***Inhibitory concentrations IC_{50} of aqueous and organic extracts***

Part of the plant	**Stems**				**Leaves**				**Reference**
Extracts	**Aqueous**		**Organic**		**Aqueous**		**Organic**		
C (µg/ml)	**Ab**	**IP(%)**	**Ab**	**IP(%)**	**Ab**	**IP(%)**	**Ab**	**IP(%)**	
200	0.349	23.88	0.2024	55.86	0.086	81.24	0.1426	68.9	
150	0.3719	18.89	0.2388	47.92	0.128	72.08	0.1596	65.19	**Ascorbic acid**
100	0.3888	15.2	0.2962	35.4	0.143	68.81	0.2237	51.21	
70	0.4193	8.55	0.3555	22.46	0.1596	65.19	0.2301	49.81	
30	0.4282	6.609	0.3827	16.53	0.224	51.15	0.305	33.48	
IC_{50} (µg/ml)	**> 200**		**163**		**< 30**		**76,1**		**< 50**

As for the organic stem extract, it has an antiradical activity with an IC_{50} in order of 163µg/ml and the aqueous stem extract with an IC_{50} greater than 200µg/ml. Therefore, it is the aqueous extract of the leaves of *A. herba-alba* which presents a very significant antioxidant activity compared to the other extracts. The presence of phenolic compounds (Flavonoids, Coumarins ...), Alkaloids and Terpenoids would probably the origin of the antioxidant activity of the species [28, 45]. Flavonoids, recognized as excellent anti-oxidants, could perform an important role in the defense system. These metabolisms are further known for other diverse biological properties.

3.3.2. Antimicrobial activity

The diffusion method is a technique allowing to have a preliminary idea on the capacity of an extract to inhibit the microbial growth. The antibacterial activity, when it exists, its manifested by zones of inhibition around the disks, the diameter of these zones is proportional to the intensity of the antibacterial activity. The diameters of the zones of inhibition observed are presented in the following table 5.

Table 5: ***Diameters of the zones of inhibition of the aqueous and organic extracts*** *(BS = Bacillus subtilis, ML = Micrococcus luteus, EC = Escherichia coli, PA = Pseudomonas aeruginosa, CA = Candida albicans)*

Part of the plant		**Stems**		**Leaves**	
Extracts		**Aqueous**	**Organic**	**Aqueous**	**Organic**
DMSO		500 µl	250 µl	500 µl	500 µl
Inhibition diameters en mm	**BS**	-	7	-	11
	ML	-	-	-	-
	EC	-	-	-	-
	PA	-	8	-	10
	CA	-	7	-	-

The results in Table 5 above reveal that Bacillus subtilis and Pseudomonas aeruginosa bacteria have sensitivity to organic extracts of leaves and stems with inhibition diameters that vary between 7 and 11 mm. While Micrococcus luteus and Escherichia coli bacteria showed no sensitivity to the extracts. The Candida albicans yeast showed sensitivity to the organic extract from the stems about 7mm. According to the results obtained, we notice the absence of a zone of inhibition for all the aqueous extracts of the leaves and the stems and which did not show any antibacterial activity. The organic extracts of the leaves reacted more positively compared to the extracts of the stems, which confirm that the leaves of the plant have highly appreciated antibacterial properties. In several studies, the antioxidant and antimicrobial effects are explained by the presence of phenolic derivatives in extracts or isolated [46-48].

3.4. Spectral analysis (FTIR)

The FTIR spectra were carried out using a Shimadzu FTIR-8400S type FTIR spectrometer, over a range of 400 to 4000 cm^{-1}. Fig. 2 represents the FTIR spectra of commercial cellulose and cellulose isolated from the leaves and stems of *A. herba-alba*. Examination of these spectra (figure 2) reveals absorption bands which are as follows:

The absorption plug characteristic of elongations bonded O-H bonds is located around 3350 cm^{-1} and for commercial cellulose, the O-H band is spread out between 3200 and 3600 cm^{-1}.

The band observed at 2900 cm^{-1} is attributed to C-H vibrations [49]. The deformation of the hydroxyl groups of the absorbed water is localized around 1646 cm^{-1} [49]. Pyranose skeleton vibrations (-C-O-C-) are observed at 1060 cm^{-1}

[16], the band of -CH_2- bonds located at 1429 cm^{-1} and -CH- bonds located at 896 cm^{-1}. The FTIR spectra of the celluloses of the stems and leaves of *Artemisia herba-alba* have been shown in figures 3, 4 and 5. The absence of an absorption band characteristic of the elongation of C=C at 1614 cm^{-1} [49] on the Cellulose-acrylamide spectra is a strong indication of acrylamide grafting on the cellulosic backbone.

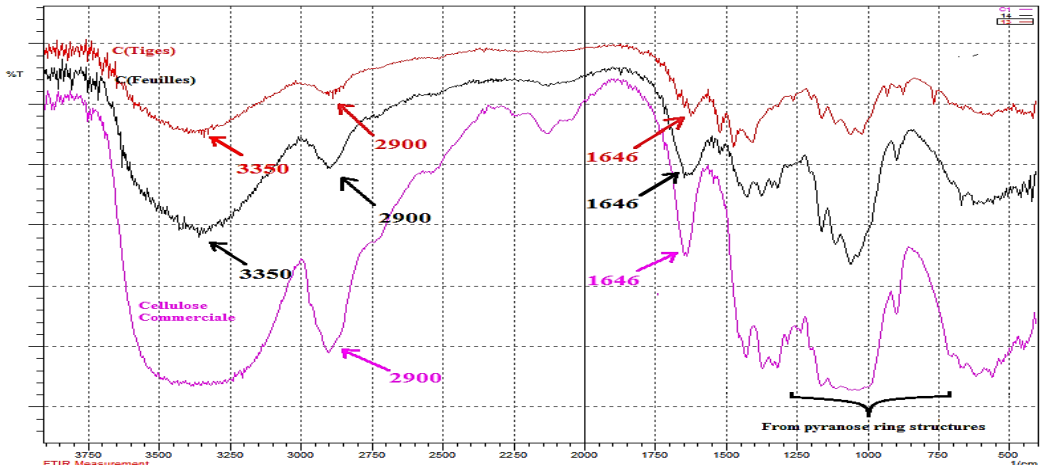


Figure 2: FTIR spectra of commercial cellulose and cellulose from Artemisia herba-alba leaves and stems

In addition, a spread of the band around 3440 cm^{-1} demonstrated the superposition of the OH and NH bands. The Cellulose-acrylamide spectra show the appearance of new absorption bands attributed to the grafted acrylamide group. Indeed, the new bungs detected at 1650 cm^{-1} and 1567 cm^{-1} are attributed to the C=O vibrations of the primary amide group and the carboxylate, respectively. The appearance of the carboxylate functions on the FTIR spectra is due to the saponification of the grafted amide group under the action of the NaOH base.

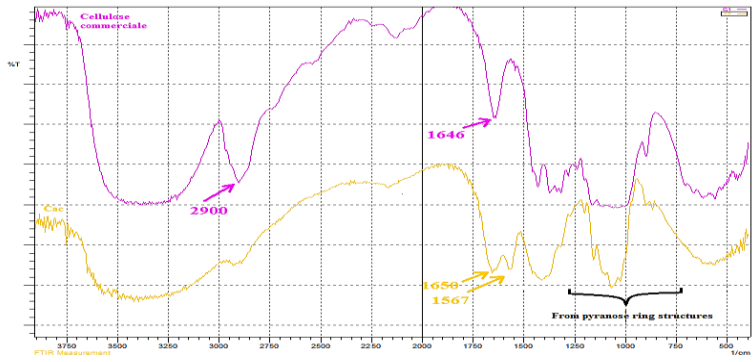


Figure 3: FTIR spectra of commercial cellulose and Cellulose-acrylamide

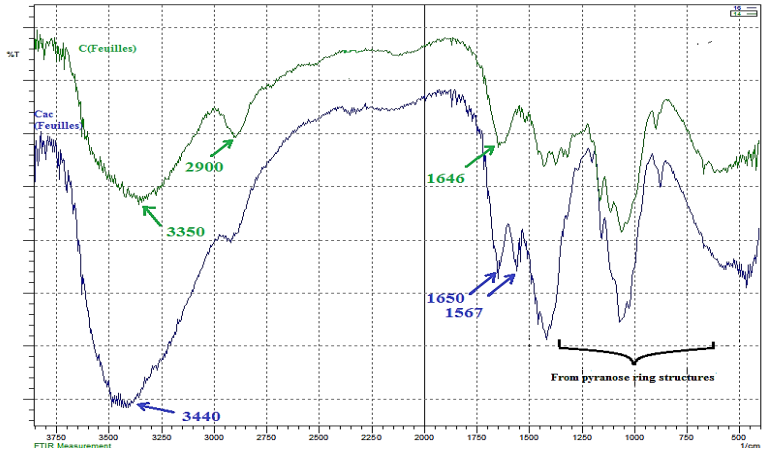


Figure 4: Cellulose and Cellulose-acrylamide FTIR spectra of leaves

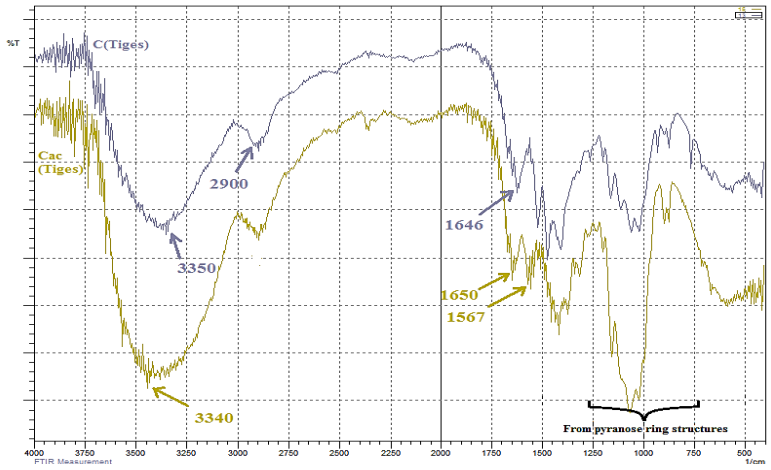


Figure 5: Cellulose and Cellulose-acrylamide FTIR spectra of stems

3.5. Cu (II) removal capacity

Table 6 represents the absorbance of the samples studied and the concentrations of adsorbate in the solution at equilibrium Ce (Figure 6).

Table 6: ***Absorbance and Ce of the samples studied***

Témoin		**Cellulose-acrylamide**			
		Leaves		**Stems**	
C_0 (mg/L)	**Ab**	**Ab**	**C_e (mg/L)**	**Ab**	**C_e (mg/L)**
100	0.0062	0.0034	54.26	0.0024	38.34
200	0.0112	0.0070	117.71	0.0063	103.14
300	0.0145	0.0093	167.71	0.0084	147.31
400	0.0226	0.0146	293.27	0.0132	260.31
500	0.0284	0.0189	352.47	0.0190	356.05
600	0.0346	0.0232	412.11	0.0238	423.32
700	0.0398	0.0267	471.95	0.0275	487.89
800	0.0434	0.0316	553.14	0.0341	595.07
900	0.0484	0.0367	640.13	0.0412	738.12
1000	0.0528	0.0417	751.57	0.0450	831.39

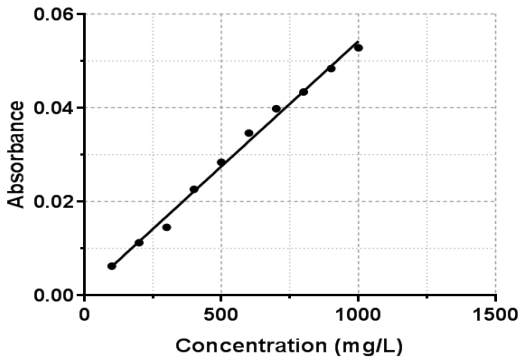


Figure 6: Calibration curve of copper (II) solution

3.5.1. Effect of initial concentration

In order to study the effect of the initial concentration of Cu (II) between 100 to 1000 mg/L on the adsorption capacity Qe, the results obtained are represented in figures 7 and 8. The data show that the adsorption capacities Qe of Cellulose-acrylamide increased with the increase of the initial concentration of Cu (II), which implies the elevation of the quantity adsorbed on the free active sites, for a constant mass and concentrations copper variables. After calculating the adsorption yields, we show a high efficiency of the modified cellulose stems to absorb copper (II) in an aqueous solution with a maximum percentage of 61.29%. It may be deduced from the figure 9 and 10 that the adsorption yield is inversely proportional to the initial concentration, this is explained by the fact that at low concentrations the ratio between the active sites of the surface and the total metal ions in the solution is high, and therefore all metal ions can be retained by the adsorbent and completely eliminated from the solution.

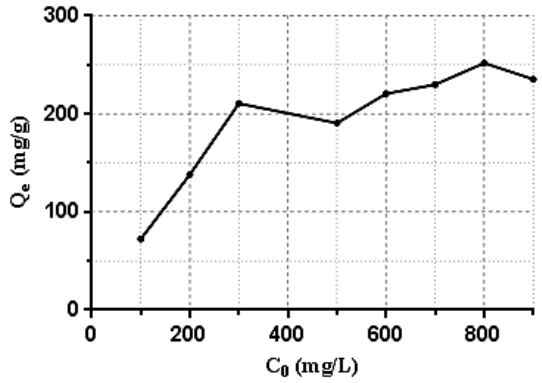


Figure 7: The variation of Qe as a function of C_0 for Cellulose-acrylamide of stems

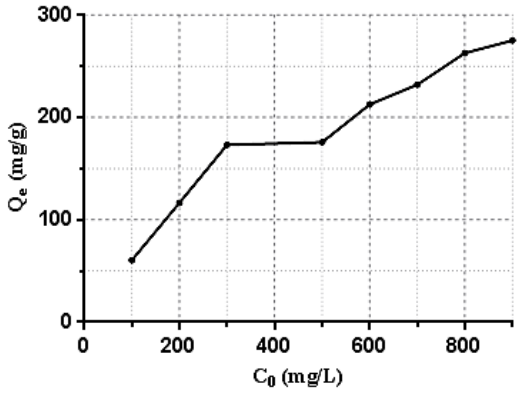


Figure 8: The variation of Qe as a function of C_0 for Cellulose-acrylamide of leaves

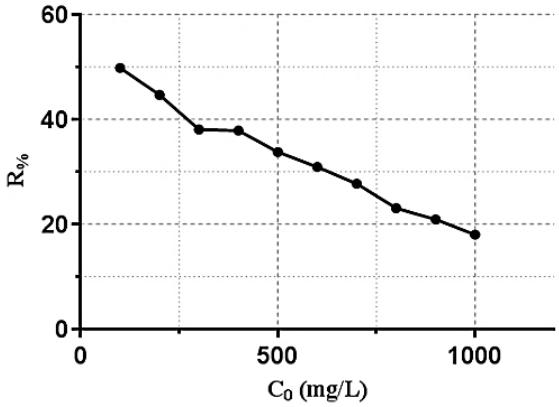


Figure 9: The variation of the adsorption yield as a function of C_0 for Cellulose-acrylamide of the leaves

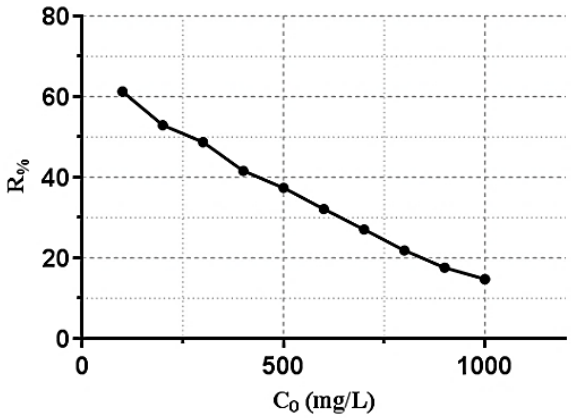
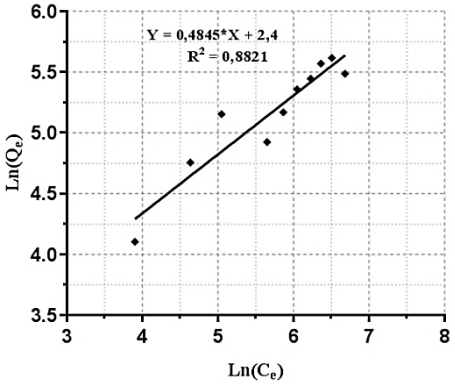


Figure 10: The variation of the adsorption yield as a function of C_0 for Cellulose-acrylamide of the stems

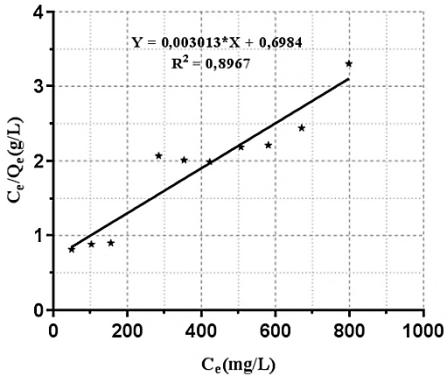
3.5.2. Adsorption isotherms

In order to identify the isotherm that best represents the adsorption of copper ions on the cellulosic flocculant Cac, four theoretical models were tested on the experimental results obtained, namely Freundlich, Langmuir, Temkin and Elovich. The analysis of the experimental results according to these models made it possible to have the following graphic representations (Figures 11 & 12). According to the graphic representation of each isotherm (Figures 11 and

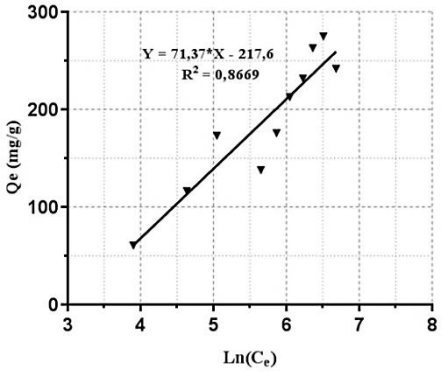
12) and the table 7 below which gives the values of the constants of each mathematical model as well as the coefficient of determination (R^2) accounting for the more or less good correlation between the function and its associated variable, it is obvious that the adsorption of copper (II) on Cellulose-acrylamide of the stems and leaves of *A. herba-alba* is characterized by the Langmuir model with determination coefficients R^2 (Stems)= 0.9612 and R^2 (Leaves)= 0.8967. So according to the Langmuir isotherm theory assumes that the adsorption is monolayer and takes place at specific homogeneous sites of the adsorbent. Cellulosic flocculant received more attention of researchers until now [50-52]. The kinetic study results revealed that the adsorption process was pseudo-second-order [50].



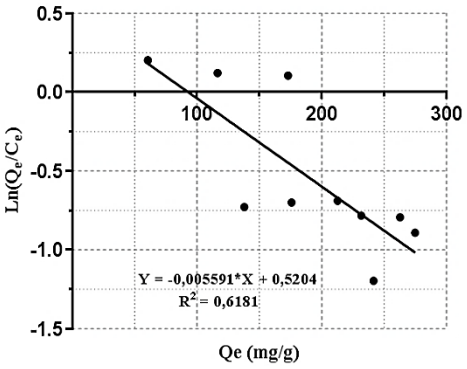
Freundlich linear regression



Langmuir linear regression

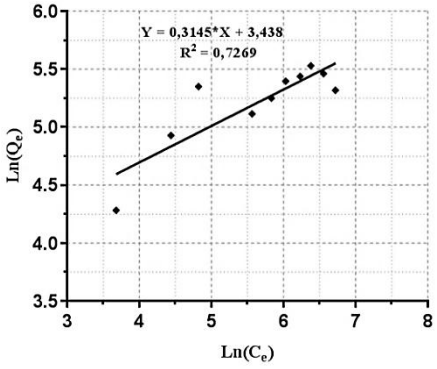


Temkin linear regression



Elovich linear regression

Figure 11: Linearization of Cu (II) adsorption isotherms on Cellulose-acrylamide (leaves) according to four models



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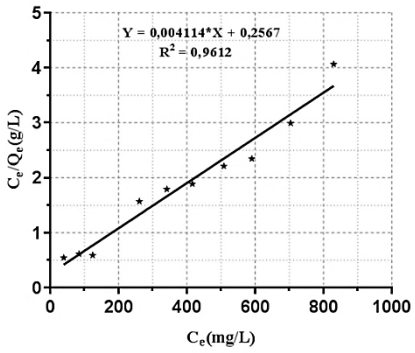
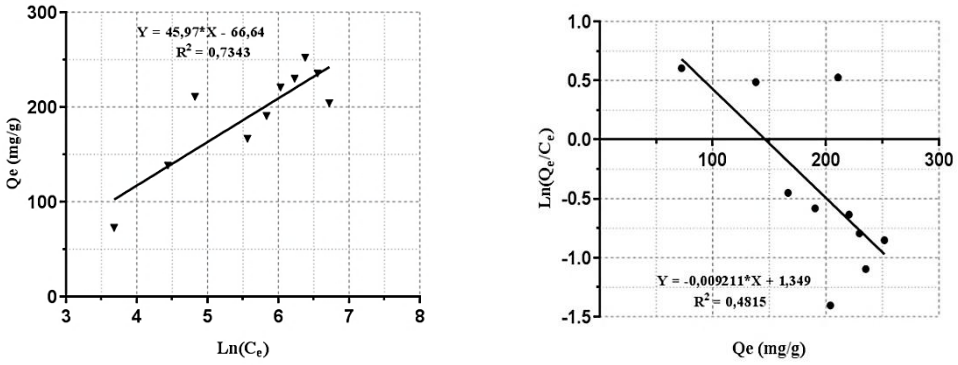


Langmuir linear regression



Temkin linear regression **Elovich linear regression**

Figure 12. Linearization of Cu (II) adsorption isotherms on Cellulose-acrylamide (stems) according to four models

Table 7: ***Constants of the different models of isotherms calculated for the adsorption of Cu (II) on the flocculant Cellulose-acrylamide***

Type d'isotherme	Stems		Leaves	
Freundlich	R^2	0.7269	R^2	0.8821
	n_f	3.1797	n_f	2.064
	K_f(mg/g)	31.125	K_f(mg/g)	11.023
Langmuir	R^2	**0.9612**	R^2	**0.8967**
	Q_m(mg/g)	243.07	Q_m(mg/g)	331.895
	K_L(L/mg)	0.016	K_L(L/mg)	4.314
Temkin	R^2	0.7343	R^2	0.8669
	K_t(L/g)	0.235	K_t(L/g)	0.0474
	b_t	53.923	b_t	34.732
Elovich	R^2	0.4815	R^2	0.6181
	Q_m(mg/g)	-108.57	Q_m(mg/g)	-178.86
	K (L/mg)	-0.0355	K (L/mg)	-0.0094

Conclusion

In the present work, cellulose was successfully isolated from *A. herba-alba* stems and leaves using alkaline treatment followed by bleaching with a yield of about 30.75% for *A. herba-alba* stems. We confirmed the structure of cellulose by the FTIR. In addition to cellulose, several other substances are part of the structure of plant cells. Among these substances, there are extractable compounds which are easily extractable using organic or aqueous solvents (water), without resorting to severe treatments. In the first part, we studied the phytochemistry of organic and aqueous extracts which showed the richness of the leaf extracts in secondary metabolites, where we found the presence of flavonoids, tannins, steroids, polyterpenes, terpenoids and anthocyanins. We also carried out an antimicrobial test; the microbiological results showed that the antimicrobial activity is variable from one strain to another; this is due to the variability of the chemical composition of each extract. The results of the antioxidant activities express that IC_{50} concentration of the aqueous extract of the leaves has a good DPPH radical scavenging activity which is less than 30µg/ml in comparison with the standard antioxidant (ascorbic acid) which has an IC_{50} less than 50µg/ml.

In the second part, we carried out a chemical modification of cellulose by grafting acrylamide onto hydroxyl groups. In the last part we carried out the adsorption tests to investigate the affinity of Cellulose-acrylamide to absorb Cu (II)

and its elimination. The experimental results show that the adsorption of copper (II) on Cellulose acrylamide is characterized by the model of Langmuir. So the adsorption occurs at specific homogeneous sites within the adsorbent. It is concluded that cellulose-acrylamide is a more effective adsorbent for the removal of heavy metals. Its advantage is its ability to treat large volumes of effluent at low concentrations of pollutants.

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