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Research Article

Antidiabetic Potential and Chemical Constituents of *Haloxylon scoparium* Aerial Part, An Endemic Plant from Southeastern Algeria

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Abstract: Diabetes mellitus is a chronic metabolic disease. Traditional medicines are currently still popular as an alternative in the treatment of this disease. However, the mechanism of action in lowering blood sugar of most folk recipes remains unproven. The objective of this study is to evaluate the antidiabetic potential of an Algerian halophyte in regulating postprandial hyperglycemia via α-amylase inhibitory activity. For this, methanolic and aqueous crude extracts were prepared from the aerial part of *Haloxylon scoparium* Pomel and analyzed by HPLC/ UV method. Total flavonoids, total tannins and total alkaloids as specific extracts were also prepared from the same part. The *in vitro* α-amylase inhibition assay using starch-iodine was performed. As results, the methanolic crude extract seems to be the best with 29 phenolic compounds of which the most abundant is gallic acid. All tested extracts showed better α-amylase inhibitory activities. Among these extracts and compared to acarbose (IC_{50} = 17.96 µg/ mL), the methanolic crude extract had the highest inhibitory activity (IC_{50} = 22.9 µg/ mL), followed by total flavonoids and alkaloids. Finally, we conclude that *Haloxylon scoparium* aerial part had displayed maximum inhibition against α-amylase enzyme especially with its methanolic crude extract. It can be used for management of postprandial hyperglycemia with lesser side effects and provide a strong rationale for further animal and clinical studies.

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1. INTRODUCTION

Diabetes mellitus is defined as a chronic disease characterized by an increase in fasting blood sugar (WHO, 2016). Among all cases of diabetes in the world, about 90% are type II. Postprandial hyperglycemia (PPHG) is a very important risk factor in the onset and development of type II diabetes (Dong *et al*., 2012). Dietary carbohydrates such as starch give after hydrolysis several molecules of glucose which are the main source in PPHG. With α-amylase enzyme, dietary polysaccharides are hydrolyzed to oligosaccharides and disaccharides

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and then to monosaccharides by α-glucosidase (Bischoff *et al*., 1985). To date, the most effective strategy in the management of post-prandial hyperglycemia is the reduction of glucose intake by decreasing or blocking the digestion of carbohydrates into monosaccharides in the gastrointestinal tract. α-amylase and α-glucosidase are digestive enzymes released in the intestinal lumen to digest carbohydrates into simple glucose molecules (Ortiz-Andrade *et al*., 2007; Shang *et al*., 2012).

Inhibition of α-amylase enzyme may slow and delay the digestion by hampering breakdown of starch and may be considered an effective strategy in reducing the intensity of metabolic disturbances and regulating the hyperglycemic condition (Ashok Kumar *et al*., 2011). This endocrine problem is certainly due to impaired insulin secretion and insulin sensitivity (Ceriello, 2005; Nyenwe *et al*., 2011). Delayed secretion of this hormone, after eating something, can cause a persistent increase in postprandial blood sugar (PPG) in the range of 140 to 190 mg/ dl, which further increases to 200 mg/ dl and in extreme cases up to 400 mg/ dl (Bachhawat *et al*., 2011; Mohamed Sham Shihabudeen *et al*., 2011). The first hours of the postprandial phase of diabetes, which follow the strong insulin secretion, are very particular due to the increase in the level of glycated hemoglobin (HbA1c) leading to several vascular complications (neuropathy, retinopathy, etc.) and an increased risk of cardiovascular problems (Bonora & Muggeo, 2001; Aryangat & Gerich, 2010; Campos, 2012).

In recent decades, certain synthetic inhibitors, such as acarbose, miglitol and voglibose, have been developed and received considerable and particular attention for the management of type II diabetes (Toeller, 1994). These synthetic inhibitors or α-amylase inhibitor drugs are generally used with other oral hypoglycemic drugs (sulfonylurea, metformin) to reduce the level of HbA1c. However, the unwanted side effects of these synthetic inhibitors like diarrhea, flatulence, abdominal distension, meteorism, bloating, nausea and intestinal cystoid pneumatosis (Hollander, 1992; Puls, 1996; Kojima *et al*., 2010) have attracted scientists' interest in medicinal plants. Plant-based α-amylase inhibitors may present a particularly credible alternative for controlling PPHG (Horii *et al*., 1986; Kwon *et al*., 2006).

Since ancient times, people have used plants for self-care and defense against many chronic and infectious diseases. Among these plants, *Haloxylon scoparium* Pomel which is distributed in temperate salt habitats, especially in the coastal regions of the Mediterranean Sea, arid steppes, and deserts (Mulas, 2004), is widely used as a remedy for the treatment of eye and vision disorders, hypertension and skin diseases (Allali *et al*., 2008), and also for the treatment of cancer, hepatitis, inflammation and obesity (Eddouks *et al*., 2002).

This study aims to evaluate the antidiabetic potential of this Algerian halophyte through the *in vitro* evaluation of the α-amylase inhibitory activities of its aerial part extracts.

2. MATERIAL and METHODS

2.1. Plant Material

From a random samples of *Haloxylon scoparium* Pomel of Amaranthaceae family (Täckholm, 1974; Boulos, 1999) collected in 2016 in southeastern Algeria (Figure 1), aerial parts were isolated, cleaned of microorganisms and residual soil and air dried at room temperature for 15 to 20 days. These parts are then ground and a voucher specimen has been deposited in the Herbarium of the Plant Biology and Environment Laboratory of the Faculty of Sciences for future reference.

Figure 1. General habitus of the studied species.

2.2. Phytochemical Screening

A phytochemical screening was carried out following standard procedures for the highlighting of the presence or absence of bioactive compounds of the secondary metabolism of *Haloxylon scoparium* (Ronchetti & Russo, 1971; Fadeyi *et al*., 1989; Odebiyi & Sofowora, 1990; Harborne, 1998; Hagerman *et al*., 2000; Abulude *et al*., 2004; Abulude, 2007).

2.3. Plant Extracts and Total Polyphenols Contents

2.3.1. *Crude extracts*

According to Falleh *et al*. (2008) and by cold maceration of 2.5g of dry plant matter in 25 mL of absolute solvents (methanol and distilled water), methanolic and aqueous crude extracts of the studied plant were prepared and then stored at 4°C for later use.

2.3.2. *Specific extracts*

2.3.2.1. Total Flavonoids: According to Foungbe *et al*. (1976), total flavonoids extraction was carried out according to the CHARAUX-PARIS standard method (Paris, 1954). It's a universal method which consists in stabilizing a mass of dried herbal drug equal to 10 g for one hour in 200 mL of ethanol at a temperature of 96 °C. After filtration and drying, the drug was pulverized and then depleted using a Soxhlet with 200 mL of absolute ethanol brought to a temperature of 96 °C for 4 hours. After maceration for 12 to 24 hours, the two ethanolic solutions were combined and evaporated under reduced pressure. The residue was taken up in 20 mL of boiling water, the resulting aqueous solution was left to stand for 24 hours. Finally, the liquor was exhausted in a separating funnel in three successive stages with ether, ethyl acetate and n-butanol. According to Solfo (1973), flavonoid compounds don't pass in ether, they are in trace amounts in ethyl acetate and only the butanol compound contains an amount that can be studied. The butanol extract was then evaporated using a rotary evaporator at a temperature of 30 °C. The residue was then collected in little of methanol and stored at a temperature of 4 °C for future use.

2.3.2.2. Total Tannins: To extract the total tannins existing in the aerial part of our plant, we followed the method of Sowunmi *et al*. (2000) which consists in macerating 50 g of dried plant material for 24 hours with magnetic stirring in a mixture of ethanol and boiling water (200 mL/ 500 mL). After filtration, the resulting liquor was depleted in a separating funnel several times with chloroform. After evaporating the organic phase using a rotary evaporator, the residue was taken up in 10 mL of methanol (1%) and then stored in the refrigerator at a temperature of 4 °C.

2.3.2.3. Total Alkaloids: The extraction of total alkaloids was carried out according to Fattorusso & Taglialatela-Scafati (2007): 100 g of herbal drug was degreased with 300 mL of petroleum ether. This step lasts 24 hours to ensure proper elimination of fats and pigments. Filtration was subsequently carried out; the filtrate was discarded. The marc was left in the open air for 30 minutes to be dried and to remove the organic solvent. The marc undergoes maceration for 24 hours in 200 mL of an alkalinized chloroform solution by adding a few drops of ammonia until a basic pH (pH = 9). Filtration was then carried out, the filtrate was collected. In order to allow good depletion of the marc and to improve the extraction yield, this maceration was done in triplicate. The collected filtrates were grouped together and partially concentrated using a rotary evaporator. The recovered concentrate is extracted with 200 mL of 3% aqueous sulfuric acid (H_2SO_4) solution. The acid phase was then basified with an ammonia solution to pH = 9. Then, liquid-liquid extraction was carried out using a separating funnel with 20 mL of chloroform. It was mixed by stirring up and down for a few minutes. After standing for about 30 minutes, two phases were observed, the aqueous phase above and the organic phase below. The organic phase (organic solution of total alkaloids) was recovered and then concentrated until the chloroform was completely eliminated in a rotary evaporator at 40 °C. The concentrate

thus obtained is a brown paste of alkaloids, to which 20 mL of acetone or very little of methanol has been added. Finally, the mixture was stored in the refrigerator at a temperature of 4 °C.

2.3.3. *Total polyphenols contents*

To evaluate the total polyphenols content, we followed the standard method of Singleton & Rossi (1965) using the Folin-Ciocalteu reagent. The content was expressed in mg gallic acid equivalent per gram of dry weight (mg GAE/ g DW).

2.4. Phytochemical Analysis (HPLC determination of phenolic compounds)

HPLC/ UV analysis was carried out at the Chromatographic Analysis Laboratory of the Center for Research and Physico-Chemical Analysis (CRAPC) in Algiers (Capital of Algeria) using a Young Line 9100 brand device equipped a high pressure liquid chromatography pump fitted with a UV deuterium detector. The chromatographic separations were carried out in reverse phase with a column Zorbax Eclipse XDB-C18 (stationary phase: 150 mm x 4.6 mm, 5 µm) and a mobile phase formed from two different solvents: A: Acidified water with 1% of acetic acid and B: absolute methanol. The temperature was maintained at 25°C and the chosen injection volume was 20 µL. The mobile phase solvents were of HPLC grade and the flow rate was set at 1mL / min. The chromatographic conditions consist of a gradient mode: Initial A 95%; B 5%, at 55min: A 5%; B 95%, at 60min: A 95%; B 5%. The UV-visible detector was tuned to signals 254 and 280 nanometers.

2.5. Antidiabetic Activity (α-amylase inhibitory activity)

In order to evaluate the antidiabetic activity of different extracts of *Haloxylon scoparium* in Algerian northern Sahara, the α-amylase inhibition test was performed using a modified method of Kusano *et al*. (2011). The undigested starch due to enzyme inhibition was detected at 630 nm (blue, starch-iodine complex). To do that, 200 mg of starch were dissolved in 25 mL of NaOH (0.4 M). The substrate solution was heated at 100°C for 5 minutes. After cooling, the pH was adjusted to 7.0 and the final volume was made up to 100 mL with distilled water. Acarbose was used as a positive control. 40 µL of substrate solution was pre-incubated at 37°C for 3 minutes with 20 µL of acarbose or plant extract in increasing concentrations. 20 µL of 3 U/mL of α-amylase were then added (20 mM phosphate buffer with 6.7 mM NaCl, pH 6.9), and the mixture was further incubated at 37°C for 15 min. Termination of the reaction was done by adding 80 µL of HCl (0.1 M). Then, 100 µL of iodine reagent (2.5 mM) were added, and the absorbance was measured at 630 nm. Percentage of inhibition of α-amylase enzyme was calculated using the formula:

$$\% \text{ Inhibition} = (1-[Abs_2-Abs_1/\ Abs_4-Abs_3]) \times 100$$

Where, Abs_1 is the absorbance of the incubated mixture containing plant sample, starch, and amylase; Abs_2 is the absorbance of incubated mixture of sample and starch; Abs_3 is the absorbance of the incubated mixture of starch and amylase; Abs_4 is the absorbance of incubated solution containing starch. Results were expressed as IC_{50}. IC_{50} value represents the concentration of inhibitor required to achieve 50% enzyme inhibition. In the case of significant inhibition, IC_{50} values were determined through nonlinear regression by fitting to a sigmoid dose-response equation with variable slope using GraphPad Prism version 7.00 for Windows, GraphPad Software, Inc. La Jolla California USA.

2.6. Statistical Analysis

Experimental tests were realized in triplicate and all results were expressed as mean ± standard error of the mean (SEM). All values of α-amylase inhibitory activity of *H. scoparium* aerial extracts were statistically compared by ANOVA test (analysis of variance) using MINITAB version 16.0 program (Values were considered significant at $p < 0.05$).

3. RESULTS

3.1. Phytochemical screening

The results of phytochemical tests of the different compounds of *H. scoparium* aerial part are grouped in Table 1.

Table 1. Phytochemical compounds of *H. scoparium* aerial part.

Flavonoids	Tannins	Saponins	Cardinolids	Anthocyanins	Leuco anthocyanins	Alkaloids	Terpenes and Sterols
+	+	+	-	+	-	+	+

(+) : Detected, (-) : Not detected

These tests revealed the presence of six major compounds of secondary metabolism (flavonoids, tannins, saponins, anthocyanins, alkaloids, terpenes and sterols) and the absence of two other important compounds: Cardinolids and leucoanthocyanins. The presence of these secondary metabolites suggests that the plant might be of medicinal importance.

3.2. Yields and total polyphenols contents

Yields of different extracts and results of the colorimetric analysis of total polyphenoFls of the studied species are represented in Table 2.

Table 2. Yields and different compound contents in *H. scoparium* extracts.

Plant extract	Yield (%)	Total polyphenols content (mg GAE/ g DW)
Methanolic Crude Extract (MCE)	20.66	228.582 ± 0.689
Aqueous Crude Extract (ACE)	44.44	336.756 ± 0.855
Total flavonoids (T. Flav)	04.36	-
Total Tannins (T. Tan)	26.27	-
Total Alkaloids (T. Alc)	0.53	-

From this Table 2; *H. scoparium* is found to be richer in aqueous crude extract with 44.44% in its aerial part. Concerning total polyphenols which are known by their several biological activities, the obtained results of colorimetric assays show a very high content of total polyphenols (336.756 ± 0.855 mg GAE/ g DW) in the aqueous crude extract (ACE) of *H. scoparium* aerial part, and 228.582 ± 0.689 mg GAE/ g DW in crude methanol extract (MCE).

3.3. Phytochemical analysis

HPLC/ UV analysis showed the richness of *H. scoparium* crude extracts in phenolic compounds. The obtained chromatogram profiles are shown in Figures 2 and 3.

Figure 2. HPLC/ UV chromatogram profile of methanolic crude extract.

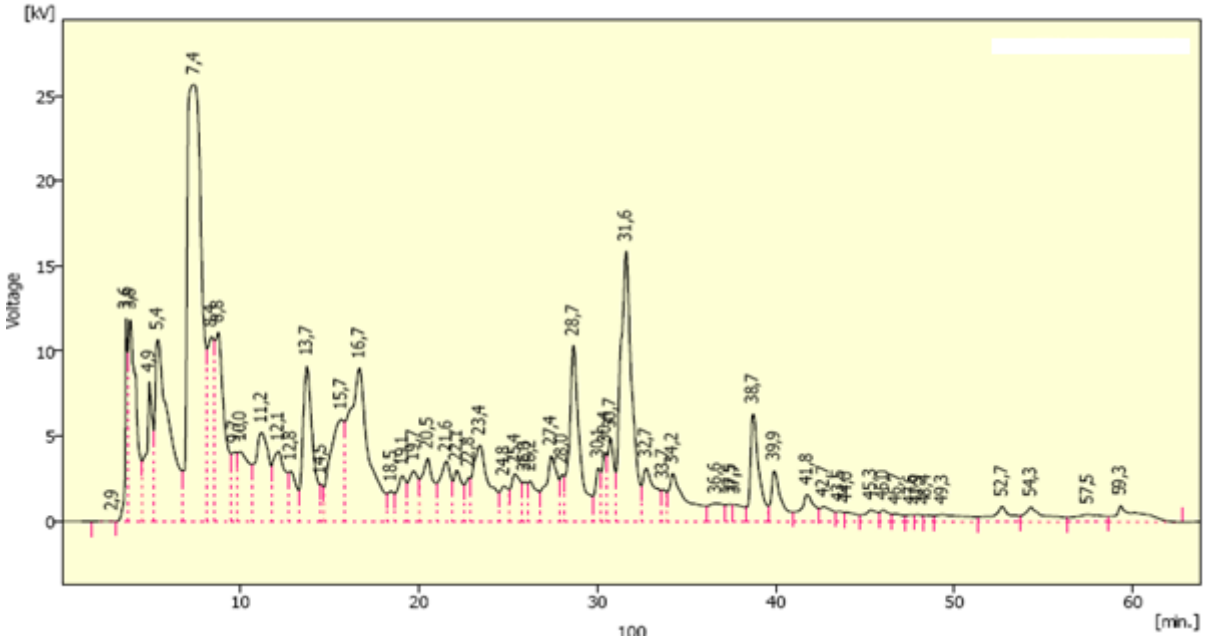
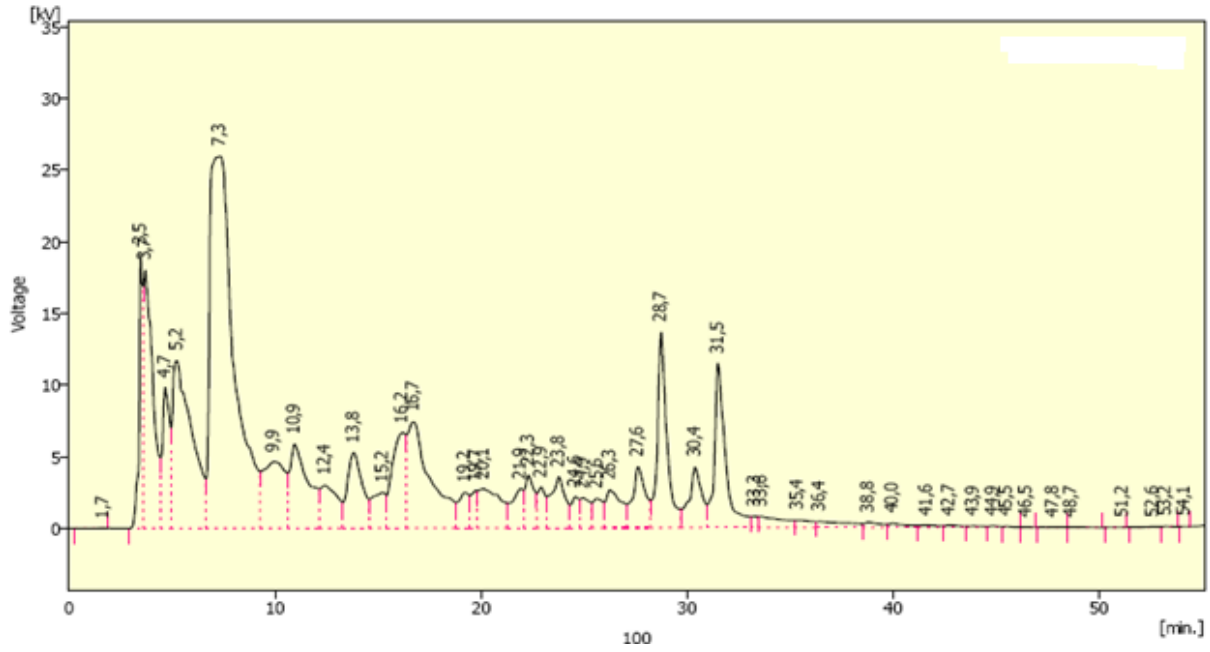


Figure 3. HPLC/ UV chromatogram profile of aqueous crude extract.



Based on the retention time, the sample peak area and the standard peak area, several compounds were identified (Table 3). From this table, 29 phenolic compounds were identified in MCE solution of which the most abundant is gallic acid (14.4%) followed by catechic acid (7.0%), rutin (7.0%) and trans-cinnamic acid (4.2%). However, ACE analysis revealed only 18 phenolic compounds with a predominance of gallic acid (24.5%) and catechic acid (6.6%).

Table 3. Phenolic compounds of methanolic and aqueous crude extract.

P	MCE			ACE		
	RT	A	Compounds	RT	A	Compounds
1	3.837	3.7	Ascorbic acid	3.477	2.8	Ascorbic acid
2	7.420	14.4	Gallic acid	7.327	24.5	Gallic acid
3	11.203	2.8	Resorcinol	10.943	4.2	Resorcinol
4	13.737	3.6	Catechin	13.827	3.1	Catechin
5	15.653	3.2	Gentisic acid (2,5-dihydroxy benzoïc acid)	16.177	3.4	Gentisic acid (2,5-dihydroxy benzoïc acid)
6	16.687	7.0	Catechic acid	16.727	6.6	Catechic acid
7	20.503	1.6	Cafeic acid	20.127	2.4	Cafeic acid
8	21.553	1.6	Isovanillic acid	21.927	1.2	Isovanillic acid
9	22.120	1.0	Syringic acid	22.310	1.3	Syringic acid
10	22.820	0.5	Vanillic acid	22.927	2.8	Vanillic acid
11	23.420	2.8	Epicatechin	23.777	2.0	Epicatechin
12	24.787	0.7	Benzoïc acid	24.593	0.6	Benzoïc acid
13	25.387	1.1	Para-coumaric acid	25.643	0.8	Para-coumaric acid
14	26.237	0.8	Scopoletin	26.260	1.6	Scopoletin
15	27.420	1.8	Ferulic acid (3-hydroxy 4-methoxycinnamic)	27.627	2.1	Ferulic acid
16	28.670	4.2	Trans-cinnamic acid	28.743	5.1	Trans-cinnamic acid
17	30.053	0.7	Berberin	30.393	2.1	Robinin
18	30.437	0.8	Robinin	31.510	4.9	Rutin
19	30.737	1.2	Salicylic acid	/	/	/
20	31.620	7.0	Rutin	/	/	/
21	32.737	1.6	Euleropein	/	/	/
22	33.687	0.4	M-anisic acid	/	/	/
23	34.220	2.0	Myricetin	/	/	/
24	38.720	2.1	Quercetin	/	/	/
25	39.903	1.2	Naringenin	/	/	/
26	41.753	0.8	Apigenin	/	/	/
27	52.670	0.6	Kaempferol	/	/	/
28	54.287	0.7	Tangiritin	/	/	/
29	59.303	0.9	3-hydroxy-flavone	/	/	/
1	3.837	3.7	Ascorbic acid	3.477	2.8	Ascorbic acid
2	7.420	14.4	Gallic acid	7.327	24.5	Gallic acid

P: Peak, RT: Retention time (min), A: Area (%)

3.4. α-amylase inhibitory activity

Results of α-amylase inhibitory activity of different plant extracts of *H. scoparium* are represented in the table below (Table 4). From these results, all the extracts and acarbose showed dose-dependent inhibition of α-amylase enzyme. Enzyme inhibition is directly proportional to the concentration of the tested sample. When the concentration is high, the inhibition is strong. A very large percentages of inhibition were recorded that could exceed 90% with the exception of the aqueous crude extract (ACE) which showed only moderately low inhibition values.

Table 4. α-amylase inhibitory activity results.

Sample	Concentration (µg/mL)	Inhibition (%)	IC_{50} (µg/mL)
Methanolic Crude Extract (MCE)	5	22.158±0.005	22.9±0.009[b]
	10	46.884±0.009	
	25	58.431±0.008	
	50	62.095±0.015	
	100	71.395±0.006	
	250	78.251±0.005	
	500	80.387±0.018	
	1000	88.355±0.135	
Aqueous Crude Extract (ACE)	5	21.326±0.014	45.244±0.027[e]
	10	30.930±0.005	
	25	49.723±0.005	
	50	52.758±0.005	
	100	66.880±0.005	
	250	68.649±0.006	
	500	72.401±0.045	
	1000	79.306±0.005	
Total Flavonoids (T. Flav)	5	20.010±0.002	24.337±0.005[c]
	10	39.150±0.002	
	25	45.337±0.004	
	50	66.787±0.002	
	100	82.788±0.001	
	250	83.060±0.002	
	500	85.095±0.006	
	1000	88.259±0.002	
Total Tannins (T. Tan)	5	18.993±0.004	28.957±0.005[d]
	10	29.029±0.002	
	25	39.340±0.002	
	50	65.720±0.002	
	100	80.514±0.005	
	250	87.060±0.001	
	500	91.725±0.006	
	1000	92.609±0.047	
Total Alkaloids (T. Alc)	5	21.772±0.005	25.787±0.005[c]
	10	37.754±0.005	
	25	44.978±0.001	
	50	59.621±0.005	
	100	76.372±0.005	
	250	92.494±0.004	
	500	92.656±0.005	
	1000	94.015±0.003	

Table 4. Continues.

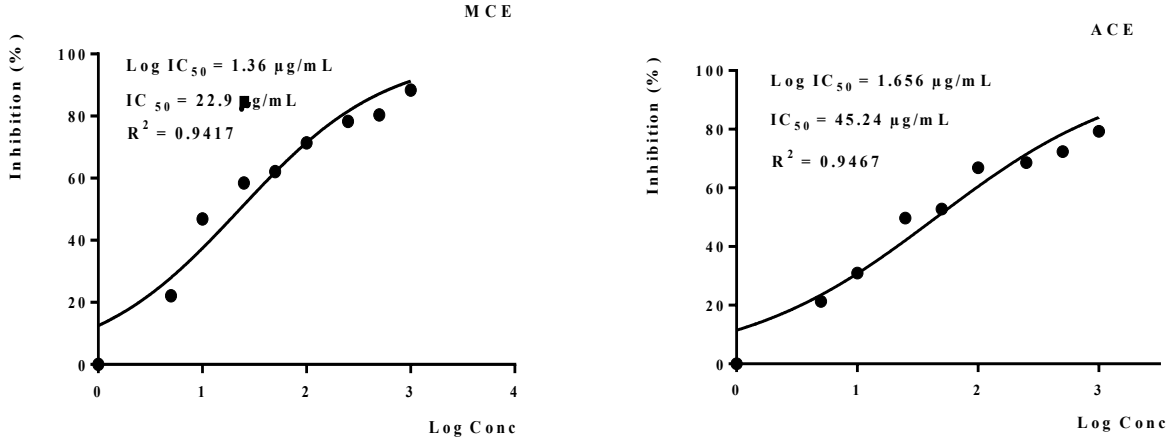
Acarbose (Positive control)	2	18.74±0.017	17.96±0.014[a]
	4	24.594±0.013	
	8	49.050±0.030	
	16	70.314±0.013	
	32	83.104±0.042	
	64	87.064±0.042	
	128	95.20±0.022	

In the last column, means followed by different letters are significantly different ($p < 0.05$)

In general and concerning concentrations which are less than 100 µg/ mL of plant samples (Table 4), the ACE recorded the lowest percentages of inhibition with a maximum of 66.880 ± 0.005%. As for the crude methanolic extract (MCE) and by comparison with the other plant extracts which are found to be more or less similar, a remarkable and very particular increase in inhibition percentages is observed from the concentration 5 to 25 µg/ mL.

Concerning the positive control (acarbose), more or less similar results are recorded compared to those obtained with MCE, especially at low concentration. For concentrations above 50 µg/ mL, acarbose appears to be better with very strong inhibition values.

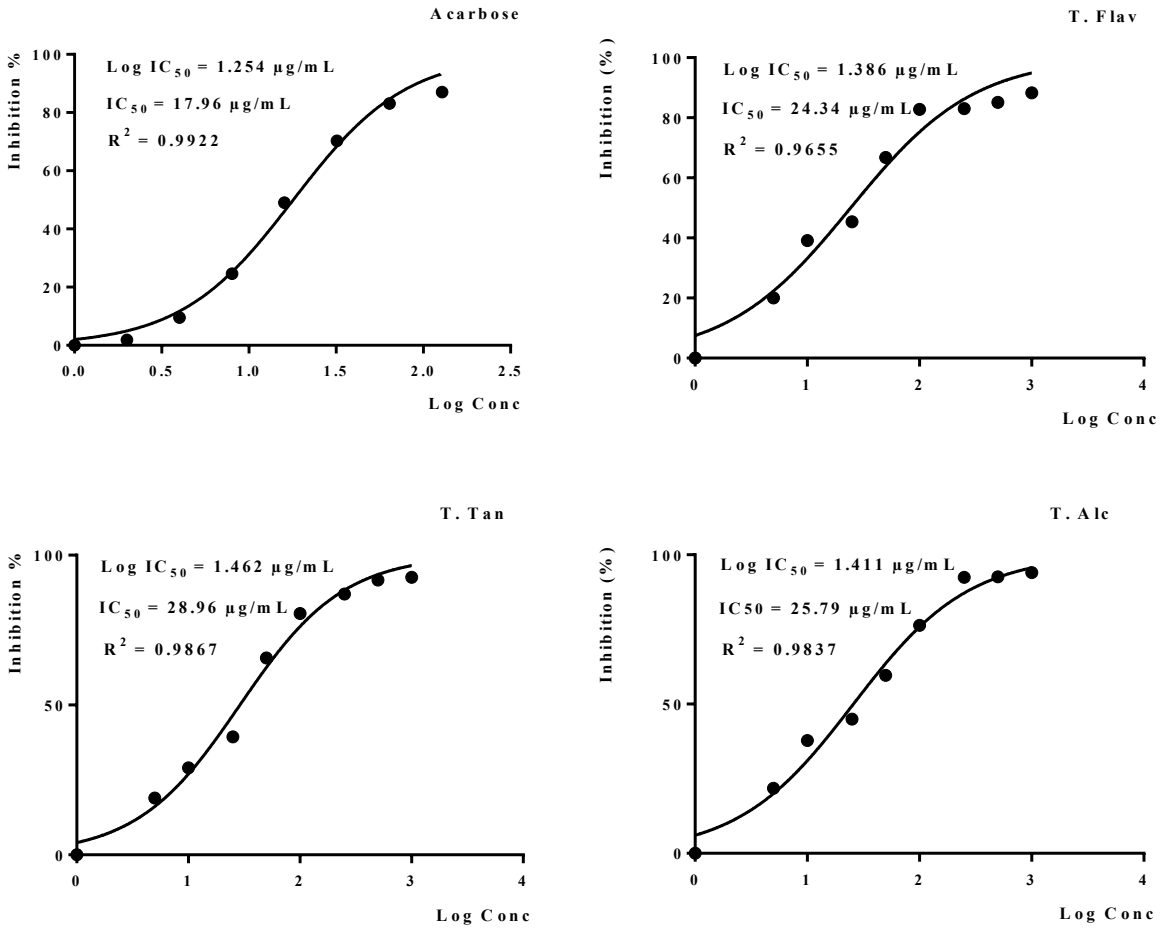
Figure 4. α-amylase inhibition of methanolic and aqueous crude extracts.



As for IC_{50} values, the MCE comes first compared to other plant extracts with 22.9 µg/ mL (Figure 4). By comparison with acarbose (IC_{50} = 17.96 µg/ mL) (Figure 5), this extract was found to be the best in inhibiting the enzymatic activity of α-amylase.

The other plant extracts also seem to be very strong in inhibiting the activity of the α-amylase enzyme, with values more or less near to that of acarbose (positive control) and more particularly flavonoids and alkaloids (Figure 5). The crude aqueous extract comes last with a large IC_{50} value of around 45.24 µg/ mL (Figure 4).

Figure 5. α-amylase inhibition of specific extracts and positive control (acarbose).



4. DISCUSSION and CONCLUSION

First of all and from the obtained results of yields, it seems that the phytochemicals existing in the aerial part of *H. scoparium* have a big affinity for water and are more extractable with water than with absolute methanol. By referring to qualitative tests results (Table 1), the recorded yields confirm the intensity of the results of preliminary phytochemical tests and therefore it can said that the crude extract of aerial part is composed essentially of polyphenols. These results seems to be similar to those of Mezghani-Jarraya *et al*. (2009) with 15.10% of methanolic extract of *H. scoparium* aerial part from Sfax in Tunisia and better than those of Bouaziz *et al*. (2016) which obtained only 6.15% as yield of methanolic extract of the same plant species in the same region of Sfax in Tunisia. Furthermore, and by comparison with the results of Bourogaa *et al*. (2014) on the same plant species in southern Tunisia (only 11%), a very big difference is recorded in this study with more than 44% of yield of aqueous crude extract of the aerial part of *H. scoparium* in southeastern Algeria. However, this low yield (11%) is also reported in the results of Taîr *et al*. (2016) with the same plant species in the region of Naâma in northwestern Algeria.

In addition, a similarity is recorded by comparison with some previous results of Allaoui *et al*. (2016) obtained on the same part of *H. scoparium* of Ghardaïa in Algerian northern Sahara, where a very high contents of total polyphenols (397.743 mg GAE/ g of extract) and flavonoids (82.835 mg QE/ g of extract) were obtained in ethyl acetate extracts which is less polar than water and methanol. This confirms the richness of this plant on polyphenols and also the effect

of the extraction solvent on secondary metabolites contents. However, the obtained results are completely better than those of Tahar *et al*. (2015) carried out on crude extracts of *H. scoparium* aerial part from Laghouat in the North of the Algerian Sahara (prepared in different solvents of increasing polarity: ethyl acetate, dichloromethane and n-butanol); very low levels of total polyphenols were recorded, ranging from 2.416 to 18.666 mg GAE/ g DW.

Concerning specific extracts yields (total flavonoids, tannins and total alkaloids), we can affirm that the recorded differences strongly depend on the quality and the polarity of the solvent or the mixture of extraction solvents. These results confirm the intensity of the phytochemical screening results and justify the high extractability of polar solvents and the high affinity of alkaloids and phenolic compounds for solvents of increasing polarities. Thus, the obtained results from quantitative and qualitative tests show the superior biochemical quality of the studied plant.

Moreover and concerning the biochemical composition of both of crude extracts of this halophyte which has not been the subject of many publications, few researchers have studied its phenolic composition. The only reported studies were those of Ben Salah *et al*. (2002) & Jarraya *et al*. (2005) on *H. scoparium* of Sfax in east-central Tunisia. If we refer to their results, we can affirm that there is good agreement in the Chemotypes which are revealed from chromatographic analyzes. They reported the presence of isorhamnetin and 1-methylsalsolinol and few of triglycoside flavonols such as Quercetin and Quercetin-3-o-robinobioside. In addition, Chao *et al*. (2013) showed the presence of some phenol acids (Coumaric acid, Cinnamic acid and Caffeoylquinic acid), simple phenols such as Catechol and a Chrysoeriol which is considered to be a flavone. In general, this difference in yields, in phenolic compounds or any other secondary metabolite contents and also in phytochemical composition of *H. scoparium* aerial part extracts or even underground part of the same plant species in different regions; can be attributed to many operating conditions of the experiment like polar or non-polar extraction solvent, quantity of plant material, dry or fresh, temperature and extraction time, and even extraction methods (Lee *et al*., 2003) and to several another factors as environmental and climatic factors (geographical area, drought, soil, microclimate type and bioclimatic stages, some aggressions and diseases) (Atmani, 2009); Genetic heritage, period and time of harvest, stage of development of the plant and also quantification methods (Miliauskas *et al*., 2004).

The intensity and severity of diabetes mellitus, characterized by chronic hyperglycemia with metabolic disturbances (Puavilai *et al*., 1999) as a result of abnormal elevation of blood glucose due to insufficient insulin secretion by the β cells of the pancreas and/ or a resistance to the insulin exploit associated with disturbances in the metabolism of carbohydrates (lipids and proteins too) which lead to long-term complications (Khavandi *et al*., 2013), can be reduced by the inhibition of the α-amylase enzyme which allows the 'elimination of undigested carbohydrates thus slowing the absorption of D-glucose into the bloodstream.

Universal scientific communities are trying to adopt a therapy that not only targets the average glucose concentration and the HbA1c indicator, but at the same time tries to treat the instability of the glucose level (Monnier & Colette, 2006). Initial management of PPHG is necessary in the early prevention of diabetic complications, especially in type II diabetes (Ratner, 2001). Drugs such as acarbose, voglibose and miglitol have been shown to be effective in inhibiting α-amylase activity and controlling type 2 diabetes by suppressing carbohydrate hydrolysis (Kim *et al*., 1999). As reported in other studies, phenolic compounds and alkaloids exhibited a wide range of biological activities (Arunachalam *et al*., 2014a; Arunachalam *et al*., 2014b). The obtained results of the antidiabetic activity evaluated by the *in vitro* tests clearly demonstrated that MCE, with the other specific extracts but to a lesser extent, of *H. scoparium* species had a strong inhibitory activity against α-amylase enzyme. They may therefore be

potentially useful in managing glucose-induced hyperglycemia and merit further phytochemical and preclinical studies.

In conclusion, we can say that *H. scoparium* is very rich in phenolic compounds with a Chemotype of 29 identified compounds especially in its crude methanolic extract of its aerial part with predominance of gallic acid. Our *in vitro* results indicate also that among these plant extracts, the potential top three extracts that have shown an effective α-amylase inhibition are Methanolic crude extract, total Flavonoids and total Alcaloïds respectively. The aqueous crude extract did not show a strong α-amylase inhibitory potential but might have some other mode of inhibitory mechanism. This work is the first to report the isolated compounds from the aerial part of *H. scoparium* which has potential α-amylase inhibitory activity. The main advantage of these extracts is their non-toxicity, but they have not gained medicinal importance and worldwide acceptance due to absence of scientific validation. In perspective, this study merits to be carried out *in vivo* using animal models to know the extent of emulation with *in vitro* results.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Authorship contribution statement

Authors are expected to present author contributions statement to their manuscript such as; **Salah Benkherara**: Plant collection and performing the *in vitro* experimentation. **Ouahiba Bordjiba**: Methodology, Supervision and Validation. **Samiha Harrat**: Manuscript review and analysis. **Ali Boutlelis Djahra**: Investigation, resources and Visualization. All authors have read and approved the final manuscript.

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