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Research Article

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Comparative Study of Phytochemical Profiles and Antioxidant Activities of Three Endemic Moroccan Capparis Species

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Abstract

This study investigates the phytochemical composition and antioxidant activity of flower buds from three wild caper species (*Capparis atlantica*, *Capparis ovata*, and *Capparis sicula*) collected from twelve populations across the Safi, Rif, and Fès-Meknès regions of Morocco. Aqueous extracts were subjected to qualitative phytochemical screening and quantitative assays of polyphenols, flavonoids, and tannins, followed by evaluation of antioxidant activity using 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) tests. The results revealed a marked abundance of polyphenols and flavonoids, with significant variability among species and sites. *C. sicula* exhibited the highest contents of polyphenols (50.07 mg GAE/g) and flavonoids (20.41 mg QE/g), while *C. ovata* recorded the highest tannin concentration (2.41 milligrams catechin equivalent per gram of extract (mg CE/g)). Antioxidant activity followed a similar trend, with *C. sicula* showing the lowest inhibitory concentration (IC_{50}) values in both DPPH (361.16 µg/mL) and ABTS (359.75 µg/mL) assays, indicating the strongest radical scavenging potential. A strong negative correlation between polyphenol/flavonoid content and IC_{50} values confirmed the key role of these compounds in antioxidant activity. Overall, these findings highlight the bioactive potential of the studied *Capparis* species and their promising applications in nutraceutical and pharmaceutical fields.

Keywords

Capparis, Phytochemical composition, Antioxidant activity, Morocco

Introduction

Medicinal and aromatic plants represent an important source of bioactive compounds, particularly polyphenols and flavonoids, which are well known for their major role in preventing oxidative stress and associated chronic diseases [1]. The genus *Capparis* (family Capparidaceae) holds a special place in Mediterranean flora due to its chemical diversity and long-standing traditional use. Different parts of these plants are employed in folk medicine for the treatment of digestive, hepatic, and inflammatory disorders [2, 3].

Recent studies have shown that *Capparis spinosa* and related species contain a wide range of secondary metabolites with strong antioxidant potential [4, 5], linked to promising pharmacological properties such as antimicrobial [6] and anti-inflammatory activities [7]. However, most research has focused on cultivated or widely distributed species, while data on local wild species remain scarce, especially in biodiversity-rich regions such as Morocco.

In this context, the present study aims to evaluate the phytochemical composition and antioxidant potential of three wild *Capparis* species (*C. atlantica, C.*

ovata, and *C. sicula*) collected from different Moroccan regions (Safi, Rif, and Fès-Meknès). Comparative analysis between species and geographical sites will highlight the variability in bioactive compound content and its impact on antioxidant activity, thus paving the way for the potential valorization of these plant resources in pharmaceutical, agro-food, and biotechnological fields.

Materials and Methods

Plant material and experimental areas

A total of twelve wild populations of *Capparis* flower buds were collected between July and August 2021 from three Moroccan regions (Safi, Rif, and Fès-Meknès) representing different climatic and altitudinal conditions (Figure 1 and table 1). The sampling encompassed three endemic species: *C. atlantica*, *C. ovata*, and *C. sicula*.

It is important to note that the three species were not collected from all three regions. Specifically, *C. atlantica* was represented by eight populations distributed across the three regions, whereas *C. ovata* and *C. sicula* were each represented by two populations collected from their main natural habitats, in the Rif and Fès–Meknès regions, respectively. This sampling design reflects the natural geographical distribution of these endemic species in Morocco and defines the comparative framework of the study.

The collected flower buds were immediately freeze-dried, ground to a fine powder (80-mesh particle size), and stored at -20 °C in airtight amber glass containers until analysis to preserve metabolite stability.

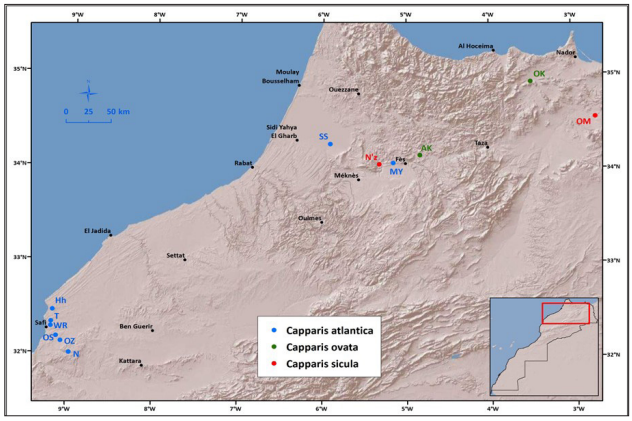

Figure 1: Geographical distribution of *Capparis* flower bud's populations.

Although samples were collected in 2021, all analyses were conducted in the same year following controlled storage protocols to prevent compound degradation.

Phytochemical composition

Preparation of phenolic extracts

Extracts from flower bud powder are prepared by maceration, an extraction technique that involves soaking the powdered plant material in a solvent to extract soluble compounds. The solvent used in this method is distilled water.

To achieve this, a mixture of 10 g of powder and 100 ml of solvent is vortexed for a few seconds. The mixture is then placed in a water bath at a temperature of 40 °C with stirring for 4 h, followed by centrifugation at a speed of 4,000 rpm for 20 min. After centrifugation, the surface liquid, known as the supernatant, is filtered and collected in opaque vials. Once extraction is complete, extracts are stored in a refrigerator at -20 °C.

Phytochemical screening

Phytochemical screening using conventional tests enables the qualitative evaluation of the various compounds present in plants.

In our study, this screening revealed the presence of several secondary metabolites in *Capparis* extracts, including polyphenols, tannins, flavonoids, alkaloids, reducing sugars, glycosides and saponosides (Table 2). Identification of these compounds is based on qualitative chemical analysis using staining or precipitation reactions, specific to each class of active ingredient [8].

Determination of total polyphenols

The total phenolic content was determined using the Folin–Ciocalteu method with minor modifications. A 200 µL aliquot of each extract or gallic acid standard was mixed with 1 mL of ten-fold diluted Folin–Ciocalteu reagent. After 4 min, 800 µL of 20% sodium carbonate solution was added. The mixture was incubated for 2 h in the dark at room temperature, and absorbance was measured at 760 nm using a UV–Vis spectrophotometer.

Table 1: Essential characteristics of *Capparis* flower bud's populations.

Region	Population (site)	Population abbreviation	Date of harvesting	Species	Altitude (m)
Safi	Ouled salman	OS	05-07-2021	*C. atlantica*	184
	Naga	N	06-07-2021		494
	Had hrara	Hh	06-07-2021		63
	Wad rabah	WR	07-07-2021		54
	Ouled znin	OZ	06-07-2021		163
	Takabour	T	05-07-2021		106
Rif	Ouad kert	OK	13-07-2021	*C. ovata*	411
	Ouad melili	OM	15-07-2021	*C. sicula*	610
Fès-Meknès	Sidi Slimane	SS	09-08-2021	*C. atlantica*	28
	N'zalat	Nz	12-08-2021	*C. sicula*	268
	Moulay yacoub	MY	11-08-2021	*C. atlantica*	498
	Ain kansera	AK	13-08-2021	*C. ovata*	370

Table 2: Different phytochemical screening tests for the detection of secondary metabolites in *Capparis* flower buds.

Chemical groups	Reagents	Positive results
Polyphenols	$FeCl_3$ (1%) + $K_3[Fe(CN)_6]$ (1%)	Green-blue coloring
Tannins	$FeCl_3$	Dark blue, green coloring
Flavonoids	Sulfuric acid + ammonia	Yellow coloring
Alkaloids	Dragendorff reagent	Red or orange precipitate
Reducing sugars	Fehling liqueur	Brick-red precipitate
Glycosides	Picric acid	Red color
Saponosides	Distilled water + agitation	Foam formation

A blank was prepared in parallel by replacing the extract with distilled water. The total phenolic content was calculated from a gallic acid calibration curve and expressed as mg gallic acid equivalent per gram of dry matter (mg GAE/g DM).

All assays were conducted in triplicate, and results were expressed as mean ± standard error (SE).

Total polyphenol content was calculated based on a calibration curve using a standard "gallic acid" at different concentrations under the same conditions as the sample (Figure 2).

Flavonoid assay

Flavonoid content was quantified by the aluminum chloride colorimetric method. Each extract or quercetin standard (1 mL) was mixed with 1 mL of 2% $AlCl_3$ solution prepared in methanol. The mixture was vortexed and incubated in the dark for 10 - 15 min. Absorbance was measured at 430 nm, and total flavonoid content was expressed as mg quercetin equivalent per gram of dry matter (mg QE/g DM), based on a quercetin calibration curve. Measurements were performed in triplicate, with blanks prepared using methanol as the solvent control.

The total flavonoid content was calculated based on a calibration curve produced by a standard "Quercetin" was serially diluted to obtain the different concentrations under the same conditions as the extract (Figure 3).

Tannin assay

Condensed tannins were quantified using the vanillin–hydrochloric acid (HCL) colorimetric method. A 50 µL aliquot of extract or catechin standard was mixed with 1.5 mL of 4% vanillin solution, followed by the addition of 750 µL concentrated HCl. The reaction mixture was incubated for 20 min in the dark at room temperature, and absorbance was recorded at 510 nm. Results were expressed as mg CE/g. All assays were performed in triplicate.

Concentrations of condensed tannins are deduced from the calibration ranges established with catechin and are expressed in mg CE/g (Figure 4).

Determination of antioxidant activity

Measurement of free radical scavenging capacity of DPPH

The evaluation was carried out according to the method described by Braca et al. [9], with a few modifications. Diluted

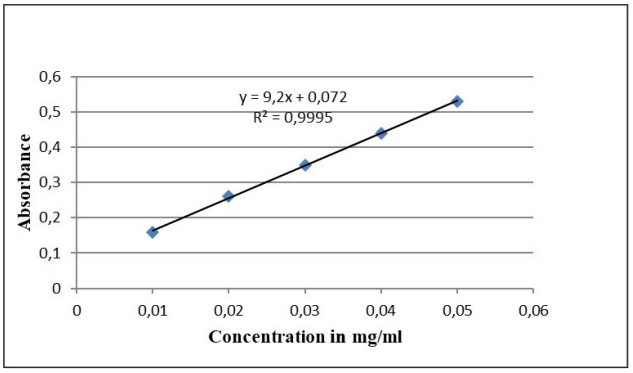

Figure 2: Gallic acid calibration curve.

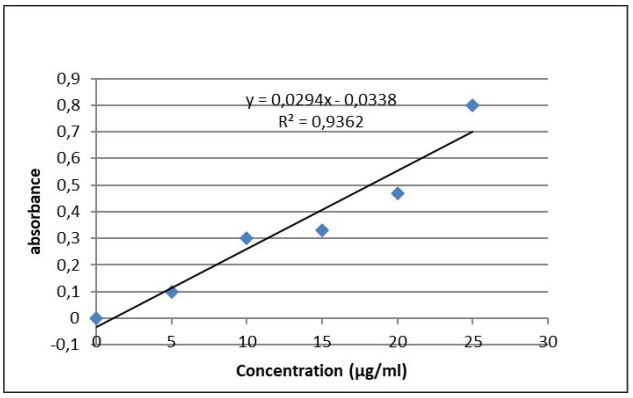

Figure 3: Quercetin calibration curve.

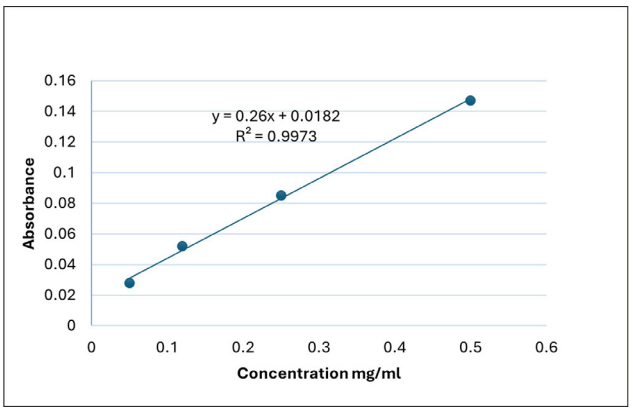

Figure 4: Catechin calibration curve.

solutions of caper extract (0.5, 1, 2, 5, 10, and 20 mg/mL) were prepared in methanol. Ascorbic acid, used as a standard, was prepared at concentrations ranging from 2 to 20 mg/mL. A 0.004% DPPH solution was also prepared in methanol. Next, 1 mL of this solution was mixed separately with 1 mL of the sample solution and 1 mL of the standard solution. The resulting mixtures were placed in the dark for 30 min, then their optical density was measured at 517 nm using a spectrophotometer, with methanol as the blank. A control was prepared by mixing 1 mL methanol with 1 mL DPPH solution (0.004%).

The IC_{50} value is the sample concentration required to trap 50% of the DPPH free radical. Measurements were performed in triplicate. Extract IC_{50} indicates the corresponding concentration for which the radical scavenging potential is 50%. The IC_{50} of the extract and standards were determined graphically.

Measurement of free radical scavenging potential of ABTS

The radical cation ABTS± is generated by mixing 10 mL of aqueous ABTS solution (7 mM) with 100 µL of potassium persulfate (2.45 mM). The mixture is then stored in the dark at 4 °C for 12 to 16 h before use. The ABTS± solution thus obtained is diluted with methanol to achieve an absorbance of 0.7 ± 0.020 at 734 nm.

For each analysis, 1 mL of sample at different concentrations (0.5, 1, 2, 5, 10, and 20 mg/mL) is mixed with 1 mL of diluted ABTS± solution. After a 7 min incubation in the dark, absorbance is measured at 734 nm. A blank is prepared in parallel using the same protocol, replacing the sample with the extraction solvent. Ascorbic acid is used as the standard.

Statistical analysis

All experiments, including extractions, were conducted in triplicate, and results were expressed as mean ± SE. Statistical analyses were performed using SAS and GenStat software (18_{th} edition).

A one-way analysis of variance followed by Tukey's honestly significant difference post hoc test was applied to evaluate significant differences ($p < 0.05$) among means. Correlations between phenolic content, flavonoid levels, and antioxidant activity (DPPH IC_{50} and ABTS IC_{50}) were determined using Pearson's correlation coefficients.

Results

Phytochemical screening

The results of phytochemical screening of *Capparis* flower bud extracts are summarized in table 3. Table 3 shows the qualitative distribution of primary and secondary plant metabolites in samples from various regions. Polyphenols stand out for their abundant presence (+++) in samples Hh, Oz, Wr, My, and Ak, while moderate abundance (++) is observed in the other samples. Flavonoids are moderately present (++) in Hh, OS, Oz, and My, but weakly detected (+) in the others, with the exception of samples where they are absent. Tannins are weakly present (+) in most samples, with total absence (-) in Wr and Nz, and occasional detection (±) in OM. As for alkaloids, they show a weak presence (+) in several samples, notably Hh, N, OM, OK, Nz, My, and SS, but are absent (-) in OS, Oz, T, and Ak. Reducing sugars and saponosides are totally absent (-) in all samples, as are coumarins. Finally, glycosides are moderately abundant (++) in Wr and Ak, weakly present (+) in several samples, and absent (-) in N and Nz. This distribution highlights the variable richness of polyphenols and flavonoids in the samples, while other compounds such as reducing sugars, saponosides and coumarins remain uniformly absent.

Table 4: Phytochemical content of extracts from flower buds of the three species.

Variable	*C. atlantica* (n = 8)	*C. ovata* (n = 2)	*C. sicula* (n = 2)
Polyphenols (mg GAE/g)	$21.51^{c} \pm 0.27$	$35.44^{b} \pm 0.57$	$50.07^{a} \pm 0.43$
Flavonoides (mg QE/g)	$7.28^{c} \pm 0.08$	$16.88^{b} \pm 0.26$	$20.41^{a} \pm 0.47$
Tannins (mg CE/g)	$1.91^{b} \pm 0.08$	$2.41^{a} \pm 0.11$	$2.25^{ab} \pm 0.13$

Polyphenol, flavonoid and tannin content

A study of the bioactive composition of the flower buds of three *Capparis* species (Table 4) revealed a significant variation in phenolic compounds ($p < 0.0001$).

Table 4 shows the average contents of bioactive compounds in flower buds of three *Capparis* species (*C. atlantica*, *C. ovata* and *C. sicula*), expressed in mg per gram of dry extract. Polyphenols show significant variations between species, with values of 21.51 ± 0.27 mg GAE/g for *C. atlantica*, 35.44 ± 0.57 mg GAE/g for *C. ovata* and 50.07 ± 0.43 mg GAE/g for *C. sicula*, the latter having the highest content. Flavonoids follow the same trend, with *C. sicula* having the highest concentration (20.41 ± 0.47 mg EQ/g), followed by *C. ovata* (16.88 ± 0.26 mg EQ/g) and *C. atlantica* (7.28 ± 0.08 mg EQ/g). *C. ovata* had the highest tannin content (2.41 ± 0.11 mg EQ/g), slightly higher than *C. sicula* (2.25 ± 0.13 mg EQ/g), while *C. atlantica* had the lowest (1.91 ± 0.08 mg EQ/g). Superscript letters (a, b, c) indicate significant differences between species for each parameter measured.

Table 5 shows polyphenol, flavonoid and tannin concentrations in *Capparis* flower buds collected in three Moroccan regions: Safi, Rif and Fès-Meknès. In the Safi region, polyphenol levels ranged from 19.77 ± 0.06 mg GAE/g (site T) to 22.12 ± 0.37 mg GAE/g (site Hh and OS). Flavonoids show values ranging from 6.66 ± 0.12 mg EQ/g (Oz site) to 7.76 ± 0.09 mg EQ/g (N site), while tannin contents oscillate between 1.44 ± 0.12 mg EC/g (Oz site) and 2.51 ± 0.11 mg EC/g (OS site).

Table 3: Phytochemical screening in flower bud extracts of *Capparis* populations from 12 Moroccan localities.

Regions / Composes	Hh	N	OS	OZ	T	Wr	OM	OK	Nz	My	SS	Ak
Polyphenols	+++	++	++	+++	++	+++	++	++	++	+++	++	+++
Flavonoids	++	+	++	++	+	+	++	+	+	++	+	+
Tannins	+	+	+	+	±	-	±	+	-	+	+	+
Alkaloids	+	+	-	-	-	-	+	+	+	+	+	-
Reducing sugars	-	-	-	-	-	-	-	-	-	-	-	-
Glycosides	+	-	+	+	+	++	+	+	-	+	+	++
Saponoside	-	-	-	-	-	-	-	-	-	-	-	-
Coumarins	-	-	-	-	-	-	-	-	-	-	-	-

Note: +++ Very abundant; ++ abundant; + presence of metabolite; ± trace; - absence of metabolite.

Table 5: Phytochemical content of flower bud extracts of the three species from the 12 sites studied.

Region	Site	Polyphenols (mg GAE/g)	Flavonoids (mg QE/g)	Tannins (mg CE/g)
Safi	Hh	$22.12^{f} \pm 0.37$	$7.19^{def} \pm 0.14$	$1.84^{def} \pm 0.12$
	N	$21.81^{f} \pm 0.34$	$7.76^{d} \pm 0.09$	$2.17^{bcd} \pm 0.05$
	OS	$22.12^{f} \pm 0.16$	$7.37^{def} \pm 0.2$	$2.51^{ab} \pm 0.11$
	Oz	$20.27^{hi} \pm 0.11$	$6.66^{f} \pm 0.12$	$1.44^{f} \pm 0.12$
	T	$19.77^{i} \pm 0.06$	$7.00^{ef} \pm 0.21$	$1.47^{f} \pm 0.10$
	Wr	$21.54^{fg} \pm 0.10$	$7.62^{de} \pm 0.14$	$2.04^{cde} \pm 0.15$
Rif	OM	$50.95^{a} \pm 0.27$	$21.25^{a} \pm 0.60$	$2.38^{abc} \pm 0.26$
	Ok	$36.59^{c} \pm 0.44$	$17.19^{c} \pm 0.39$	$2.23^{abcd} \pm 0.17$
Fès-Meknès	Nz	$49.19^{b} \pm 0.28$	$19.57^{b} \pm 0.23$	$2.12^{bcde} \pm 0.06$
	My	$23.60^{e} \pm 0.27$	$7.04^{def} \pm 0.08$	$2.10^{cde} \pm 0.19$
	SS	$20.85^{gh} \pm 0.36$	$7.55^{de} \pm 0.16$	$1.76^{ef} \pm 0.16$
	Ak	$34.29^{d} \pm 0.28$	$16.56^{c} \pm 0.24$	$2.60^{a} \pm 0.07$

In the Rif region, polyphenols reach their maximum concentration with 50.95 ± 0.27 mg GAE/g at the OM site, followed by 36.59 ± 0.44 mg GAE/g at the Ok site. Flavonoids range from 17.19 ± 0.39 mg GAE/g (Ok site) to 21.25 ± 0.60 mg GAE/g (OM site). Tannins ranged from 2.23 ± 0.17 mg EC/g (Ok site) to 2.38 ± 0.26 mg EC/g (OM site).

For the Fès-Meknès region, polyphenols record high values with 49.19 ± 0.28 mg GAE/g at site Nz, and more moderate values, such as 20.85 ± 0.36 mg GAE/g at site SS. Flavonoids range from 7.04 ± 0.08 mg EQ/g (My site) to 19.57 ± 0.23 mg EQ/g (Nz site). Tannins ranged from 1.76 ± 0.16 mg EQ/g (SS site) to 2.60 ± 0.07 mg EQ/g (Ak site).

These results illustrate the heterogeneity of phytochemical content across regions and sampling sites, with particularly high concentrations

Antioxidant activity

The antioxidant activity of *Capparis* flower bud extracts was assessed using two chemical assays: the DPPH and ABTS tests. The results, reported in table 6, are expressed as IC_{50} values (mg/ml extract), corresponding to the extract concentration capable of scavenging 50% of the radical tested.

Results for the antioxidant activity of flower bud extracts from the three *Capparis* species, assessed by DPPH and ABTS tests, reveal significant variations between species. For DPPH- radical reduction, *C. atlantica* species presented an IC_{50} value of 401.85 ± 1.75 µg/mL, indicating a lower antioxidant activity compared to *C. ovata* (377.00 ± 5.54 µg/mL) and *C. sicula* (361.16 ± 1.36 µg/mL). Similarly, for ABTS± radical reduction, *C. atlantica* also displayed the lowest antioxidant activity, with an IC_{50} of 402.48 ± 1.45 µg/mL, followed by *C. ovata* (377.02 ± 4.35 µg/mL) and *C. sicula* (359.75 ± 3.28 µg/mL). These results show that *C. sicula* has the highest antioxidant activity, while *C. atlantica* has the lowest, highlighting a significant difference between the species in terms of antioxidant potential (Table 7).

Antioxidant activity results, assessed by the DPPH- and ABTS± radical reduction tests for the different sites, show significant variations. In the Safi region, the Oz and T sites show the highest IC_{50}s for both tests, indicating lower antioxidant activity, while the Hh and OS sites show lower IC_{50}s, revealing better antioxidant activity. In the Rif region, the OM site had the lowest IC_{50} for both tests (358.15 ± 0.19 µg/mL for DPPH- and 352.47 ± 0.14 µg/mL for ABTS±), indicating higher antioxidant activity. In Fès-Meknès, the Ak site stood out with relatively low IC_{50}s for both tests, suggesting good antioxidant activity, in contrast to the SS site, which showed high IC_{50}s for both methods. These results highlight significant differences in the antioxidant potential of extracts depending on geographical location.

Table 6: Antioxidant activity of *Capparis* flower bud extracts from three species.

Variable	*C.atlantica* (n = 8)	*C.ovata* (n = 2)	*C.sicula* (n = 2)
Reduction de DPPH• IC_{50} (µg/mL)	$401.85^{a} \pm 1.75$	$377.00^{b} \pm 5.54$	$361.16^{c} \pm 1.36$
Reduction d'ABTS+• IC_{50} (µg/mL)	$402.48^{a} \pm 1.45$	$377.02^{b} \pm 4.35$	$359.75^{c} \pm 3.28$

Table 7: Antioxidant activity of flower bud extracts of the three species from the 12 sites studied.

Region	Site	Reduction in DPPH• IC_{50} (µg/mL)	Reduction in ABTS+• IC_{50} (µg/mL)
Safi	Hh	$390.92^{e} \pm 0.09$	$393.51^{f} \pm 0.25$
	N	$409.03^{ab} \pm 0.30$	$407.35^{b} \pm 0.05$
	OS	$393.59^{d} \pm 2.24$	$396.97^{d} \pm 0.44$
	Oz	$410.04^{ab} \pm 0.37$	$413.65^{a} \pm 0.13$
	T	$411.07^{a} \pm 0.40$	$407.7^{b} \pm 0.06$
	Wr	$400.15^{c} \pm 0.67$	$394.93^{e} \pm 0.23$
Rif	OM	$358.15^{g} \pm 0.19$	$352.47^{i} \pm 0.14$
	Ok	$364.62^{f} \pm 0.11$	$367.30^{h} \pm 0.36$
Fès-Meknès	Nz	$364.18^{f} \pm 0.38$	$367.04^{h} \pm 0.75$
	My	$391.18^{e} \pm 0.21$	$398.32^{c} \pm 0.26$
	SS	$408.77^{b} \pm 0.16$	$407.42^{b} \pm 0.21$
	Ak	$389.39^{e} \pm 0.29$	$386.73^{g} \pm 0.05$

Analysis of the correlation between bioactive composition and antioxidant activity of Capparis flower bud extracts

Table 8 shows the correlation coefficients between total polyphenols, total flavonoids, condensed tannins, as well as the IC_{50}s of the DPPH- and ABTS± tests. A strong positive correlation was observed between total polyphenols and flavonoids (r = 0.97056), indicating a close relationship between these two compounds. Condensed tannins show moderate

Table 8: Correlation coefficients for bioactive composition and antioxidant activity of *Capparis* flower bud extracts.

Coefficients	Total polyphenols	Total flavonoids	Condensed tannins	DPPH IC_{50}	ABTS IC_{50}
Total polyphenols	1	-	-	-	-
Total flavonoids	0.97056	1	-	-	-
Condensed tannins	0.43676	0.47576	1	-	-
DPPH IC_{50}	-0.9117	-0.8835	-0.4823	1	-
ABTS IC_{50}	-0.9347	-0.9215	-0.4954	0.97552	1

correlations with total polyphenols (r = 0.43676) and flavonoids (r = 0.47576).

On the other hand, strongly negative correlations were found between the IC_{50}s of the DPPH- and ABTS± tests with total polyphenols (r = -0.91174 and -0.93472) and flavonoids (r = -0.88349 and -0.92150).

Discussion

The phytochemical analysis of flower bud extracts from three Moroccan *Capparis* species (*C. atlantica*, *C. ovata*, and *C. sicula*) revealed the presence of polyphenols, flavonoids, and alkaloids, along with traces of tannins. These findings confirm that Moroccan *Capparis* species share a similar chemical profile to *C. spinosa*, the most extensively studied member of the genus [10-12]. However, our results also highlight significant quantitative differences among species and regions, suggesting that both genetic and environmental factors influence the biosynthesis of secondary metabolites [13-18].

The highest levels of polyphenols and flavonoids were recorded in *C. sicula*, particularly in populations collected from the Fès-Meknès region, characterized by moderate humidity and calcareous soils that may favor phenolic compound production [19]. In contrast, *C. ovata* exhibited lower concentrations, possibly reflecting its adaptation to drier and more arid habitats in the Rif region. *C. atlantica*, which occurs across a broader ecological range, displayed intermediate and relatively stable levels among populations, indicating greater ecological plasticity [20]. These interspecific and regional variations are consistent with previous findings showing that climatic factors (temperature and rainfall), soil composition, and altitude can modulate secondary metabolite accumulation in plants [21, 22].

Antioxidant assays (DPPH and ABTS) supported these phytochemical trends. *C. sicula* extracts showed the strongest antioxidant capacity (lowest IC_{50} values), correlating with their higher polyphenol and flavonoid contents. This inverse relationship between IC_{50} and phenolic concentration confirms the major contribution of these compounds to radical scavenging activity. Moreover, the strong positive correlation (r = 0.97552) between DPPH and ABTS confirms the reliability and consistency of the methods employed [23-25].

These findings establish a clear hierarchical pattern among the studied species, with *C. sicula* emerging as the most promising in terms of antioxidant potential, followed by *C. atlantica* and *C. ovata* [26]. This ranking aligns with the study's main objective of comparing Moroccan *Capparis* species and highlights the pharmacological potential of *C. sicula* as a valuable source of natural bioactive compounds for nutraceutical or therapeutic development [27, 28].

Nevertheless, certain limitations should be acknowledged. The absence of chromatographic and spectrometric profiling (HPLC, LC-MS/MS) restricted the identification of individual compounds such as rutin, quercetin, or catechin that may underline the observed activity. Future studies should include bioassay-guided fractionation and detailed chemical characterization to isolate and identify the most active molecules. In addition, *in vivo* and mechanistic studies are necessary to validate these antioxidant effects and clarify their biological relevance. The relatively small sample sizes for *C. ovata* and *C. sicula* may also limit the statistical strength of interspecific comparisons, suggesting the need for further validation using larger and more environmentally diverse populations.

In summary, this study provides new evidence that species- and region-specific variability strongly influences the phytochemical and antioxidant profiles of Moroccan *Capparis* species. These results not only enhance our understanding of their ecological and biochemical diversity but also underscore their potential for future valorization in health-promoting and natural product applications.

Conclusion

The present study has shown that the flower buds of three wild Moroccan *Capparis* species (*C. atlantica*, *C. ovata* and *C. sicula*) are a rich source of bioactive compounds, particularly polyphenols and flavonoids, playing a major role in their antioxidant potential. Significant variability was observed between species and sampling regions, with *C. sicula* showing the highest levels of phenolic compounds and the highest free radical scavenging activity. The strong negative correlations between polyphenol/flavonoid content and IC_{50} values (DPPH and ABTS tests) confirm the direct involvement of these metabolites in antioxidant activity.

These results highlight the potential of local *Capparis* species as promising natural sources of antioxidants, opening interesting prospects for their valorization in the nutraceutical, pharmaceutical and agri-food fields. Further research, particularly *in vivo* and using biotechnological approaches, is recommended to fully exploit these plant resources, which are still little used in the context of Morocco's rich biodiversity heritage.

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None.

Conflict of Interest

None.

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