Journal of
Food Chemistry & Nanotechnology

https://doi.org/10.17756/jfcn.2023-158

Research Article

Open Access

Bioactive Compounds and Nutritional Quality of Wild Endemic Moroccan *Capparis* Flower Buds: *Capparis atlantica* Inocencio

Fatima Zahra El Arnabi[1,2*], Souad El Hajjaji[1], Fatima Gaboun[2], Hamza Iaaich[2], El Haj El Maadoudi[2], Aouatif Benali[2] and Khadija Bakhy[2]

[1] *LS3MN2E, Faculty of Sciences, Université Mohammed V de Rabat Siège, Rabat 10000, Morocco*
[2] *National Institute of Agricultural Research (INRA), Rabat BP 6570, Morocco*

***Correspondence to:**
Fatima Zahra El Arnabi
LS3MN2E, Faculty of Sciences,
Université Mohammed V de Rabat Siège,
Rabat 10000, Morocco.

National Institute of Agricultural Research (INRA),
Rabat BP 6570, Morocco.
E-mail: fatimazahra_elarnabi@um5.ac.ma

Received: August 14, 2023
Accepted: September 11, 2023
Published: September 15, 2023

Citation: El Arnabi FZ, El Hajjaji S, Gaboun F, Iaaich H, El Maadoudi EH, et al. 2023. Bioactive Compounds and Nutritional Quality of Wild Endemic Moroccan *Capparis* Flower Buds: *Capparis atlantica* Inocencio. *J Food Chem Nanotechnol* 9(3): 124-131.

Copyright: © 2023 El Arnabi et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY) (http://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

Abstract

This research aims the assessment of nutritional and functional potential of wild endemic Moroccan caper specie *Capparis atlantica* Inocencio. Proteins, total sugars, lipids, fiber, ash, mineral content, and antioxidant compounds were determined for capers collected from 8 locations in two Moroccan regions (Fes-Meknes (F-M) and Safi (SA)). The dominant nutrients were total sugars (175.35 ± 52.10 %), proteins (27.58 ± 2.07%), and lipids (24.77 ± 1.87%). Fatty acids profile revealed high stearic acid (SteA) content (79.88 g/100 g) followed by palmitic acid (PalA) (17.44 g/100 g) with minor amounts of linolenic acid (1.40 g/100 g), eicosenoic acid (0.49 g/100 g), myristic acid (0.68 g/100 g), and lauric acid (0.14 g/100 g). Mineral average concentration was 539.10 ppm for potassium (K), 611.64 ppm for iron (Fe), and 145.68 for manganese (Mn). Antioxidants analysis revealed considerable amounts in *C. atlantica*, in particular (21.27 to 22.23 mg EAG/g DW) for polyphenols, (7.27 to 7.30 mg EQ/g DW) for flavonoids, and (1.91 to 1.93 mg EC/g DW) for tannins. Significant differences within regions and locations were observed for several traits. The results of this study highlight the potential nutritional value of *C. atlantica* species, labelling it as an intelligent food with promising health benefits.

Keywords

Wild *Capparis atlantica*, Nutritional composition, Antioxidants, Regional variability, Morocco

Introduction

Capparis L. (Commonly known as caper) is a large, diverse, and economically important genus of the Capparidaceae family. Authors report between 250 and 400 species worldwide [1-3]. With wide distribution in the Mediterranean countries, Spain is the global producer of capers, followed by Morocco, Italy, and Turkey, and then Greece [4]. In Morocco, Inocencio et al. [1] and Dobignard and Chatelain [5] stated that the genus comprises 7 species (*C. atlantica* Inocencio, D. Rivera, Obon and Alcaraz; *C. decidua* (Forssk.) Edgew; *C. orientalis* Veill. ex. Duhamel; *C. ovata* Desf; *C. sicula* Veill. ex. Duhamel; *C. spinosa* L., and *C. zoharyi* Inocencio, D. Rivera, Obon and Alcaraz) which are growing spontaneously in different biogeographic zones of the country [6]. The main producing regions are, Doukka Abda SA and F-M (The Department of Agriculture's Strategy and Statistics Branch of Morocco, 2019/2020). Caper (*Capparis* spp.) is a perennial shrub known for its ability to effortlessly reach heights of 50 to 80 cm and spread out to widths of 1 to 1.5 m during its growth. It is a xerophytic plant with morphological and physiological characteristics allowing growth under arid and semi-arid areas climates [7]. It is cultivated for its flower buds called capers. The harvest of capers begins at the time of their growth before their opening.

Capparis is not only renowned for its adaptability to different agro-environmental growing conditions and its high drought tolerance, but also thanks to its high nutritional quality, especially the flower buds which contain high amount of protein (23.5 to 30.12%), lipids (1.5 to 2.5%) [8, 9], carbohydrates (2304.14 ± 194.54%) [10], and vitamins: A (134.28%), E (700.23 ± 10.49%), C (0.4 ± 0.03%) [11]. Studies has shown that *Capparis* is rich in calcium (Ca) (871 ppm), K (542 ppm), sodium (Na) (226 ppm), manganese (Mg) (636 ppm), Fe (13 ppm), and raw fibers (5.4%) [8, 12]. Flower buds are characterized by an interesting fatty acid profile, notably by the presence of PalA (16.69 - 51.95%), linoleic acid (10.08 - 31.42%), and SteA (3.30 - 15.72%) [13, 14].

Since 2000, an upward trend in the export of Moroccan cappers has been very noticeable; The exported quantities have doubled between 2000 and 2013 from 9 thousand to 18 thousand tons. During the 2014/15 crop year, the production of capers was estimated at 35 thousand tons, its exploitation contributes considerably to improving socio-economic conditions of local population. The European Union market absorbed nearly 68% of Moroccan capers exports, Italy and Spain alone imported more than 61% (The Department of Agriculture's Strategy and Statistics Branch of Morocco, 2019/2020). This increased interest toward Moroccan caper is mainly due to its high quality. Few studies have been conducted on the chemical profile of Moroccan *Capparis*. For this reason, the present investigation has as objective the assessment of nutritional and antioxidant content of *C. atlantica* Inocencio, widely grown in two Moroccan regions F-M and SA.

Materials and Methods

Plant material and experimental areas

C. atlantica Inocencio flower buds of eight sites representing two areas (SA and F-M) were surveyed. A total of 8 samples were collected: 6 from SA and 2 from F-M (Table 1 and figure 1). The SA region is under semiarid and arid climates, with precipitations gradient that is decreasing in north-south direction and increasing in west-east direction, ranging generally between 200 mm and 400 mm. Average annual temperatures are generally around 10 °C for the coldest month and 25 °C for the hottest. The climate has conditioned soil formation along with bedrock and topography, the dominant soil types are Entisols (essentially used for grazing), Alluvial Regosols, Vertisols and other calcareous soils. In a slightly contrasting environment, the F-M region is under Mediterranean semi-arid and sub-humid climates, with mean annual

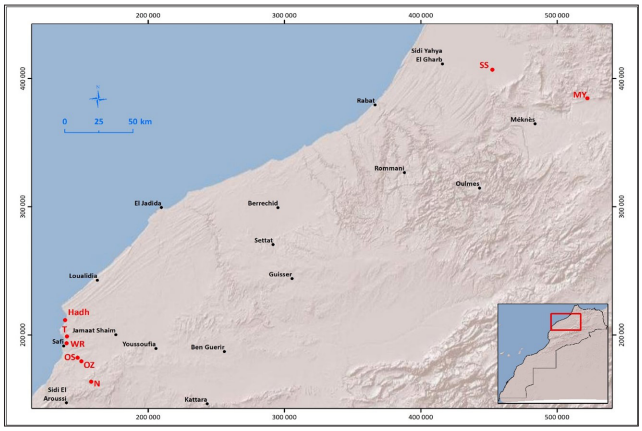

Figure 1: Location of sampling sites and geographic origin of the *C. atlantica* Inocencio surveyed populations.

rainfalls ranging from 500 mm to 600 mm with a slight north-south gradient. The mean monthly temperature is about 12 °C, the mean minimum is about 5 °C and the mean maximum is about 39 °C. Soil formation in F-M region is mainly influenced by the topography, the bedrock type and, in a lesser extent, by basin direction, and dominant soil types are Vertisols, Calcareous Chernozems and Alluvial Regosols.

Harvesting was realized in July 2021 when the flower buds reached their optimal size. The geographical coordinates for every station were recorded (Table 1). Each sample contained at least 500 g of uniformly sized flower buds, collected from 5 shrubs in a limited area. All the samples were carefully placed inside labeled plastic boxes within an isothermal container, ensuring proper identification. They were then transported to the laboratory of the National Institute of Agronomic Research (INRA). All samples underwent freeze-drying and were subsequently stored under suitable conditions for future utilization. The collected plant specimens were taxonomically identified at the Scientific Institute of Rabat by Pr. Hamid Khamar, specifically the Department of Botany and Plant Ecology, using the Index Synonymic of Flora of North Africa [5] as the adopted nomenclature. Voucher specimens were carefully preserved in the National Herbarium of the Scientific Institute-Rabat, assigned the code number RAB113735 for proper registration.

Nutritional composition assessment

Macronutrients

The macronutrient composition of the fruit samples was determined following the protocols established by the Asso-

Table 1: Geographic coordinates of the 8 prospected locations.

Region	Sampling site	Sample codes	Altitude (m)	Latitude	Longitude
SA	Ouled salman	OS	184	32° 10' 52.77"	9° 07' 46.87"
	Naga	N	494	32° 00' 58.74"	9° 01' 04.44"
	Had hrara	Hh	63	32° 26' 35.80"	9° 14' 19.69"
	Wad rabah	Wr	54	32° 16' 48.13"	9° 13' 13.19"
	Ouled znin	Oz	163	32° 08' 35.65"	9° 05' 57.62"
	Takabour	T	106	32° 19' 41.86"	9° 13' 10.51"
F-M	Sidi Slimane	Ss	28	34° 15' 54.64"	5° 54' 25.64"
	Moulay yaâcoub	My	498	34° 03' 50.32"	5° 09' 26.76"

ciation of Official Analytical Chemists (AOAC). Ash content was assessed by placing 2 g of the fruit sample in a muffle furnace, incinerating it for six hours at 550 °C. For fat content determination, 5 g of lyophilized fruits were subjected to extraction using petroleum ether and the Soxhlet apparatus. Protein content (PC) was estimated utilizing the macro-Kjeldahl method, with a protein conversion factor of 6.25. The quantity of crude fiber (CF) was calculated employing the van Soest method [15]. Total sugar content (TSC) was ascertained through a spectrophotometric approach employing the phenol-sulfuric acid reagent, following the method outlined by DuBois et al. [16].

Micronutrients

The sample weighing 1 g was subjected to incineration in a muffle furnace for a duration of 6 h at a temperature of 500 °C. The resulting ash was then dissolved in 3 ml of hydrochloric acid (HCl). The ash solution was collected in a joggled flask and supplemented with distilled water to reach a final volume of 100 ml [17].

Mineral analysis was conducted using atomic absorption spectrophotometry with a flame air-acetylene setup, as specified [17]. The levels of K and Na were determined using a flame photometer. P content was assessed by means of a chemical reaction involving an acidified solution containing ammonium molybdate, ascorbic acid, and antimony, following the procedure outlined by Lupton et al. [18]. The resulting data were quantified by measuring optical density at 825 nm, utilizing a UV-Visible spectrophotometer (Model 6405 UV/VIS spectrometer, Jenway, UK).

Antioxidants compounds

Extract preparation

Aqueous extracts were prepared by dissolving 10 g of powder from each sample in 100 ml of distilled water. The mixture was allowed to undergo maceration at room temperature for a duration of 4 h, homogenized every 5 min. The mixture was then centrifuged in a 4000-rpm centrifuge for 30 min. The extracts were collected in UV-resistant glass bottles and stored at freezing temperature. Obtained extracts served for the quantification of polyphenol components, flavonoids content, and condensed tannins content.

Total polyphenols determination

The determination of total polyphenols is performed by a colorimetric method using the Folin-Ciocalteu reagent according to the method described by Singleton et al. [19]. 200 µl of extract was added to 1 ml of tenfold diluted Folin's reagent. After 5 min incubation at 25 °C, 800 µl of 20% (w/v) sodium carbonate was added. The absorbance is read at 760 nm after 90 min of incubation. Gallic acid is used as a standard and results are expressed as mg gallic acid equivalent per g dry matter.

Flavonoids content

Flavonoid determination was performed based on the chelating properties of $AlCl_3$ [20]. 1 ml of each extract or standard was added to 1 ml of $AlCl_3$ solution (2% in methanol). The mixture was vigorously shaken and incubated for 10 min at room temperature and the absorbance was read at 430 nm. The results were expressed as microgram equivalent of quercetin per milligram of extract (mg QE/g).

Condensed tannins content

The quantitative evaluation of condensed tannins in our extracts is performed according to the method cited by Julkunen-Titto [21]. A volume of 50 µl of each extract was mixed with 1.5 ml of vanillin (4%), then 750 µl of concentrated HCl was added. After vigorous shaking, the solution was incubated at room temperature in the dark for 20 min. The absorbances were measured at 510 nm. Catechin is used as standard, and results are expressed as mg equivalent catechin per g dry matter [22].

Fatty acid composition

Lipid extraction.

10 g of caper buds were extracted with 30 ml hexane/isopropanol (3:2, v/v) at room temperature under vigorous under magnetic stirring for 2 h [23]. Then the suspension was filtered, and the residue was washed with 20 ml of the solvent mixture. next, 35 ml of 6.7% sodium sulphate (w/v) were added into the funnel to wash the lipid extract solution. The liquid phase collected was evaporated with a rotary evaporator until dryness.

Preparation of fatty acid methyl esters

Fatty acid methyl esters (FAME) were derived from the extracted oil using a modified version of the Slover and Lanza method [24]. In summary, approximately 40 mg of the extracted oil was treated with 1 ml of methanolic NaOH at 100 °C for 15 min in a Pyrex culture tube equipped with a Teflon-lined screw cap. Afterward, the tubes were cooled on ice, and 2.5 ml of boron trifluoride (10%) was introduced. The tubes were then subjected to a further 15-min boiling step. Following this, the tubes were once again cooled on ice, and a mixture of 1 ml of hexane and 2 ml of saturated sodium chloride was added to the samples. Subsequently, the samples were vortexed for 30 s and centrifuged at 3,000 rpm for 20 min. The resulting supernatant was subjected to analysis by GC-MS (Gas chromatography-mass spectrometer), in accordance with the method described by Slover and Lanza [24].

FAME analysis by GC-MS

The analysis involved the use of a Clarus © 580 Gas Chromatograph (Perkin Elmer) equipped with a 30 m x 0.25 mm x 0.25 µm 5MS capillary column for sample injection. Helium was employed as the carrier gas at a flow rate of 1 ml/min. A volume of 0.5 µl from each extract was injected at a temperature of 250 °C in split mode, resulting in a total analysis time of 53 min. Initially, the oven temperature was set at 50 °C and then increased by 10 °C/min until reaching 200 °C, where it was maintained for 25 min. Subsequently, the temperature was raised by 10 °C/min to 230 °C and held for 10 min. Detection was accomplished using a Clarus© SQ8S Mass Spectrometer (Perkin Elmer), with the transfer line and source both maintained at 250 °C. Full scan analysis was conducted in EI^+ mode, encompassing the 10 - 600 m/z interval. The results are presented as percentages after the fatty acids

were identified by comparing their mass spectra with the mass spectral database [25].

Physicochemical analysis of soil

Soil physicochemical analysis was performed on 8 different populations, with each location providing one soil sample for examination. The analysis encompassed several parameters, including pH levels, total organic matter (OM) content, the percentage of nitrogen, as well as the chemical composition involving Na^+, K_2O, and P_2O_5. The methods and techniques employed for this analysis closely followed the procedures outlined in the publication authored by Naanaa and Susini [26].

Results

Nutritional constituents

Macronutrient composition

C. atlantica Inocencio buds were harvested from Moroccan sites where they grow spontaneously. A total of 8 samples were collected from 8 different stations, as indicated in figure 1. The average nutritional composition of the buds, expressed on a DW basis, is provided in table 2. The most abundant macronutrient was TSC (175.35 ± 52.10 g EG/100 g), PC (27.58 ± 2.07 g/100 g DW), and fat (24.77 ± 1.87 g/100 g DW). However, In Moroccan caper, CF was found to be one of the less abundant macronutrients, with an average content of 6.35 ± 1.00 g/100 g DW. Among the 8 samples surveyed, the highest variation was observed for TSC and CF.

Table 2: Macronutrient value average of *C. atlantica* Inocencio flower buds harvested from Morocco.

Variable	Mean ± SD	Min	Max	CV%
PC (g/100 g DW)	27.58 ± 2.07	23.95	30.72	7.52
Fat (g/100 g DW)	24.77 ± 1.87	22.02	27.34	7.56
CF (g/100 g DW)	6.35 ± 1.00	5.04	8.07	15.72
TSC (g EG/100 g)	175.35 ± 52.10	113.2	264.3	29.71

Micronutrient composition

The buds of *C. atlantica* Inocencio mineral profile was characterized by a notable abundance of Fe (611.64 ± 157.8 mg/100 g DW), K (539.10 ± 18.58 mg/100 g DW), and Mn (145.68 ± 73.53 mg/100 g DW). While P, Na, and copper (Cu) were found at a content reaching 20.43 mg/100 g DW, 20.21 mg/100 g DW, and 21.70 mg/100 g DW, respectively, with a low concentration of Zn (3.9 mg/100 g DW) (Table 3). Mn showed a wider variability range (28.87 - 290.77 mg/100 g DW). Similarly, for Fe (393.83 - 861.92 mg/100 g DW). K, Na, and Zn were quite variable, among the samples, ranging between 516.74 to 566.47, 18.76 to 23.05, and 0.23 to 0.49 mg/100 g DW (Table 3).

Fatty acids profile

In this study, both SteA (79.88%) and PalA (17.44%) were found in large concentrations, demonstrating the prevalence of saturated fatty acids (Table 4). While linolenic acid (0 - 3.16%), myristic acid (0.52 - 0.89%), lauric acid (0 - 0.30%), and eicosenoic acid (0 - 1.66%) (Table 4) accounted for only traces.

Table 3: The average value of the micronutrient composition of Moroccan *C. atlantica* Inocencio flower buds.

Parameters	Variable (mg/100 g DW)	Mean ± SD	Min	Max
Macroelement	K	539.10 ± 18.58	516.74	566.47
	P	20.43 ± 3.50	16.04	26.13
	Na	20.21 ± 1.42	18.76	23.05
Microelement	Fe	611.64 ± 157.8	393.83	861.92
	Mn	145.68 ± 73.53	28.87	290.77
	Cu	21.70 ± 5.02	13.70	28.50
	Zn	0.35 ± 0.09	0.23	0.49

Table 4: The average value of fatty acids of Moroccan *C. atlantica* Inocencio flower buds.

%	Mean ± SD	Min	Max
Lauric acid 12:0	0.14 ± 0.12	0.00	0.30
Myristic acid 14:0	0.68 ± 0.11	0.52	0.89
PalA 16:0	17.44 ± 1.87	14.66	21.08
SteA 18:0	79.88 ± 3.26	75.45	83.22
Linolenic acid 18:3	1.40 ± 1.18	0.00	3.16
Eicosenoic acid 20:1	0.49 ± 0.70	0.00	1.66

Phenolic compounds

The results show that the aqueous extract of flower buds contains an appreciable content of polyphenols (21.51 mg EAG/g DW), flavonoids (7.28 mg EQ/g DW) compared to tannins (1.92 mg EC/g DW) (Table 5).

Table 5: The average value of total polyphenols, flavonoids, and condensed tannins of *C. atlantica* Inocencio flower buds.

Phenolic compounds	Mean ± SD	Min	Max
Total polyphenols (mg EAG/g DW)	21.51 ± 1.21	19.68	24.08
Flavonoids (mg EQ/g DW)	7.28 ± 0.41	6.42	7.87
Condensed tannins (mg EC/g DW)	1.92 ± 0.39	1.23	2.67

Nutritional value variability of C. atlantica Inocencio

Looking at the 8 populations, the contents of total sugar, Fe, and Mn varied drastically from sample to sample. The main macronutrients were TSC (113.2 - 264.3 g EG/100 g), PC (23.95 - 30.72 g/100 g), and fat (22.02 - 27.34 g/100 g) (Table 1). All the samples contained appreciable amounts of SteA (75.45 - 83.22%) and PalA (14.66 - 21.08%) while linolenic acid (0 - 3.16%), myristic acid (0.52 - 0.89%), lauric acid (0 - 0.30%), and eicosenoic acid (0 - 1.66%) (Table 4) accounted for only traces.

Fe (393.83 - 861.92 mg/100 g DW), K (516.74 - 566.47 mg/100 g DW), and Mn (28.87 - 290.77 mg/100 g DW) were the main minerals beside P (16.04 - 26.13 mg/100 g), Na (18.76 - 23.05 mg/100 g), Cu (13.70 - 28.50 mg/100 g), and Zn (0.23 - 0.49 mg/100 g) (Table 3).

Table 6: Summary of the variation in nutritive value and mineral composition and the classification of harvested samples across groups generated by using cluster analysis.

Traits	GI (N = 2)		GII (N = 3)		GIII (N = 2)		GIV (N = 1)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TS (mg/100 g DW)	138.97	23.03	152.68	16.25	**259.65**	3.99	147.57	5.53
P (mg/100 g DW)	24.71	0.46	28.66	1.45	27.52	0.30	**30.18**	0.27
K (mg/100 g DW)	534.47	11.34	555.20	16.86	518.57	2.00	541.12	0.00
Fe (mg/100 g DW)	547.02	167.81	588.86	141.35	585.32	100.22	**861.92**	0.00
Mn (mg/100 g DW)	**228.27**	68.47	126.09	28.39	150.89	42.38	**28.87**	0.00
PalA (%)	17.17	0.30	15.67	0.77	18.53	0.04	**21.08**	0.00
SteA (%)	**81.77**	0.65	**82.68**	0.54	76.02	0.25	75.45	0.00

The nutritional compositions of the 8 samples were subjected to a principal component analysis considering seven different traits (Protein, total sugar, K, Fe, Mn, PalA, and SteA). The plot of principal component analysis identified two principal components that explained 71.18% of the total variance. The first axis explained 44% of the total variation and displayed a strong negative correlation with SteA and positive correlation with PalA. The second axis explained 27.17% of total variance. This axis is negatively correlated to two parameters (Mn and TS).

The cluster analysis was shown as a dendrogram indicating the estimated relations between studied populations (Figure 2). The dendrogram showed four distinct groups. The regrouped populations could have similar values for each studied descriptor. The following groups have been defined:

Group I: This group contains two populations (OS and Oz) and is characterized by high amounts of Mn and SteA and is the poorest in P, Fe, and TSC (Table 6).

Group II: This group was composed of three populations (N, Wr, and My) and represents a profile rich in K, SteA, and P (Table 6).

Group III: Was represented by two populations (T and Hh) in which TS reached its highest value (259.65 mg/100 g DW) and K the lowest content (518.57 mg/100 g DW). In this group, the amount of P and Mn were appreciable (Table 6).

Group IV: This group (Ss) composed only by one population, characterized by the highest proportion of Fe (861.92 mg/100 g DW) and less Mn content (28.87 mg/100 g DW) were noted in this sample (Table 6).

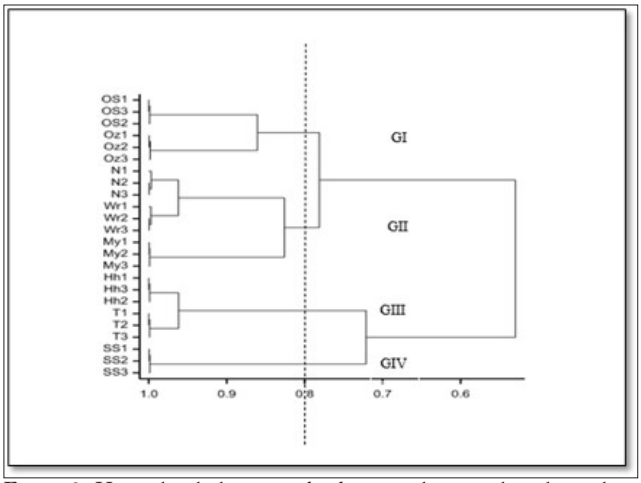

Figure 2: Hierarchical clustering dendrogram showing the relationships between the twenty-four samples belonging to the regions studied.

Eight populations have been harvested across two regions (SA and F-M): SA (6 localities of harvest), and F-M (2 localities). Concerning the distribution of samples in the 4 groups with respect to the locality of harvest, it is noticeable that almost of the samples from the SA area of harvest belonged to group I (OS and Oz) and group III (T and Hh). Group II consists of two populations (N and Wr) from SA and one from F-M (My). The population Ss from F-M produced mainly buds belonging to group IV.

Regarding the phenolic compounds, the content of polyphenols varied from 19.77 to 23.6 mg EAG/g DW. The flavonoids content was greater (6.66 - 7.76 mg EQ/g DW) while the condensed tannin was showed in the lowest levels (1.44 - 2.51 mg EC/g DW) (Table 7).

Table 7: Phenolic compounds of flower buds of *C. atlantica* Inocencio values having different letters differ significantly ($p < 0.05$).

Site	PolyT	FlavT	TannC
My	**23.60^{a}**	7.04^{cd}	2.10^{bc}
N	21.81^{b}	**7.76^{a}**	2.17^{ab}
Hh	22.12^{b}	7.19^{bc}	1.84^{bcd}
OS	22.12^{b}	7.37^{abc}	2.51^{a}
Wr	21.54^{bc}	7.62^{ab}	2.04^{bc}
Ss	20.85^{cd}	7.55^{ab}	1.76^{cde}
Oz	20.27^{de}	6.66^{d}	1.44^{e}
T	19.77^{e}	7.00^{cd}	1.47^{de}
Mean	**21.51**	**7.28**	**1.92**
SE	**1.21**	**0.41**	**0.39**

Nutritional composition: variation with altitude, soil chemical composition, and area of harvest

Capper buds of wild *C. spinosa* were harvested from 8 sites in two different origins of Morocco (SA and F-M). It should be mentioned that SA area of harvesting is a coastal region while F-M area was a continental one (Figure 1).

Altitude of every site of harvest and chemical parameters of the soil are reported in the table 8. Altitude varied from 28 m to 500 m: less than 100 m, 3 samples; 100 - 200 m, 3 samples and 400 - 500 m, 2 samples. The soil texture was

Table 8: Physicochemical characteristics of soils for the studied populations.

Code	Alt	pH	OM (%)	N (%)	$CaCo_3$ (%)	P_2O_5 (ppm)	K_2O (ppm)	Na^+ (meq/100 g)
OS	184	6.91	2.43	0.17	0.00	4.60	102.40	0.30
N	494	7.42	1.38	0.13	13.09	74.30	397.70	1.00
Hh	63	7.46	**8.97**	**0.57**	7.92	48.90	599.50	1.80
Wr	54	7.23	1.91	0.16	0.00	7.30	69.30	0.30
Oz	163	7.09	3.73	0.16	0.54	**82.90**	545.30	0.40
T	106	7.28	**6.28**	**0.35**	2.45	26.50	479.00	0.60
Ss	28	7.05	1.59	0.16	0.00	3.00	316.30	1.20
My	498	7.23	3,59	0.15	13.36	27.00	322.30	0.30

clayey in most sites of harvest. The pH values indicated neutral to slightly alkaline soils (pH ≥ 7.0 for 7 samples out of 8). The percentage of OM ranged from 1.4 to 4% for 6 samples, 6 - 9% for 2 samples. The content of P_2O_5 was low in most samples: less than 8 ppm, 3 samples; 26 - 27 ppm, 2 samples, 48 - 83 ppm, 3 samples. The content of K_2O varied substantially from sample to sample: less than 100 ppm, 1 sample; 100 - 400 ppm, 4 samples, 400 - 600 ppm, 2 samples. It could be stated that most soils where *C. spinosa* samples have been collected are sufficiently rich in OM and K, while phosphate and nitrogen levels are in general low.

Significant correlation coefficients were shown between some studied parameters and soil composition (Table 9). OM and nitrogen show a strong positive correlation with TSC and negative one with K and SteA. Therefore, sites Hh and T (group III) which are rich in OM and N (Table 8), represent high total sugar (259.65 mg/100 g DW) and low K (518.57 mg/100 g DW) and SteA (76.02%) content (Table 6). The soil of Oz which exhibited the high content of P, represents a high content Mn, conforming the positive correlation between P and Mn (Table 9).

Discussion

This study aimed to investigate and analyze the nutrient composition data of the samples under investigation. Phenolic compounds and fatty acid profile of *C. atlantica* Inocencio flower buds from Morocco were studied.

The nutrient content, encompassing total PC, fat, CF, TSC, and minerals, was assessed in the two most prominent regions of Moroccan Capparis. The study revealed TSC, PC, and fat contents ranging from 113.2 to 264.3 g/100 g, 23.95 to 30.72g/100 g, and 22.02 to 27.34 g/100 g, respectively. These results are in agreement with previous studies on *Capparis*, in which they reported similar content of proteins (23.32 to 28.5%) and very low content of fat (2.8 to 3.4%) [7]. In Turkey, Özcan et al. [27] find 8.73% of PC and 8.72% of CF. The Fe, K, and Mn are the major minerals in Moroccan *Capparis* (611.64 ± 157.8, 539.10 ± 18.58, and 145.68 ± 73.53, respectively). Rodrigo et al. [8] showed that *Capparis* was rich in Ca (871 ppm), Mg (636 ppm), K (542 ppm), Na (226 ppm), and Fe (13 ppm). The Moroccan *Capparis* could be considered as a source of Fe, K, and Mn.

The fatty acid composition of *C. atlantica* Inocencio oil was detected by GC-MS techniques, the fat content of the flower buds varied from 22.02 to 27.34%. SteA (79.88%) and PalA (17.44%) were found in high concentrations, these results are not corroborated by previous studies on oils from Italian *Capparis*, in which, PalA (51.95%) was determined as the main fatty acid in the oil, followed by SteA (15.72%) and linoleic acids (10.08%) [15].

The results show that the flower buds contained appreciable content of polyphenols (21.51 mg EAG/g DW), which is in agreement with Arslan et al. [28] who reported that the main constituents of Caper are phenolic acids, flavonoids, alkaloids, lipids, and glucosinolates. Our results are close to those of Meddaour et al. [29], who suggested the content of polyphenols of flower buds, was 29.01 ± 0.84 mg EAG/g and that of flavonoids was 5.97 ± 0.42 mg ER/g of extract. Fur-

Table 9: Correlation coefficients between nutritional parameters and soil compositions.

Parameters	Alt	pH	OM	N	$CaCO_3$	P_2O_5	K_2O	Na
P	0.29	0.31	-0,12	-0,06	**0.5***	-0.32	-0.03	0.26
TS	-0.32	**0.57****	**0.78*****	**0.87*****	0.09	-0.02	**0.43***	**0.55***
Fe	-0.13	-0.20	-0.08	-0.20	-0.12	-0.15	0.20	-0.06
Mn	0.20	-0.09	0.16	-0.07	-0.06	**0.67*****	0.39	**-0.40***
K	0.26	0.11	**-0.73*****	**-0.65*****	0.07	0.21	-0.36	-0.24
SteA	**0.60****	-0.13	**-0.58***	**-0.65****	0.24	0.19	**-0.51***	**-0.62****
PalA	**-0.46***	-0.17	0.27	0.34	-0.27	-0.14	**0.44***	**0.57***

thermore, Akkari et al. [30] proved that the total polyphenol content of aqueous extracts of *C. spinosa* was higher at flowering stage than at vegetative stage, ranging from 67.29 mg EAG/g DW in flower buds.

The rates of TSC, Fe, Mn, and K exhibited a significant level of variability among the populations studied, with high coefficients of variation. The coefficient of variation ranged from approximately 18.58% for K to a substantial 157.79% for Fe. The TSC is high in both populations (T and Hh) from SA while the Ss population from F-M was the richest on Fe. Looking at the locations among the two surveyed regions, it should be mentioned that the mineral contents of flower buds might be influenced by geographical locations and their edaphic conditions (Table 9). Therefore, significant correlation coefficients between some studied parameters and the soil composition were observed.

It should be pointed out that fat content and its profile rates showed a low variability among populations (SD = 1.87). SteA (79.88 %) and PalA (17.44 %) are the most abundant fatty acids in the oil. In Italy, the studies show that the content of saturated fatty acids was higher than that of monounsaturated and polyunsaturated fatty acids in the studied oil. However, PalA (51.95%) was determined as the main fatty acid, followed by SteA (15.72%) and linoleic acid (10.08%) [15]. A study in Ispan indicates that more than 50% of the acids being polyunsaturated acids are linoleic (18.2%) and linolenic (35%) with a content of PalA equal to 31.9% [8].

Some saturated fatty acids have a very important structural and functional role in the living cell, through their ability to acylate proteins. Therefore, a more precise inventory of acylated cellular proteins and of the regulation of their function by acylation is necessary. In this context, the physiological importance of dietary saturated fatty acids must be considered [31]. The nutritional quality is affected by the chemical composition of the soil. Table 10 shows significant correlation coefficients between some studied parameters and the soil composition. These variations could be attributed to factors such as geographical dispersion of the flower bud, soil, climatic conditions of the location, size of the flower bud, or the use of different analytical procedures [7, 12, 27].

Conclusion

The present study has covered almost the entire distribution of *C. atlantica* Inocencio in the largest two regions in Morocco. The most abundant macronutrients among the evaluated nutrients were TSC, PC, and fats. The fatty acid profile was characterized by a notable abundance of SteA and PalA. Moreover, buds are very rich in K, Fe, and Mn whereas P was recorded in very low levels. This study confirms the dietary importance of *Capparis* for human beings. The quantitative heterogeneity observed in wild Moroccan *C. atlantica* Inocencio indicated the presence of both intra- and inter-population variability within the collected samples particularly for TSC, Fe and Mn. The observed variability among the samples could be attributed to both genetic and environmental effects. However, to gain a deeper understanding, further investigation was directed towards evaluating the influence of the collection area on the total glucosinolate content.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Inocencio C, Rivera D, Obón MC, Alcaraz F, Barreña JA. 2006. A systematic revision of *Capparis* section *Capparis* (Capparaceae). Ann Missouri Bot Gard 93(1), 122-149. https://doi.org/10.3417/0026-6493(2006)93[122:ASROCS]2.0.CO;2
2. Lansky EP, Paavilainen HM, Lansky S. 2013. Caper: The Genus *Capparis*. CRC Press.
3. Çelik M, Özcan T. 2016. Analysis of some *Capparis* L. accessions from Turkey based on IRAP and seed protein pattern. *Int J Environ Agric Res* 2: 43-55.
4. Gull T, Anwar F, Sultana B, Alcayde MAC, Nouman W. 2015. *Capparis* species: a potential source of bioactives and high-value components: a review. *Ind Crops Prod* 67: 81-96. https://doi.org/10.1016/j.indcrop.2014.12.059
5. Dobignard A, Chatelain C. 2011. Synonymic Index to the Flora of North Africa. Volume 3: Dicotyledoneae: Balsaminaceae-Euphorbiaceae. Conservatoire et Jardin Botaniques de la ville de Genève, Switzerland.
6. Fennane M, Ibn Tattou M. 1999. Observations sur la flore vasculaire endémique, rare ou menacée du Maroc. *Flora Mediterranea* 9: 113-124.
7. Errachidi F, Bour A, Bouhaddaoui S, Chabir R. 2019. Morphological and nutritional properties of Moroccan *Capparis spinosa* seeds. *Sci World J* 2019: 8594820. https://doi.org/10.1155/2019/8594820
8. Rodrigo M, Lazaro MJ, Alvarruiz A, Giner V. 1992. Composition of capers (*Capparis spinosa*): influence of cultivar, size and harvest date. *J Food Sci* 57(5): 1152-1154. https://doi.org/10.1111/j.1365-2621.1992.tb11286.x
9. Tlili N, El Guizani T, Nasri N, Khaldi A, Triki S. 2011. Protein, lipid, aliphatic and triterpenic alcohol content of caper seeds "*Capparis spinosa*". *J Am Oil Chem Soc* 88: 265-270. https://doi.org/10.1007/s11746-010-1662-2
10. Roamba EN, Bengaly MD, Diao M , Konate K, Dicko MH. 2020. Evaluation of the nutritional and antioxidant potentialities of *Capparis corymbosa*. *Afr J Food Sci* 14(7): 201-208. https://doi.org/10.5897/AJFS2020.1977
11. Tlili N, Nasri N, Khaldi A, Triki S, Munné-bosch S. 2011. Phenolic compounds, tocopherols, carotenoids and vitamin C of commercial caper. *J Food Biochem* 35(2): 472-483. https://doi.org/10.1111/j.1745-4514.2010.00396.x
12. Giuffrida D, Salvo F, Ziino M, Toscano G, Dugo G. 2002. Initial investigation on some chemical constituents of capers (*Capparis spinosa* L.) from the island of Salina. *Italian J Food Sci* 14(1): 25.
13. Matthäus B, Özcan M. 2005. Glucosinolates and fatty acid, sterol, and tocopherol composition of seed oils from *Capparis spinosa* Var. *spinosa* and *Capparis ovata* Desf. Var. *canescens* (Coss.) Heywood. *J Agric Food Chem* 53(18): 7136-7141. https://doi.org/10.1021/jf051019u
14. Mollica A, Stefanucci A, Macedonio G, Locatelli M, Luisi G, et al. 2019. Chemical composition and biological activity of *Capparis spinosa* L. from Lipari Island. *S Afr J Botany* 120: 135-140. https://doi.org/10.1016/j.sajb.2018.02.397
15. Official Methods of Analysis. Association of Official Analytical Chemists, 2000, 17th Edition, Gaithersburg, MD, USA.

16. DuBois M, Gilles KA, Hamilton JK, Rebers PT, Smith F. 1956. Colorimetric method for determination of sugars and related substances. *Anal Chem* 28(3): 350-356. https://doi.org/10.1021/ac60111a017
17. Official Methods of Analysis. Association of Official Analytical Chemists. 1984, 14th Edition, Arlington.
18. Trumbo P, Schlicker S, Yates AA, Poos M. 2002. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *J Am Diet Assoc* 102(11): 1621-1631. https://doi.org/10.1016/s0002-8223(02)90346-9
19. Singleton VL, Orthofer R, Lamuela-Raventós RM. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods Enzymol* 299: 152-178. https://doi.org/10.1016/S0076-6879(99)99017-1
20. Dohou R, Yamni K, Tahrouch S, Hassani LI, Badoc A, et al. 2003. Screening phytochimique d'une endémique iberomarocaine, *Thymelaea lythroides. Bull Soc Pharm Bordeaux* 142(1/4): 61-78.
21. Julkunen-Tiitto R. 1985. Phenolic constituents in the leaves of northern willows: methods for the analysis of certain phenolics. *J Agric Food Chem* 33(2): 213-217. https://doi.org/10.1021/jf00062a013
22. Schofield P, Mbugua DM, Pell AN. 2001. Analysis of condensed tannins: a review. *Animal Feed Sci Technol* 91(1-2): 21-40. https://doi.org/10.1016/S0377-8401(01)00228-0
23. Ryan E, Galvin K, O'Connor TP, Maguire AR, O'Brien NM. 2007. Phytosterol, squalene, tocopherol content and fatty acid profile of selected seeds, grains, and legumes. *Plant Foods Hum Nutr* 62: 85-91. https://doi.org/10.1007/s11130-007-0046-8
24. Slover HT, Lanza E. 1979. Quantitative analysis of food fatty acids by capillary gas chromatography. *J Am Oil Chem Soc* 56(12): 933-943. https://doi.org/10.1007/BF02674138
25. NIST Standard Reference Database.
26. Naanaa W, Susini J. 1988. Méthodes d'analyse physique et chimique des sols. Laboratoire de Pédologie, Institut National de Recherches Forestières, Tunis, Tunisia.
27. Özcan M, Hacıseferoğulları H, Demïr F. 2004. Some physico-mechanic and chemical properties of capers (*Capparis ovata* Desf. var. *canescens* (Coss.) Heywood) flower buds. *J Food Eng* 65(1): 151-155. https://doi.org/10.1016/j.jfoodeng.2004.01.006
28. Arslan R, Bektas N, Ozturk Y. 2010. Antinociceptive activity of methanol extract of fruits of *Capparis ovata* in mice. *J Ethnopharmacol* 131(1): 28-32. https://doi.org/10.1016/j.jep.2010.05.060
29. Meddour A, Yahia M, Benkiki N, Ayachi A. 2013. Etude de l'activité antioxydante et antibactérienne des extraits d'un ensemble des parties de la fleur du *Capparis spinosa* L. *Lebanese Sci J* 14(1): 49-60.
30. Akkari H, B'chir F, Hajaji S, Rekik M, Sebai E, et al. 2016. Potential anthelmintic effect of *Capparis spinosa* (Capparidaceae) as related to its polyphenolic content and antioxidant activity. *Vet Med* 61(6): 308-316. https://doi.org/10.17221/169/2015-VETMED
31. Ezanno H, Beauchamp E, Lemarié F, Legrand P, Rioux V. 2013. L'acylation des protéines: une fonction cellulaire importante des acides gras saturés. *Nutr Clin Métab* 27(1): 10-19. https://doi.org/10.1016/j.nupar.2012.11.001