Trop J Nat Prod Res, February 2024; 8(2):6244-6249 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Short Communication

Mineral Constituents and Antimicrobial Potential of Extracts of *Ajuga iva* L. Collected from Different Geographical Locations in Morocco

Laila Lahrizi[1], Faouzi Errachidi[1], Driss Ousaaid[2*], Lahsen El Ghadraoui[1]

[1]*Laboratory of Functional Ecology and Environmental Engineering, Department of Biology, Faculty of Sciences and Technologies, Sidi Mohamed Ben Abdellah University, Fes 30050, Morocco*
[2]*Laboratory of Natural Substances, Pharmacology, Environment, Modeling, Health and Quality of Life (SNAMOPEQ), Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez 30000, Morocco*

ARTICLE INFO

Article history:
Received 22 December 2023
Revised 24 January 2024
Accepted 02 February 2024
Published online 01 March 2024

ABSTRACT

Fungal infections are a serious health concern that poses a danger to global healthcare systems. The innate resistance of fungi to chemical agents has made researchers investigate natural sources with bioactive contents against a wide spectrum of pathogenic microbes. The present study aimed to explore the variability of the mineral profile, as well as the antifungal effect of different extracts of *Ajuga iva* L. collected from different geographical locations in Morocco. Different extracts (aqueous, ethanol, and methanol) were prepared from *Ajuga iva* samples using the maceration technique. The mineral profile of the extracts was determined using inductively coupled plasma atomic emission spectroscopy (ICP-AES). Eight pathogenic fungi were used to determine the antifungal effect of different extracts of *Ajuga iva* using agar disc diffusion method. The results showed high variability in the mineral profile according to geographical origin with the abundance of Na (between 160.52 and 192.40 mg/L), K (between 10.52 and 41.41 mg/mL), Ca (between 32.07 and 58.76 mg/L), Mg (between 4.16 and 8.42 mg/L), and P (between 1.69 and 10.54 mg/L). All the test extracts exhibited considerable antifungal effects against all fungi except *Cryptococcus.* The findings of the present study confirmed that *Ajuga iva* is a valuable source of essential minerals and is effective in inhibiting the growth of pathogenic fungi.

Keywords: *Ajuga iva* L., Antifungal effect, Geographical origin, Mineral profile

Introduction

The Lamiaceae family is one of the most important herb families due to its unique beneficial properties for humans.[1] This cosmopolitan flowering herb family contains approximately 7136 species spread worldwide.[2,3] Several species of the Lamiaceae family have been documented in various publications that describe their different traditional uses, including antibacterial, antidiabetic, cholesterol-lowering, insecticidal, and anticancer effects.[4–6] Among the long list of Lamiaceae family members, *Ajuga iva* L. was included. The plant has been reported to be effective against a wide spectrum of human diseases, such as hyperglycemia, ulcers, inflammation, wounds, and breast hardness.[7–12] Unfortunately, infectious diseases place a heavy cost on global healthcare systems. The emergence and spread of chemical drug resistance have led to the search for alternative sources of safer and more effective antimicrobial agents.

Several studies have been carried out in this area to investigate the phytochemistry of different natural sources to identify antimicrobial phytocompounds that are efficient against a range of pathogenic microbes.[13–17] Different studies have explored the antimicrobial properties of *Ajuga iva* against multiple pathogenic microbes. These pathogens include *Staphylococcus aureus* CECT976, *Bacillus subtilis* DSM6633, *Listeria innocua* CECT 4030, *Escherichia coli* K12, *Proteus mirabilis*, *Pseudomonas aeruginosa* CECT118, *Staphylococcus epidermidis* 5994, *Staphylococcus aureus* BLACT 4IH2510, *Streptococcus agalactiae* (B) 7DT1887, *Escherichia coli sauvage* 3DT1938, *Escherichia coli* BLSE 2DT2057, *Enterobacter cloacae* 02EV317, *Klebsiella pneumoniae* 3DT1823, *Proteus mirabilis* 2DS5461, *Pseudomonas aeruginosa* 2DT2138, *Candida albicans* Ca, *Candida dubliniensis* Cd, *Saccharomyces cerevisiae* Sacc, *Aspergillus niger* AspN, *Candida tropicalis* Ct, *Candida krusei* Ckr, *Candida parapsilosis* Cpa, and *Candida kyfer* C.ky.[18,19] The antimicrobial properties of *Ajuga iva* L. have been linked to its abundant chemical composition. After a thorough analysis of the phytochemistry of the plant, it was discovered that ferulic acid, quercetin, coumaric acid, apigenin-7-(2-*O*-apiosylglucoside), naringenin, eriodyctiol, and apigenin were implicated.[18,20] The isolation and identification of new natural antimicrobial agents constitute a promising approach to combating microbial resistance.[16,21] Plant phytochemistry depends on numerous factors, such as herb species, sampling season, pedoclimatic conditions, extraction procedure, and extractor solvent.[18] The chemical and biological characteristics of essential plant oil are influenced by the phenological stage of *Ajuga iva*.[22]

The present study was conducted to explore the variation in the mineral profile of *Ajuga iva* samples collected from different regions in Morocco. The antimicrobial activity of the extracts from the plant against eight pathogenic fungi was also determined.

*Corresponding author. E mail: driss.ousaaid@usmba.ac.ma
Tel: +212614400762

Citation: Lahrizi L, Errachidi F, Ousaaid D, El Ghadraoui L. Mineral Constituents and Antimicrobial Potential of Extracts of *Ajuga iva* L. Collected from Different Geographical Locations in Morocco. Trop J Nat Prod Res. 2024; 8(2):6244-6249. http://www.doi.org/10.26538/tjnpr/v8i2.23

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria.

Materials and Methods

Plant collection and identification

The *Ajuga iva* plant samples were collected during November 2023, from five different locations, including Azzaba (33°55'15" N 4°49'54" W), Immouzzer Kandar (33°44'0.24 N, 5°0'37.8" W), Fez (34°01'26" N 5°00'06" W), Moujou (33°46'31" N 4°57'03" W), and Jbel Zerhou

(34°02'02" N, 5°30'42" W). The samples were identified and authenticated under voucher number FE2023/11 in the Functional Ecology and Environmental Engineering Laboratory under the supervision of Professor L. El Ghadraoui in the Faculty of Sciences and Technologies, Sidi Mohamed Ben Abdellah University, Fes 30050, Morocco. The samples were shade-dried and ground into a fine powder for the extraction procedure.

Determination of mineral composition
The mineral content of the different samples under investigation was determined using the calcination technique described by Laaroussi *et al*. by employing inductively coupled plasma atomic emission spectroscopy (ICP-AES).[23] Briefly, the ashes of separate samples were mixed with 5 mL of 0.1 M nitric acid, and the resulting mixtures were agitated using a hot plate to evaporate the nitric acid. To make up to 25 mL, 10 mL of nitric acid were mixed with distilled water.

Plant extraction
The extraction procedure was based on the previously described maceration technique,[23] combining 10 g of each powder sample with 100 mL of each extractor solvent (water, ethanol, and methanol). The mixtures were agitated for 72 h, and the resulting content was sieved through filter paper in preparation for further analyses.

Source of fungal strains
Eight fungi were selected to evaluate the antifungal effects of extracts from *the Ajuga iva* plant collected from different geographical locations in Morocco. Five yeasts, including *Candida* sp. (LSEAF X3), *Pichia* sp. (LSEAF X4), *Geotricum candidum* (LSEAT X1), *Cryptococcus* sp. (LSEAF X2), *Rhodotorula* sp. (LESEAT X3), and three molds, which included *Aspergillus niger* (CSEAF Y1), *Fusarium oxysporum* (CSEAF Y3), and *Penicillium notatum* (CSEAT Y4) were obtained. The microorganisms used in the current study were provided by the Laboratory of Functional Ecology and Engineering Environment, Faculty of Sciences and Technologies (FST), Fez, and were clinically isolated.

Preparation of inoculum suspension
The fungal strains were cultured in 1% yeast extract, 2% peptone, and 2% glucose (YPG) to obtain fresh cultures. Inoculum suspensions were prepared by diluting fresh colonies in distilled water and stirring for 20 seconds and the density was adjusted to $6x10^8$ CFU/mL.

Evaluation of the antimicrobial activity of Ajuga iva extracts
The agar disc diffusion method was used to determine the antifungal effect of the different extracts under study. All fungi mentioned above were grown in YPG medium. An aliquot of 100 µL of the fresh culture of different fungi consisting of 0.5 McFarland standard ($6x10^8$ CFU/mL) was prepared in physiological saline. Also, different concentrations (5, 10, and 20 mg/mL) of the test extracts were prepared. Discs (Whatman 6 mm paper discs) were placed in the Petri dishes and impregnated with 40 µL of each concentration. The incubation of cultures was maintained for 24-72 hours at 37ºC. Subsequently, the inhibition zones were measured.[24]

Statistical analysis
The data are presented as mean±standard error of mean (SEM). To determine significance, a one-way analysis of variance (ANOVA) was performed using the Past 3 program. Différences at $p < 0.05$ were considered to be significant.

Results and Discussion

Mineral composition of Ajuga iva samples
The mineral composition of all samples is presented in Table 1. The most abundant minerals were Na, K, Ca, Mg, and P with values ranging between 160.52 and 192.40, 10.52 and 41.41, 32.07 and 58.76, 4.16 and 8.42, and 1.69 and 10.54 mg/L, respectively. The highest potassium value was recorded in the sample collected from Jbel Zerhoun with 41.41 mg/L, while the Immouzzer Kandar sample had the lowest potassium amount (10.52 mg/L). The sample collected from the Azzaba region had the highest amounts of sodium, calcium, and magnesium with values of 192.40, 58.76, and 8.42 mg/L, respectively. The plant *Ajuga iva* obtained its mineral compounds from the soil and water. The variation in mineral composition observed in *Ajuga iva* could be explained by the fact that the samples under study were collected from different geographical locations, resulting in different soil and environmental conditions. It has been discovered that the mineral profile of plants is highly affected by numerous factors, including geographical origin and weather conditions.[25] The results obtained for the minerals are higher than those reported by Senhaji *et al*., who found that iron (112 mg/L), potassium (44.071 mg/L), and sodium (16.572 mg/L) were the most abundant minerals present in *Ajuga iva*. Macro and micronutrients are essential to complete the plant life cycle.[26] Minerals are involved in different physiological functions of plant cells, including enzyme activation, cell charge maintenance and water balance, and electron transporters.[27] Importantly, several macro and micronutrient supplements are effective at reducing heavy metal uptake and their accumulation in crop culture.[28] The absence of heavy metals in all study samples could be attributed primarily to the presence of significant concentrations of zinc, iron, manganese, phosphorus, and selenium. Furthermore, minerals play an important role in phytochemical synthesis, improving the antioxidant profile of medicinal plants.[29]

Antifungal activity of Ajuga iva extracts
The results of the antibacterial activity of several extracts prepared from various *Ajuga iva* samples are summarized in Table 2. All the fungi were sensitive to the test extracts, except *Cryptococcus. Fusarium* sp. and *Aspergillus niger* were the most sensitive fungi, with inhibition zones ranging between 8.22 and 35 mm. Importantly, no growth of *Penicillium* was observed in plates treated with the methanol extract of the sample collected from Aazzaba. The findings obtained from the present study are consistent with those reported by Saidi *et al.*[18] In the same context, Makni *et al*. observed that methanol extract was the most effective against *Aspergillus clavatus*, *Aspergillus niger*, and *Fusarium* sp., with inhibition zones of 11, 10, and 18 mm, respectively.[30] The extracts obtained from *Ajuga iva* exhibited the least potent antifungal activity against *Candida albicans* with an inhibition zone of 11 mm.[20] *Ajuga iva* possesses a wide range of properties, such as antiviral activities against numerous viruses, including Coxsackie Virus type B-3 (CVB-3), Adenovirus type 5 (ADV-5), Respiratory Syncytial Virus type B (RSV-B), and Herpes Simplex Virus type 2 (HSV-2).[31] The antifungal effect of *Ajuga iva* is associated with its rich chemical composition. The phytochemistry of the herb revealed the presence of several active compounds, such as ferulic acid, quercetin, coumaric acid, and apigenin-7-(2-*O*-apiosylglucoside), which are well known for their antimicrobial properties.[18] Ferulic acid exhibited interesting antifungal activity against *Candida albicans* by altering the morphology and internal structure of the cell surface, resulting in damage to the integrity of the cell and leakage of its contents.[32] The combination of ferulic acid and caspofungin was found to be effective against *C. albicans* by inducing apoptosis.[21] Furthermore, p-coumaric acid is found to act as a mitochondrial decoupler, facilitating its passage through cellular membranes and therefore influencing the disruption of the internal stability of fungi.[33] The synergistic interaction of different active compounds of *Ajuga iva* could explain its considerable antifungal effect against a wide range of pathogenic fungi.

Conclusion

In the current study, the mineral profile and antifungal activity of different samples of *Ajuga iva* L. collected from different geographical locations in Morocco were determined. Significant variability in mineral profile was observed among the samples studied, and significant antifungal activity was noted, particularly in the sample from Aazzaba. The biological properties of *Ajuva iva* may be related to its geographical origin, mineral profile, and phytochemicals. *Ajuga iva* is an interesting source of functional minerals and phytocompounds that require further investigation.

Conflict of Interest

The authors declare no conflict of interest.

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Table 1: Mineral composition of *Ajuga iva* L. samples

	K	Na	Ca	Mg	P	Fe	Al	Si	Zn	B	Mn	Cd	Cr	Cu	Pd	Ni	Ag
Azzaba	16.62	192.40	58.76	8.42	8.34	2.29	2.09	1.67	0.50	0.12	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Immouzzer Kandar	10.52	165.54	32.07	4.93	2.37	1.03	1.20	1.35	0.21	0.08	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fez	13.62	173.26	55.27	8.28	10.54	2.13	8.42	1.58	0.48	0.12	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Moujou	14.42	161.85	38.79	4.19	1.69	0.68	0.76	1.45	0.16	0.07	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Jbel zerhoun	41.41	160.52	43.62	5.54	3.44	0.61	0.87	1.48	0.19	0.11	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 2: The diameter of inhibition zones of different concentrations of *Ajuva iva* extracts under study

Area	Extract	Dose mg/mL	*Candida* sp.	*Pichia* sp.	*Geotricum Candidum*	*Cryptoccocus* sp.	*Rhodotorula* sp.	*Aspergillus niger*	*Fusarium oxysporum*	*Penicillium notatum*
Azzaba	Aqueous	5	-	14.83 ± 0.02	-	-	-	31 ± 1.9	16.83 ± 0.25	-
		10	-	16.33 ± 0.04	-	-	-	20.3 ± 0.28	22.66 ± 1.03	-
		20	-	15.99 ± 0.04	-	-	-	15.1 ± 0.21	19.49 ± 1.29	-
	Ethanolic	5	15.66 ± 0.09	15 ± 0.28	11.33 ± 0.42	-		-	15.88 ± 0.55	-
		10	14.99 ± 0.09	12.5 ± 0.07	18.33 ± 0.04	-	-	18.99 ± 0.04	13.22 ± 0.13	-
		20	10.49 ± 0.02	14.49 ± 0.16	15.5 ± 0.07	-	-	15.99 ± 0.33	15.2 ± 0.13	-
	Methanolic	5	10.49 ± 0.02	14.83 ± 0.02	11.33 ± 0.42	-	-	13.33 ± 0.09	8.8 ± 0.24	No growth
		10	14.99 ± 0.09	16.33 ± 0.04	15.5 ± 0.07	-	-	22.83 ± 0.11	13.22 ± 0.13	No growth
		20	15.66 ± 0.09	15.99 ± 0.04	18.33 ± 0.04	-	-	25.49 ± 0.16	15.88 ± 0.55	No growth
Immouzzer Kandar	Aqueous	5	-	13.99 ± 0.04	-	-	-	19.33 ± 0.42	24.49 ± 0.82	-
		10	-	-	-	-	-	14.66 ± 0.23	19.33 ± 0.66	-
		20	-	-	-	-	-	16.33 ± 0.56	18.16 ± 0.68	-
	Ethanolic	5	11.66 ± 0.04	16.16 ± 2.1	17.49 ± 0.11	-	18.33 ± 0.04	-	-	-
		10	8.69 ± 0.23		10.83 ± 0.16	-	16.83 ± 0.16	23.33 ± 0.04	-	-
		20	19.66 ± 0.09	14.33 ± 0.04	15.66 ± 0.09	-	17.83 ± 0.02	28.34 ± 0.61	-	-
	Methanolic	5	8.69 ± 0.23	-	10.83 ± 0.16	-	16.83 ± 0.16	-	6.77 ± 0.08	8.66 ± 0.15
		10	11.66 ± 0.04	-	15.66 ± 0.09	-	17.83 ± 0.02	14.99 ± 0.04	17.55 ± 0.75	10.11 ± 0.25
		20	19.66 ± 0.09	-	17.49 ± 0.11	-	18.33 ± 0.04	16.33 ± 0.09	25.33 ± 1.03	16.66 ± 0.92
Fez	Aqueous	5	-	-	-	-	-	22 ± 0.28	20.16 ± 0.68	-
		10	-	-	-	-	-	16.83 ± 0.09	18.66 ± 0.70	-

		20	-	-	-	-	-	16.66 ± 0.11	16.83 ± 0.58	-
		5	12.83 ± 0.11	8.5 ±	5 ± 0.14	-	11.66 ± 0.09	6 ± 0.84	-	-
	Ethanolic	10	-	8.66 ± 1.22	10.83 ± 0.02	-	-	11 ± 1.5	-	-
		20	11.99 ± 0.04	-	11.16 ± 0.11	-	-	14.66 ± 0.14	-	-
		5	-	-	5 ± 0.14	-	-	12.33 ± 0.04	8.22 ± 0.20	9.88 ± 0.05
	Methanolic	10	11.99 ± 0.04	-	10.83 ± 0.02	-	-	13.66 ± 0.04	9.88 ± 0.61	11 ± 0.1
		20	12.83 ± 0.11	-	11.16 ± 0.11	-	-	16.5 ± 0.91	14.99 ± 0.88	11.33 ± 0.12
		5	-	14.99 ± 0.09	-	-	-	23.33 ± 0.61	20.66 ± 25	-
	Aqueous	10	-	14.66 ± 0.04	-	-	-	16.99 ± 0.09	25.83 ± 0.96	-
		20	-	0.98 ± 0.11	-	-	-	21.16 ± 0.16	22.33 ± 0.89	-
		5	11.5 ± 0.07	-	13.83 ± 0.11	-	17.83 ± 0.11	10.66 ± 1.50		
Moujou	Ethanolic	10	13.99 ± 0.04	12.5 ± 0.07	-	-	13.66 ± 0.09	17.49 ± 0.02		
		20	14.99 ± 0.04	14.33 ± 0.14	13.5 ± 0.07	-	14.66 ± 0.18	21.83 ± 0.16		
		5	11.5 ± 0.07	9.8 ± 0.11	-	-	13.66 ± 0.09	11 ± 0.28	16.33 ± 0.78	10.99 ± 0.20
	Methanolic	10	13.99 ± 0.04	14.66 ± 0.04	13.5 ± 0.07	-	14.66 ± 0.18	11.49 ± 0.25	20.77 ± 1.11	11.44 ± 0.12
		20	14.99 ± 0.04	14.99 ± 0.09	13.38 ± 0.11	-	17.83 ± 0.11	14.66 ± 0.09	20.99 ± 0.76	11.11 ± 0.05
		5	-	-	-	-	-	19.83 ± 0.21	23.33 ± 1.22	-
	Aqueous	10	-	-	-	-	-	25.16 ± 1.62	23.16 ± 0.77	-
		20	-	-	-	-	-	18.33 ± 0.09	17.83 ± 1.43	-
		5	13.83 ± 0.07	-	11.83 ± 0.21	-	-	6.83 ± 0.96	-	-
Jbel Zerhoun	Ethanolic	10	-	-	15.66 ± 0.18	-	-	16.66 ± 0.04	-	-
		20	-	17.83	-	-	-	17.16 ± 0.16	-	-
		5	-	-	-	-	-	13.33 ± 0.14	12.22 ± 0.18	10.33 ± 0.1
	Methanolic	10	-	-	11.83 ± 0.21	-	-	15.99 ± 0.09	12.77 ± 0.34	12.11 ± 0.18
		20	-	14.66 ± 0.28	15.66 ± 0.18	-	-	17.33 ± 0.04	35.66 ± 1.03	15.88 ± 0.06

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

References

1. Mishra LK, Sarkar D, Shetty K. Human health-relevant bioactives and associated functionalities of herbs in the Lamiaceae family. In: *Functional Foods and Biotechnology*. CRC Press; 2019:115-131.
2. Hussein AA. Chemistry of South African Lamiaceae: Structures and biological activity of terpenoids. *Terpenes and Terpenoids*. Published online 2018:13-38.
3. Etsassala NGER, Hussein AA, Nchu F. Potential Application of Some Lamiaceae Species in the Management of Diabetes. Plants. 2021;10(2):279. doi:10.3390/plants10020279
4. Bouyahya A, El Omari N, Elmenyiy N, Guaouguaou FE, Balahbib A, El-Shazly M, Chamkhi I. Ethnomedicinal uses, phytochemistry, pharmacology, and toxicology of *Ajuga iva* (L.,) shrub. J Ethnopharmacol. 2020;258:112875.
5. Falodun A, Siraj R, Choudhary MI. GC-MS analysis of insecticidal leaf essential oil of *Pyrenacantha staudtii Hutch* and *Dalz* (Icacinaceae). Trop J Pharm Res. 2009;8(2):139-143.
6. Okolie NP, Falodun A, Davids O. Evaluation of the antioxidant activity of root extract of pepper fruit (*Dennetia tripetala*), and it's potential for the inhibition of lipid peroxidation. Afri J Trad Compl Alter Med. 2014;11(3):221-227.
7. Tahraoui A, El-Hilaly J, Israili ZH, Lyoussi B. Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in south-eastern Morocco (Errachidia province). J Ethnopharmacol. 2007;110(1):105-117. doi:10.1016/j.jep.2006.09.011
8. Lahrizi L, Errachidi F, Nekhla H, Ghadraoui LE. Unraveling traditional knowledge of *Ajuga iva* (L.) Schreb. used in the Fez-Meknes area in Morocco. Trad Integ Med. Published online December 28, 2022. doi:10.18502/tim.v7i4.11491
9. Hilaly JE, Israili ZH, Lyoussi B. Acute and chronic toxicological studies of *Ajuga iva* in experimental animals. J Ethnopharmacpl. 2004;91(1):43-50. doi:10.1016/j.jep.2003.11.009
10. El-Hilaly J, Tahraoui A, Israili ZH, Lyoussi B. Hypolipidemic effects of acute and sub-chronic administration of an aqueous extract of *Ajuga iva* L. whole plant in normal and diabetic rats. J Ethnopharmacol. 2006;105(3):441-448. doi:10.1016/j.jep.2005.11.023
11. Insaf M, Ghizlane H, Ghada B, Fadoua E, Samiha K, Youness EA, Mohamed F. Plant-based Bioproducts for the Control of Diabetes and Hypertension in TangierTetouan Region (Morocco): Trop J Nat Prod Res. 2023;7(9):4016-4025. http://www.doi.org/10.26538/tjnpr/v7i9.25.
12. Khadija EO, Abdelfattah EM, Laila B, Dalila B. Ethnobotanical Study of Medicinal Plants Used in the Treatment of Cancers in the City of Casablanca (West-Central of Morocco). Trop J Nat Prod Res. 2021;5(6):1044-1054. doi.org/10.26538/tjnpr/v5i6.11.
13. Yang Y, Kessler MGC, Marchán-Rivadeneira MR, Han Y. Combating Antimicrobial Resistance in the Post-Genomic Era: Rapid Antibiotic Discovery. Molecules. 2023;28(10):4183.
14. Shamim A, Ali A, Iqbal Z, Mirza MA, Aqil M, Kawish SM, Siddiqui A, Kumar V, Naseef PP, Alshadidi AAF, Kuruniyan MS. Natural medicine a promising candidate in combating microbial biofilm. Antibiotics. 2023;12(2):299.
15. Jadimurthy R, Jagadish S, Nayak SC, Kumar S, Mohan CD, Rangappa KS. Phytochemicals as invaluable sources of potent antimicrobial agents to combat antibiotic resistance. Life. 2023;13(4):948.
16. Firoozbahr M, Kingshott P, Palombo EA, Zaferanloo B. Recent advances in using natural antibacterial additives in bioactive wound dressings. Pharmaceutics. 2023;15(2):644.
17. Mohan S, Ajay Krishna MS, Chandramouli M, Keri RS, Patil SA, Ningaih S, Somappa S. Antibacterial natural products from microbial and fungal sources: A decade of advances. Mol Div. 2023;27(1):517-541.
18. Saidi S, Remok F, Handaq N, Drioiche A, Gourich AA, El Menyiy N, Amalich A, Elouardi M, Touijer H, Bouhrim M, Bouissane L, Nafidi HA, Jardan YAB, Bourhia M, Zair T. Phytochemical Profile, Antioxidant, Antimicrobial, and Antidiabetic Activities of *Ajuga iva* (L.). Life. 2023;13(5):1165. doi:10.3390/life13051165
19. Senhaji S, Lamchouri F, Boulfia M, Lachkar N, Bouabid K, Toufik H. Mineral composition, in vitro inhibitory effects of α-amylase, α-glucosidase, β-galactosidase enzymes and antibacterial activity of *Ajuga iva* subsp. *Pseudoiva* (DC.) Bric. Biointer Res Appl Chem. 2021;12(2):2373-2391.
20. Ammar H, Touihri I, Kholif AE, M'Rabt Y, Jaouadi R, Chahine M, de Haro Marti ME, Vargas-Bello-Pérez E, Hosni K. Chemical Composition, Antioxidant, and Antimicrobial Activities of Leaves of *Ajuga iva*. Molecules. 2022;27(20):7102. doi:10.3390/molecules27207102
21. Canturk Z. Evaluation of synergistic anticandidal and apoptotic effects of ferulic acid and caspofungin against *Candida albicans*. J Food Drug Anal. 2018;26(1):439-443. doi:10.1016/j.jfda.2016.12.014
22. Bouyahya A, El Omari N, Belmehdi O, Lagrouh F, El jemli M, Marmouzi I, Faouzi MEA, Taha D, Bourais I, Zengin G, Bakri Y, Dakka N. Pharmacological investigation of *Ajuga iva* essential oils collected at three phenological stages. Flavour Fragr J. 2021;36(1):75-83. doi:10.1002/ffj.3618
23. Laaroussi H, Bouddine T, Bakour M, Ousaaid D, Lyoussi B. Physicochemical properties, mineral content, antioxidant activities, and microbiological quality of *Bupleurum spinosum* Gouan honey from the middle atlas in Morocco. J Food Qual. 2020;2020.
24. Ousaaid D, Laaroussi H, Bakour M, Ennaji H, Lyoussi B, El Arabi I. Antifungal and antibacterial activities of apple vinegar of different cultivars. Inter J Microbiol. 2021;2021.
25. Beltrán Sanahuja A, Maestre Pérez SE, Grané Teruel N, Valdés García A, Prats Moya MS. Variability of chemical profile in almonds (*Prunus dulcis*) of different cultivars and origins. Foods. 2021: 13;10(1):153.
26. Maathuis FJM, Diatloff E. Roles and Functions of Plant Mineral Nutrients. In: Maathuis FJM, ed. *Plant Mineral Nutrients: Methods and Protocols*. Methods in Molecular Biology. Humana Press; 2013:1-21. doi:10.1007/978-1-62703-152-3_1
27. Waraich EA, Ahmad R, Ashraf MY. Role of Mineral Nutrition in Alleviation of Drought Stress in Plants. Aust J Crop Sci. 2011;5(6):764-777. doi:10.3316/informit.282340708899391
28. Sarwar N, Saifullah, Malhi SS, Zia MH, Naeem A, Bibi S, Farid G. Role of mineral nutrition in minimizing cadmium accumulation by plants. J Scie Food Agri. 2010;90(6):925-937. doi:10.1002/jsfa.3916
29. Flores IR, Vásquez-Murrieta MS, Franco-Hernández MO, Márquez-Herrera CE, Ponce-Mendoza A, Del Socorro López-Cortéz Ma. Bioactive compounds in tomato (*Solanum lycopersicum*) variety saladette and their relationship with soil mineral content. Food Chem. 2021;344:128608. doi:10.1016/j.foodchem.2020.128608
30. Makni M, Haddar A, Kriaa W, Zeghal N. Antioxidant, Free Radical Scavenging, and Antimicrobial Activities of *Ajuga*

iva Leaf Extracts. Inter J Food Proper. 2013;16(4):756-765. doi:10.1080/10942912.2011.561465

31. Medjeldi S, Bouslama L, Benabdallah A, Essid R, Haou S, Elkahoui S. Biological activities, and phytocompounds of northwest Algeria *Ajuga iva* (L) extracts: Partial identification of the antibacterial fraction. Microbial Pathogenesis. 2018;121:173-178. doi:10.1016/j.micpath.2018.05.022
32. Yan H, Meng X, Lin X, Duan N, Wang Z, Wu S. Antifungal activity and inhibitory mechanisms of ferulic acid against the growth of F*usarium graminearum*. Food Biosci. 2023;52:102414. doi:10.1016/j.fbio.2023.102414
33. Morales J, Mendoza L, Cotoras M. Alteration of oxidative phosphorylation as a possible mechanism of the antifungal action of *p*-coumaric acid against *Botrytis cinerea*. J App Microbiol. 2017;123(4):969-976. doi:10.1111/jam.13540