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AROMATIC PLANTS AS FEED FOR GOATS IN AURÈS MOUNTAINS OF ALGERIA: CHARACTERIZATION OF VOLATILE AND PHENOLIC COMPOUNDS

ALI BOUGUERRA[A]*, AGNÈS CORNU[B], NASSIM ZOUAOUI[A,C], SAMAH DJEBILI[A], MOHAMED EL-HADEF EL-OKKI[E], BRUNO MARTIN[B], THEOFILOS MASSOURAS[D], MALIKA BARKAT[A]

[a]Laboratory of BIOQUAL, INATAA, University of Mentouri Brothers-Constantine 1, Ain El Bey, 25000 Constantine, Algeria
[b]Université Clermont Auvergne, VetAgroSup, INRA, UMR Herbivores, F-63122 Saint-Genès-Champanelle, France
[c]Department of Applied Biology, Faculty of Exact Sciences and Natural and Life Sciences, University of Tebessa, 12002 Tebessa, Algeria
[d]Laboratory of Dairy Science and Technology, Agricultural University of Athens, Ieraodos 75, 11855 Athens, Greece
[e]Laboratory of Biology and Environment, University of Mentouri Brothers - Constantine 1. Ain El Bey, 25000 Constantine, Algeria
(e-mail : ali.bouguerra@umc.edu.dz)
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SUMMARY

The aim of this work was to make an inventory of the aromatic plants pastured by goats in the Aurès Mountains of Algeria and to characterize their volatile and phenolic compounds. In this context, a survey was conducted among goat farmers in this region (department of Batna). Plant volatile compounds were analyzed using HS-SPME/GC-MS and phenolic compounds using HPLC-DAD. According to the results of the survey, twenty-nine (29) aromatic plants were identified as goats' feed. The most cited ones were *Thymus algeriensis* (96 %), *Artemisia herba alba Asso* (91 %), *Rosmarinus officinalis* L. (83 %), *Juniperus phoenica* L. (80 %), *Artemisia campestris* L. (80 %), and *Marrubium vulgare* L. (70 %). The major volatile compounds were α-pinene (40 %), β-thujone (38 %), trans-caryophyllene (31 %), β-myrcene (29 %), camphor (27 %), and β-thujone (18 %). The most abundant phenolic compounds were flavonoids (rutin, kaempferol-3-O-rutinoside, apigenin, hesperidin, isoquercitrin, and quercitrin), cinnamic acid derivatives (chlorogenic acid, rosmarinic acid, caffeic acid, and ferulic acid), coumarines, and benzoic acid derivatives. The present results indicate that aromatic plants from Aurès mountains of Algeria are rich in phenolic compounds and could be offered as feed for goats.

Key words : Goats, feed, aromatic plants, phenolic compounds, volatiles compounds

ABBREVIATIONS AC, *Artemisia campestris* L.; AH, *Artemisia herba alba* Asso; MV, *Marrubium vulgare* L.; JP, *Juniperus phoenica* L.; RO, *Rosmarinus officinalis* L.; TA, *Thymus algeriensis* ; TP, *Teucrium polium* ; PDMS-DVB, polydimethylsiloxane divinylbenzene fiber-type (65 μm); GC-MS, Gas Chromatography-Mass Spectrometry; DAD, Diode Array Detector; HPLC, High-Performance Liquid Chromatography; HS-SPME, HeadSpace-Solid Phase MicroExtraction; FC, Frequency of Citation; CP, Crude Protein; ADF, Acid Detergent Fiber; NDF, Neutral Detergent Fiber; OM, Organic Matter; MM, Mineral Matter; DM, Dry Matter; DW, Dry Weight.

Just over a third of the planet's surface is arid or semi-arid (21 million km^2 are semi-arid regions). In these areas, forage consists of shrubs and herbs (Andrade-Montemayor *et al.,* 2011). In Algeria, land used by the agricultural sector occupies 40 million hectares, of which 31 are pastures and rangelands and constitute the essential domain of pastoralism (Nedjraoui, 2003). The extensive and semi-intensive system are the two dominant systems. Extensive system dominates the other systems and is present in the steppe, in the Saharan regions, in mountainous regions, and northern piedmonts. However, the semi-intensive system is practiced at the level of the cereal plains (MADR, 2003). The raising of goat represents an important contribution to the livestock productions, with differing distribution in uneven areas and under various environmental and climatic conditions (Bourabah *et al.,* 2013). Goat raising on rangeland is one of the most traditional agricultural activities. Although this population represents 13.76 % (5.007.894 heads) of the national herd (FAO, 2019). The main economic resource in these areas is livestock, mainly goats, because of the adaptation of the caprine species to its environment as well as its traditional anchoring (Bourabah *et al.,* 2013; Nedjraoui, 2003). Endogenous herbs and shrubs are an important feed source for ruminants in semi-arid regions, because they are well adapted to the growing conditions and offer nutritious feed (Mlambo & Mapiye, 2015).

Pasture plants contain different groups of chemicals like vitamins, terpenes, and phenolic compounds at different concentrations (Farruggia *et al.,* 2008), and some of them are transferred from the ingested plant into ruminants' milk and meat. Plant secondary metabolites have been considered, in the past, as antinutritional factors, as polyphenols do reduce the bioavailability of proteins and minerals (Chung *et al.,* 1998). However, aromatic plants have beneficial effects on human health thanks to their secondary metabolites including terpenes and phenolic compounds, hence, their importance for the ruminants' health and for the health value of their products (milk and meat) would also be of dual interest. Recently, researchers have reported improvements in the production performances of ruminants consuming diets rich in phenolic compounds, in terms of better growth rates, milk yield and composition, and reproductive performance (Kalantar, 2018; Mlambo & Mapiye, 2015). Algeria is considered as a real treasure of natural resources among which is a wide range of aromatic plants. In Aurès Mountains, the wide varietal diversity of aromatic plants (Senoussi *et al.,* 2020; Zouaoui *et al.,* 2020) probably contribute both to the health of the goats and to the quality of their milk. In this context, the objectives of this study were (i) to take advantage of the traditional knowledge of local farmers, to inventory the aromatic plants consumed by goats, and to select certain aromatic plants in order to offer them as feed for goat through a survey in the study area; (ii) to analyse their volatile and phenolic compounds' profiles using HS-SPME-GC-MS and HPLC-DAD respectively.

MATERIALS AND METHODS

Study area

The survey was conducted in Aurès Mountains (Batna Department, North east Algeria). This region is localized in of Algeria to a few 250 km of the Mediterranean Sea on the Saharian Atlas. (Figure 1). The Aurès chain is obliquely directed North East to South Est. It is 80 km wide from North to South, and approximately 150 km from west to east. It comprises a whole of high massifs separated by deep valleys. It is composed of a certain number of distinct compartments, juxtaposed, but very different. The study area was between latitudes 35°10' and 35°30' North and longitudes 6°20' and 7°10' East. The soil of Aurès, generated from sandstone materials, is discontinuous and shallow, showing a low water-holding capacity. The climate is Mediterranean semi-arid, with two distinct seasons: cold and wet, dry and hot. The mean total annual precipitation is low, ranging from 400 to 500 mm. The annual drought period extended from the middle of May to the middle of October at 1 040 m a.s.l. The mean annual temperature ranges from 13 to 15 °C. January is the coldest month with an average temperature of 4-10 °C. July is the hottest month with an average temperature of 23.5-25.5 °C (Beghami *et al.,* 2012; Kherchouche *et al.,* 2012).

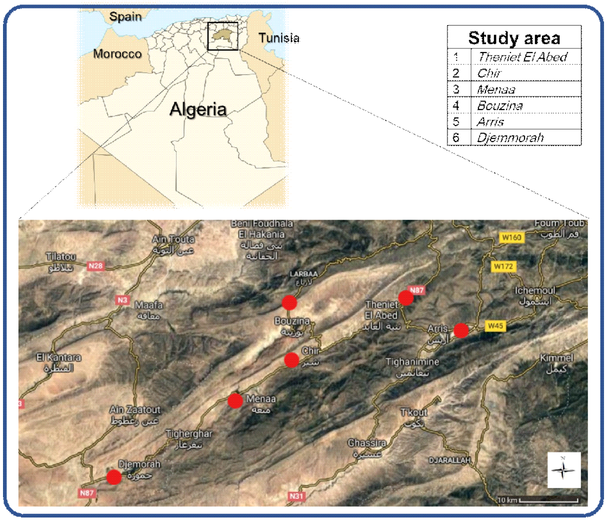

Fig. 1. Geographical location of the regions of the survey.

Survey

The survey objectives were firstly, to record the traditional knowledge about the putative effects of aromatic plants on the quality of milk; secondly, to list the aromatic plants consumed by goats. An initial version of a questionnaire was developed, to be distributed for the population of the survey. In parallel, a pre-survey was conducted to test the questionnaire's reliability with eight goat farmers (key informants) aged between 40 and 70 years. These key informants were locally known as the most knowledgeable people about goat raising and aromatic plants in the studied region. The interviews were conducted in French, Arabic and/or local language (berbere), depending on the interrogated person. In special cases, an assistance of volunteer interpreters was needed, generally a relative or friend of the person surveyed. The interviews were conducted at pasture places, at homes or at the popular places of the region. The questionnaire contained closed and open questions about the feeding behaviour of goats. It was based on four main components:

Component 1. Personal information about the farmer (gender, age, residence, and education level);
Component 2. Traditional knowledge about goats raised in Aurès mountains (races and their principal characterizations);
Component 3. Information about aromatic plants pastured by goats (pastured aromatic plants, their abundance in study area, and frequency by goats);
Component 4. Traditional knowledge on the milk of goats grazing on aromatic plants (influence of aromatic plants on goat's milk).

The identity of each plant species mentioned by the farmers was verified (vernacular common names and scientific name) using standard botanical references on Algeria flora: Quezel and Sant (1963, 1962) and Baba Aissa (2000). The plants were confirmed and authenticated by Dr. Nassima Diab, a botanist at the Technical Institute of Agricultural Development Saharan Africa (ITDAS) province of Biskra, Algeria.

Aromatic plants sampling

The plants chosen according to the survey results were *Artemisia campestris* L. (AC), *Artemisia herba alba Asso* (AH), *Marrubium vulgare* L. (MV), *Juniperus phoenica* L. (JP), *Rosmarinus officinalis* L. (RO), *Thymus algeriensis* (TA), and *Teucrium polium* (TP). Plant material was collected between March and April 2015. The freshly harvested plants were dried up during seven days in a ventilated and dry room protected from light at ambient temperature (about 30-25 °C). The samples of aromatic plants were ground through using a blade mill to pass a 1 mm sieve. The chemical compositions of studied aromatic plants, using standard procedures (AOAC, 1997), are reported in Table 1.

Volatile compounds analysis

Extraction : The commercially available SPME device for manual sampling and the fiber were purchased from SUPELCO (Bellefonte, PA, USA). A polydimethylsiloxane divinylbenzene SPME fiber (PDMS-DVB, 65 µm) was conditioned by heating at 250 °C in the port of injection of a gas chromatograph, for 10 min at the first use, then 4 min between two analyses. One-gram (1 g) samples of the dried, ground plants were weighed in 20 ml SPME vials, sealed and equilibrated at 70 °C during 30 min in a water bath, before the conditioned SPME fiber was exhibited for 30 min to the head-space.

Chromatographic analysis

The analysis of volatile compounds was carried out by GC-MS method described by Poulopoulou et al. (2012), with a minor modification. After extraction, the SPME fiber was removed from the sample vial and immediately inserted into the injection port of the A17 Shimadzu series GC coupled to a Q5050 MS detector (Shimadzu, Kyoto, Japan).

TABLE 1
Chemical composition of the studied medicinal plants (g/100g DM)

	CP	ADF	NDF	OM	MM	DM
Artemisia campestris L.	4.3±0.48^{a}	17.7±0.52^{a}	25±1.20^{a}	88.1±0.10^{b}	11.9±0.10^{b}	90.9±0.09^{a}
Artemisia herba alba asso	17.1±1.20^{d}	25.8±2.36^{bc}	30.3±0.40^{b}	88.4±0.04^{b}	11.5±0.14^{b}	90.9±0.04^{a}
Juniperus phoenica L.	16.2±0.21^{d}	29.4±0.14^{c}	44±0.98^{e}	93±0.06^{c}	7±0.04^{a}	91.4±0.055^{a}
Marrubium vulgare L.	4±0.26^{a}	18.8±0.30^{a}	32.5±0.74^{bc}	82.4±0.06^{a}	17.6±0.06^{c}	91.9±0.04^{a}
Rosmarinus officinalis L.	16.1±0.02^{d}	25.1±1.06^{b}	34.6±0.25^{c}	88.5±0.21^{b}	11.5±0.21^{b}	91.5±0.16^{a}
Teucrium polium	12.4±0.20^{c}	26.9±0.43^{bc}	38.9±0.20^{d}	82.6±0.34^{a}	17.4±0.34^{c}	94.6±1.89^{a}
Thymus algeriensis	7.9±0.35^{b}	25.7±0.84^{b}	34.8±0.21^{c}	88.3±0.60^{b}	12.1±0.20^{b}	91.9±0.05^{a}

CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; OM, organic matter; MM, mineral matter; DM, dry matter; Values are given as mean ± standard deviation (SD) (n = 3). Values in the same column followed by different letters (a-e) are significantly different ($P < 0.05$).

The column was an HP-INNOWAX capillary column (60 m x 0.25 mm x 0.25 µm). Helium was used as the carrier gas with a flow rate of 0.9 ml/min. The working conditions are: injector temperature, 250 °C; interface temperature, 230 °C; column temperature was maintained at 40 °C for 5 min and then increased to 250 °C at a rate of 3 °C/min. Mass spectra were obtained under ionization energy conditions at 70 eV in the mass range 35-400 amu. Peak identification was performed by comparing the mass spectra with the NIST (National Institute of Standards and Technology, USA) libraries.

Phenolic compounds analysis

Extraction : This extraction was adapted from Fraisse et al. (2007). Eight milliliters (8 ml) of ethanol: water (80:20 v:v) were added to 200 mg dry, ball-milled sample, in Pyrex SVL test tube. The tubes were placed in a dry bath (Grant, UK) at 90 °C for 20 minutes, vortexing every 5 minutes for 10 seconds, then centrifuged for 10 minutes at ambient temperature at 2000 rpm (635 g with the JOUAN MR23i rotor SWM180S) and the supernatant was recovered. This operation was repeated twice with 8ml of ethanol: water (80:20 v:v). The cumulated supernatant was adjusted to 25 ml with ethanol: water (80:20 v:v), homogenized and a 5 ml aliquot was evaporated to dryness in a dry bath at 40 °C under nitrogen flow. The dry residues were resuspended in 1.5 ml ultrapure water and centrifuged for 10 minutes under 914 g at 20 °C. The final extracts were placed in 2 ml vials at 4 °C in the auto-sampler of the HPLC system.

Chromatographic analysis : The analysis system consisted of an Agilent LC1200 HPLC chain, equipped with a Diode Array Detector (DAD) scanning from 190 to 400 nm. Openlab software (Agilent) was used for data acquisition and instrument control. A LichroCART SuperSpher 60 RP 8e column (125 x 4 mm, 4 µm; Merck, Saint-Quentin Fallavier, France), thermostated at 35 °C was used for the separation. The elution solvents were 0.05 % formic acid in water (A) and 0.05 % formic acid in acetonitrile: water 7:3 (v:v) (B). The gradient changed linearly as follows: (A:B) = (100:0) at initial conditions, (98:2) at 0.5 min, (88:12) at 4 min, (80:20) at 29 min, (74:26) at 34 min (30:70) at 49 min and until 50 min, (0:100) at 60 min, and until 70 min. The flow rate was 0.3 ml/min, and the injection volume 5 µl. The peaks were identified by comparing their absorbance spectra and retention times with those of the authentic standards and the bibliography. The unidentified peaks were classified into families according to their absorbance spectra and quantified in equivalents of a standard molecule belonging to the same family.

Data analysis

The frequency of citation (FC), for each cited plant species, was determined as: FC (%) = (Number of citations / Total number of citations for all recorded species) x 100. The value of FC obtained directly correlates with the extent of the use of the plant species (Youmsi *et al.,* 2017). In order to deal the survey results, a factorial correspondence analysis (AFC) was carried out, using R for Windows version 3.6.1 (2019). Statistical analysis for volatile and phenolic compounds was carried out also using ANOVA test followed by the Tukey's. Statistica software version 10 (Stat-Soft Inc - Tulsa, OK, USA) was used to perform the statistical analysis at the 5 % significance level.

RESULTS

Survey

Informants profile : A total of 70 farmers from the six localities agreed to participate in this survey. Their profile is given in Table 2. The age of respondents varied between 20 and 75 years. The majority (40 %) belonged to the age group over 60 years. The majority of interviewed participants were men (73 %). Concerning the level of education, more than a third of informants were at the primary school level (42 %); 23 % had a university education level and only 14 % had a high school level.

Goat breeds : Most farmers in the study area bred more than one breed of goats. Consequently, the most represented goat breeds were Echernon, Elarbya and Adhrar, cited respectively by 76, 69 and 33 % of the farmers. Other breeds are raised in the region but in small effective, for example Baldya and Alpine (23 % and 14 % citation, respectively).

Aromatic plants : The twenty-nine (29) cited plant species belonged to (18) eighteen botanical families, the most represented ones being *Lamiaceae* (24 %) and *Asteraceae* (14 %) followed by *Apiaceae* (7 %), and *Liliaceae* (7 %) (figure 02). The aromatic plants with the higher frequency of citation (FC) as

TABLE 2
Socio-demographic data of the informants

Socio-demographic variables		Percentage (%)
Age (years)	[20-30]	14
	[31-40]	10
	[41-50]	12
	[51-60]	24
	>60	40
Gender	Male	73
	Female	27
Origin	Thnayet Elaabed	17
	Chir	18
	Manaa	19
	Bouzina	23
	Arris	3
	Djammoura	20
Study level	Illiterate	21
	Primary	42
	high school	14
	University	23

feed for goats were: TA (96 %), AH (92 %), RO (83 %), JP (80 %), AC (80 %), MV (70 %), and TP (50 %) (Table 3).

Flowers were the most used plant part by goat with a percentage of 93 %, followed by leaves (84 %), stems (54 %), and seeds (23 %).

This survey made it possible to identify the most abundant plants in Aurès mountains: AH (91 %), TA (79 %), MV (57 %) and JP (55 %). In contrast, AC (38 %), TP (18 %) and RO (9 %) are relatively rare in the area (figure 03).

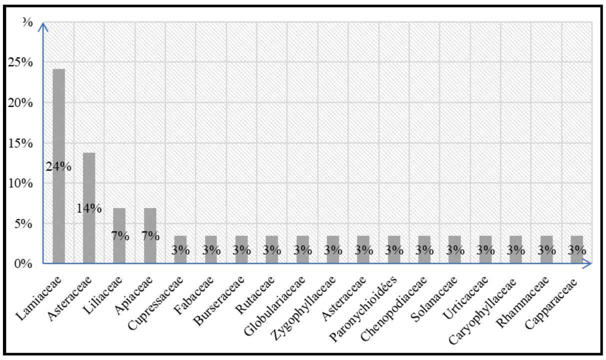

Fig. 2. Repartition in botanical families of the cited medicinal plants.

According to the results of the survey, goats are selective for some aromatic plants according to the species available. The most favored ones were: TA (75 %), TP (64 %), and AH (55 %) (figure 04). Other aromatic plants are rarely eaten such as AC (11%), JP (9%), RO (7%), and MV (6%).

3.1.4 Milk of goat consuming aromatic plants

According to the results of the survey, aromatic plants have a great influence on flavor and aroma of goat milk. AH (98 %), TA (96 %), JP (93 %), RO (90 %), and MV (82%) would be the most

TABLE 3
Information on the main cited plants consumed by goats in the survey area and their Frequency of Citation (FC in % of the mean)

Scientific name	Family	English name	French name	Local name (Tamazight and/ or Arab)	Frequency of citation (FC) in %
Thymus algeriensis	Lamiaceae	Thyme	Thym	jertil, mezzouchen, z'aitra, elhamria, eljemzzocha, azenki, jochen	96
Artemisia herba alba Asso	Asteraceae	White wormwood	Armoise blahce	elchih, elchiha, izry, afri, azer	92
Rosmarinus officinalis L.	Lamiaceae	Rosmary	Romarin	iklil eldjebel, klik, azri, touzala, raouzair, iyazir	83
Juniperus phoenica L.	Cupressaceae	Phoenician juniper	Genevrier de phoenicie	elaraar, zinba, ifezi, ramba	80
Artemisia campestris L.	Asteraceae	Wormwood	Armoise rouge, Aurône	tegouft, dkoufeth, elkaissoum, tagoufed, tirjlit,allala	80
Marrubium vulgare L.	Lamiaceae	Common white horehound	Marrube Commun	frassyoun, elmerrouyth, temerrouyth, timeresttabakennit, ifezi, aferkizoud	70
Astragalus armatus Willd	Fabaceae	Retam	Retam	elretam, aouajmith	70
Commiphora myrrha	Burseraceae	Myrrhe	Balsamier, arbre à myrrhe	elmoura, mirezaketh	60
Teucrium polium	Lamiaceae	Cat tyme, Hulwort	Germandrée tomenteuse	jaida, imezrith, timezourin, jaada	50
Ruta montana	Rutaceae	Commun rue	Rue de montagne	elfijel, fijel eljabel, ourmi, issen, elfijen	29

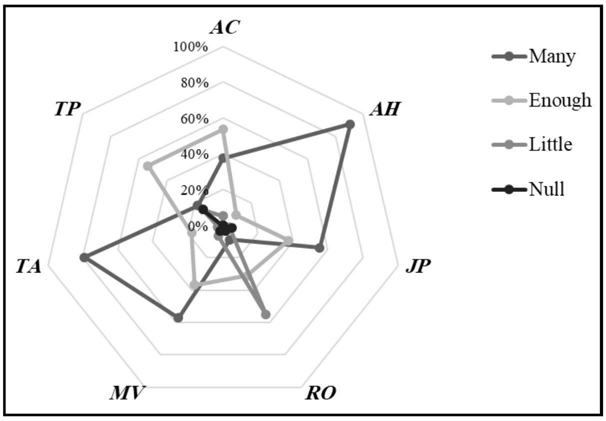

Fig. 3. Repartition of medicinal plants according to their abundance in the Aurès mountains; the answers to the question « what is the level of abundance of cited medicinal plants in pasture areas: many, enough, little, or null? »

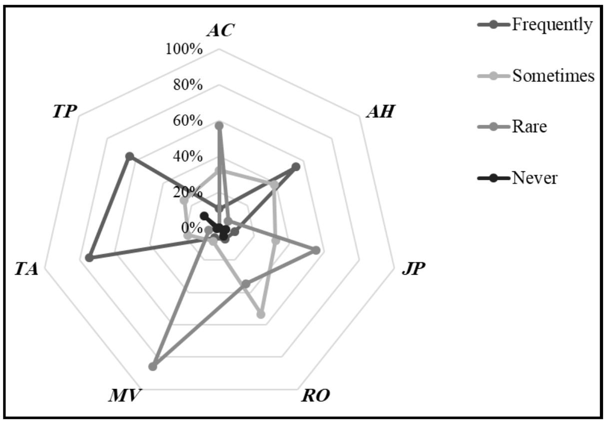

Fig. 4. Repartition of medicinal plants according to their consumption by goats; the answers to the question « what is the level of frequentation of goats to cited medicinal plants in pasture areas: frequently, sometimes, rare, or never? »

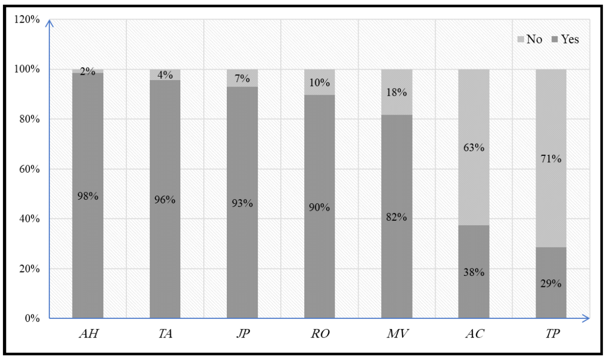

Fig. 5. Response to the question « do the cited medicinal plants influence on flavor and aroma of goat's milk: yes or no? »

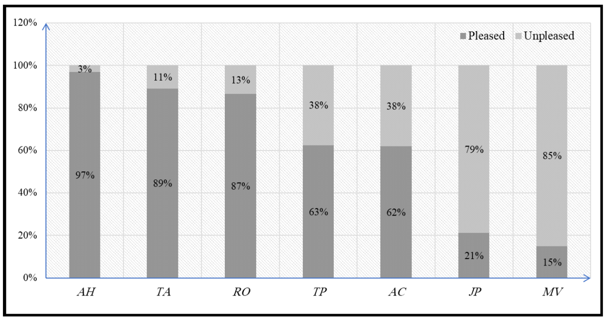

Fig. 6. Response to the question « do the medicinal plants consumed by goats give a pleasant or an unpleasant flavor and aroma? »

influent plants (figure 05). Interestingly, according to results of the survey, AH (97 %), TA (89 %), and RO (87 %) give goat milk a pleasant flavor and aroma, while MV (85 %), and JP (79 %) give an unpleasant flavor or aroma (figure 06).

Volatile compounds

The results obtained by HS-SPME-GC-MS analyses of the aromatic plants are presented in Table 4. The major volatile compounds found in the different herbs were α-pinene (40 %), β-thujone (38 %), trans-caryophyllene (31 %), β-myrcene (29 %), camphor (27 %), and α-thujone (18 %). Interestingly, β-myrcene, copaene and trans-caryophyllene were present in all plants.

Phenolic compounds

Major chemical classes and representative phenolic compounds detected in the plants are summarized in Table 5, expressed in $mg.g^{-1}$ of sample dry matter (DM). Total phenolic compound contents decreased in the following order: AC > TA > AH > RO > TP > MV > JP. The most abundant classes of phenolic compounds detected were flavonoids (3-51 mg/g DM), cinnamic acid derivatives (0.5-36 mg/g DM), benzoic acid derivatives (0.1-5.5 $mg.g^{-1}$ DM), and coumarines (0.1-2,4 mg/g DM). However, according to ANOVA test, the aromatic plants did not show any significant difference ($p < 0.05$) regarding their concentrations in chemical classes and representative phenolic compounds.

A total of 17 compounds were tentatively identified, among which seven cinnamic acid derivatives (neochlorogenic acid, chlorogenic acid, caffeic acid, 1,5-dicaffeoyl quinic acid, verbascoside, ferulic acid, and rosmarinic acid) and seven flavonoids (apigenine, hesperidine, rutine, isoquercitrine, kaempferol-3-O-rutinoside, quercitrine, and gallocatechine). The remaining peaks, about 104 unidentified compounds, belonged to the spectral families of benzoic acid derivatives (16 peaks),

TABLE 4
HS-SPME-GC/MS analysis of volatile compounds of selected herbs

Mean retention time (min)	Medicinal plants	AH	JP	MV	RO	TA	TP
	Monoterpenes						
9.43	α-pinene	-	39.6	10.6	11.6	6.2	1.7
10.61	Camphene	0.2	-	-	10.1	6	-
12.10	β-pinene	0.5	0.3	-	-	3.6	0.2
13.13	β-myrcene	1.7	6.9	6.9	5.7	29	8
14.76	Limonene	-	0.7	1.8	-	0.5	10
15.09	1,8-cineole	2	-	13.3	3.9	10.3	-
16.40	trans-ocimene	-	2.3	-	-	4.1	-
23.29	α-thujone	18.2	-	-	-	-	-
24.26	β-thujone	37.8	-	-	-	-	-
28.56	Camphor	18.8	-	25.3	27.1	12.7	-
29.64	Linalyl acetate	-	3.5	0.9	-	2.3	-
29.79	Linalool	-	2.6	3.6	-	2	1.3
34.76	Junipene	-	-	-	-	-	3.8
36.46	Geranyl acetate	-	-	-	-	3.4	-
39.15	***Borneol***	3.3	-	-	4.3	-	-
	Total monoterpenes	82.6	55.9	62.3	62.7	80.1	25
	Sesquiterpenes						
26.19	α-copaene	1.6	2.8	14.2	4	3.3	7.3
28.18	α-bourbonene	-	-	-	-	-	5.8
31.33	β-elemene	-	1.7	-	-	-	-
32.45	trans-caryophyllene	0.7	6.7	0.3	15.7	1.9	31.1
33.18	α-cubebene	-	0.2	1.1	-	0.6	8.3
34.32	α-humulene	-	4.6	-	6.7	-	-
35.13	Germacrene D	6.1	2	3.6	-	1	7.5
35.34	γ-cadinene	0.7	0.2	5.4	4.7	1.4	1.1
34.20	α-farnesene	-	-	-	-	-	6.7
35.36	Aromadendrene	0.5	-	3.1	-	0.2	4.1
35.75	Farnesol	-	4.9	3.3	0.1	1	-
36.21	δ-cadinene	-	5	4.4	1.3	2	-
36.92	α-muurolene	0.4	2.4	1.7	0.5	1.3	1.4
	Total sesquiterpenes	11.1	30.4	37	33.1	12.7	73.3
	Other volatile compounds	2.9	1.7	0.4	3.1	6.4	1

coumarines (9 peaks), cinnamic acid derivatives (48 peaks) and flavonoids (31 peaks). Some specific compounds were found in different amounts in more than one species. In particular, the cinnamic acid derivatives neochlorogenic acid and caffeic acid were found in five of the seven plant studied, and chlorogenic acid in four of them. As to flavonoids, luteoline-7-O-glucoside was found in both RO and TA.

DISCUSSION

During the survey, we tried to reach all age groups, but the majority belonged to the age group over 60 years (40 %). In fact, in the study area, interviews showed that elderly people possessed an extensive experience accumulated over time and a much greater knowledge of goat farming and native plants than younger people possess. Nonetheless, the other age groups also possessed valuable knowledge about aromatic plants. The majority of interviewed participants were men (73 %). According to Eddouks *et al.* (2017), several hypotheses may be involved to give an interpretation of such fact; however, the most probable reason is the cultural traditions of the region that do not allow women's work out of their family. Regarding education, more than half of those surveyed had a primary and illiterate level. In fact, during the survey, people with illiterate and primary levels had very relevant information to share, especially those selected as key informants.

According to Laouadi *et al.* (2018) and Ouchene-Khelifi *et al.* (2018), the goat population of Algeria comprises four major breeds: Elarbya, Makatia (Elbeldia), Kabyle, and M'zab. The Elarbya breed is the most dominant goat population. Also known as Arabia (i.e. Arabian goat), it is mainly located, from

TABLE 5
HPLC-DAD analysis of phenolic compounds of selected herbs (mg/g DM)

Mean retention time (min)	Phenolic compounds	AC	TA	RO	AH	TP	MV	JP
	Simple phenols							
13.14	Vanillyl alcohol	-	1.3	1.1	-	-	-	-
42.17	Ui catechol like*1	-	-	0.4	-	-	-	-
	Total simple phenols	-	1.3	1.5	-	-	-	-
	Benzoic acid derivatives							
11.19	Ui gallic acid-like	-	-	-	-	-	-	5.2
30.47	Syringic acid	-	-	-	-	0.3	-	-
	Other benzoic acid derivatives*2 (16 peaks)	1.3	0.1	0.8	0.2	0.4	1.6	0.4
	Total benzoic acid derivatives	1.3	0.1	0.8	0.2	0.8	1.6	5.6
	Cinnamic acid derivatives							
15.38	Neochlorogenic acid	0.2	-	0.1	0.4	0.1	0.4	-
17.17	Ui caffeic acid-like	-	-	0.4	-	0.1	1.8	-
23.29	Chlorogenic acid	13.5	0.4	-	11.2	-	0.1	-
27.87	Caffeic acid	-	0.1	0.2	0.2	0.2	0.4	-
35.90	1.5-dicaffeoyl quinic acid	-	-	-	-	-	2.8	-
42.31	Ui rosmarinic acid-like	-	-	-	-	7	4.5	-
42.71	Ui rosmarinc acid-like	-	-	-	-	5.4	-	-
43.08	Verbascoside	-	-	-	-	1.9	0.5	-
44.45	Ferulic acid	-	-	-	0.02	-	-	-
46.22	Ui caffeic acid-like	14.1	0.5	-	11.8	-	-	-
46.85	Ui caffeic acid-like	1.9	-	-	5.4	-	-	-
46.86	Ui p-coumaric acid-like	-	1.7	-	-	-	-	-
47.12	Rosmarinic acid	-	14.2	12.2	-	0.3	-	-
48.45	Ui caffeic acid-like	-	3.1	-	0.8	-	-	-
	Other cinnamic acid derivatives*3 (48 peaks)	5	5.9	2.5	4.6	4.3	1.21	0.5
	Total cinnamic acid derivatives	34.8	25.8	15.4	34.4	19.4	11.7	0.5
	Coumarines							
54.37	umbelliferone-like*4 (9 peaks)	2	-	-	2.4	-	-	0.1
	Flavonoids							
53.73	Apigenine	-	-	-	-	-	-	0.2
44.48	Luteoline-7-O-Glucoside	-	2.7	7.6	-	-	-	-
46.87	Ui apigenine-like	-	5.7	1.6	-	-	-	-
	Other flavones*5 (16 peaks)	-	5.6	7.7	1.9	1.8	0.5	0.8
	Total flavones	-	14	16.9	1.9	1.8	0.5	1
33.02	Ui taxifoline-like	-	4.1	-	-	-	-	-
45.23	Hesperidine	-	-	3.6	-	-	-	-
	Other flavanones*6 (7 peaks)	-	2.7	-	-	-	-	-
	Total flavanones	-	6.9	3.6	-	-	-	-
41.34	Ui myricetin-like	19.4	-	-	-	-	-	-
42.51	Rutine	14.5	-	-	-	-	-	-
43.47	Isoquercitrine	-	-	-	-	0.9	-	-
44.49	Kaempferol-3-O-rutinoside	0.4	-	-	-	-	-	-
44.62	Ui rutine-like	1.5	-	-	1.1	-	-	-
44.80	Ui myricetin-like	15.6	-	-	-	-	-	-
45.23	Quercitrine	-	-	-	-	0.2	-	-
45.66	Other flavonol*7 (4 peak)	-	-	-	0.6	-	-	-
	Total flavonols	51.5	-	-	1.8	1.2	-	-
	Flavanols							
13.85	Gallocatechine	-	-	-	-	-	-	0.6
	Other flavanols*8 (4 peaks)	-	0.4	-	-	-	-	2.8
	Total flavanols	-	0.4	-	-	-	-	3.4
	Total flavonoids	51.5	21.3	20.5	3.6	3	0.5	4.3
48.05	Ui	-	11.1	-	-	-	-	-
	Unclassified phenolic compounds	8.1	15.6	4.3	1.2	9.5	4.2	1
	Total phenolic compounds	97.7	64.1	42.5	41.8	32.6	17.5	11.4

Ui : unidentified phenolic compounds
*The unidentified peaks were classified into families according to their absorbance spectrum and quantified in equivalents of a standard molecule belonging to the same family: 1: catechol equivalent, 2 gallic or protocatechuic acid equivalent, 3: p-coumaric, caffeic or rosmarinic acid equivalent, 4: umbelliferone equivalent, 5: apigenine or luteoline equivalent, 6: taxifoline equivalent, 7: rutine or myricetine, equivalent 8: catechine equivalent.

east to west, between the Tell Atlas and the Saharan Atlas. Its milk production averaging 1.5 liters per day. Elbeldia is likely the result of crossing between Arabia and Cherkia and is located in the highlands and northern Algeria. Moreover, exotic breeds have been introduced in the early part of the twentieth century to improve the productivity of the Algerian goat livestock. The main exotic goat breeds in Algeria are Alpine (French Alps) and Saanen (Swiss Alps) widespread throughout the world.

The most cited herbs belonged to the Asteraceae and Lamiaceae botanical families, followed by Apiaceae, and Liliaceae. Lamiaceae and Asteraceae have been used in folk medicine for many years (Tsimogiannis & Oreopoulou, 2018). Moreover, several recent investigations undertaken in different regions demonstrate that Lamiaceae occupy a high ranking in the list of botanical families used for a medicinal purpose (Boudjelal *et al.,* 2013). In addition, most genera of Lamiaceae, Asteraceae, and Apiaceae are sources of terpenes (Gülpinar *et al.,* 2010), flavonoids and other phenolic compounds (Skendi *et al.,* 2017; Tsimogiannis & Oreopoulou, 2018), which was confirmed in the present study.

According to the results of the survey, the most abundant aromatic plant in the Aurès mountains is AH, a plant covering 3 million hectares of the Algerian arid and semi-arid regions. AH rich regions are often considered as the best fields used throughout the year, especially in bad seasons, namely summer and winter, where it constitutes important reserves (Nedjraoui, 2003). According to Al-Masri (2013), AH can withstand drought and moderate grazing pressure. In addition to being an important forage resource with a good forage value, AH contains essential oils with antiseptic, anthelmintic and antispasmodic properties (Baba Aissa, 2000), which explain its use in traditional medicine as well as animal feed. A recent study (A. Bouguerra, unpublished) showed that experimental goats did not refuse AH offered as supplement in their diet. To our knowledge, there is not much information on the effect of *Artemisia* species consumption on ruminant nutrition or on products' quality.

The goats in the study area consume the aromatic plants for two reasons: the goats consume the aromatic plants which are more abundant than the non-aromatic plants and the goats are selective for the aromatic plants which they please. The most favored ones were TA, TP, and AH. The other aromatic plants occurring in the rangelands such as JP, RO, and MV were little consumed, although JP and MV were among the most abundant plants. In agreement with the results of Elias and Tischew (2016) with goats in Central Germany, the factorial analysis of correspondence showed that there was no close relationship between the abundance of aromatic plants and their consumption by goats (Fig. 7). Goats avoided junipers when other palatable species were available, but tended to increase its consumption when exposed to this plant species for a long time. It is well known that JP contain terpenes that inhibit rumen microorganisms and decrease *in vitro* digestibility (Parissi *et al.,* 2016). Moreover, JP secondary metabolites may cause negative post-ingestive effects and decrease intake. Bitterness is the primary aversive taste influencing consumption of diets in ruminants. Many sesquiterpenes, alkaloids, flavonoids, and saponins are bitter secondary compounds, while tannins have astringent properties (Rogosic *et al.,* 2008).

The gathered information clearly indicated that the use of aromatic plants as feed for goats could influence the quality of goat's milk. According to the results of the survey, AH, TA, and RO give goat milk a pleasant flavor and aroma, while MV and JP give unpleasant flavors or aroma. Not only primary metabolites like proteins, lipids and glucides of plants, but also the secondary metabolites like phenolic compounds and terpenes have an important role on

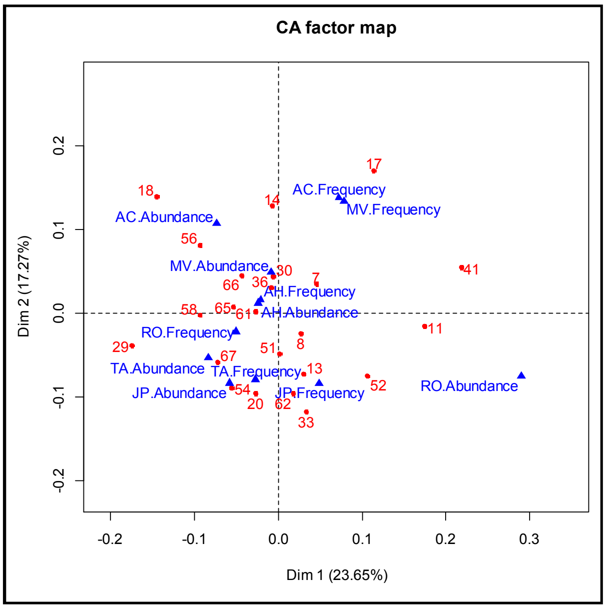

Fig. 7. CA factor map of medicinal plants Abundance/Frequency of consumption. *Numbers, 1-67 = farmers; Abundance = Abundance of medicinal plants in the Aurès mountains ; Frequency = the frequency of consumption of goats from medicinal plants; AC, AH, JP, MV, RO, TA, TP = medicinal plants; ex. AC.Abundance = the abundance of AC in the region.*

the quality of milk and milk products. In recent decades, several studies have confirmed the passage of phenolic compounds (Graulet *et al.,* 2012; Sharma *et al.,* 2019) and terpenes (Lejonklev *et al.,* 2013; Tornambé *et al.,* 2006) to ruminants products (milk). According to Boutoial *et al.* (2012, 2013), the supplementation of goat diet with rosemary and thyme affected the taste and the flavor of the resulting milk, probably related to the transfer of phenolic compounds and terpenes from the ingested plant to the milk.

The studied aromatic plants except TP had similar monoterpene proportions ($P<0.05$). Sesquiterpene proportions were lower, except for TP in which they were the major volatile compounds. The ANOVA test allowed us to classify the plants in three classes ($P<0.05$): TP containing the highest, JP, MV, and RO average proportions while AH and TA had the lowest sesquiterpenes proportion. This finding is in agreement with that of Zouaoui *et al.* (2020) who compared the same plant species collected one year later in dryland of Algeria (department of Biskra) and found that AC, TP and RO recorded the highest sesquiterpene proportions and AH and TA the lowest.

The major volatile compounds in AH were β-thujone (38 %), camphor (19 %), and α-thujone (18 %). AH also contained germacrene D (6 %) and 1,8-cineole (2 %), but in contrast to the other aromatic plants analysed, it contained no α-pinene. It is worth to note that α- and β-thujone were found in AH only. Barroso *et al.* (2012) identified fifty volatile compounds in AH growing in Algeria, with camphor (17-33 %), α-thujone (7-28 %), and chrysanthenone (4-19 %) as major volatile components. Similarly, β- and α-thujone were the major volatile compounds in the aerial parts of AH growing in the arid zone of Tunisia (Mighri *et al.,* 2010), and in AH growing in the Algerian dryland region of Biskra (Zouaoui *et al.,* 2020).

The major volatile compounds of JP were α-pinene (40 %), β-myrcene (7 %), and trans-caryophyllene (7 %). In addition, δ-cadinene (5 %), farnesol (5 %), and α-humulene (5 %) were also identified. Interestingly, α-terpinyl acetate and β-elemene were identified only in JP. However, Zouaoui *et al.* (2020) found that JP growing in Algerian dryland (Biskra) had a different composition, α-pinene (27.2 %), β-citronellol (6.1 %), and δ-3-carene being the major compounds.

Camphor (27 %) was the major volatile compound of RO, in the present study as well as in previous studies (Bramucci *et al.,* 2016; Gurbuz *et al.,* 2016). The aroma profile of RO also contained *trans*-caryophyllene (16 %), α-pinene (12 %), camphene (10 %), α-humulene (7 %) β-myrcene (6 %), and δ-cadinene (5 %). Ribeiro-santos *et al.* (2015) identified 1,8-cineole, α-pinene, camphor, myrcene, verbenone, bornyl acetate and cymene from RO.

The major volatiles compounds of TA were β-myrcene (29 %), camphor (13 %), 1,8-cineole (10 %), α-pinene (6 %), camphene (6 %), and geranyl acetate (3 %). Although, Naghdi Badi *et al.* (2004) observed a high chemical polymorphism in *Thymus* species, our results are in line with those reported by Zouaoui *et al.* (2020). Nevertheless, these authors also found linalyl acetate (9.1 %) in this plant while Ben El Hadj Ali *et al.* (2012) found thymol (7.2 %).

The main constituents identified of TP were trans-caryophyllene (31 %), limonene (10 %), germacrene D (8 %), farnesol (8 %), β-myrcene (8 %), and γ-cubebene (8 %). In the study by Zouaoui *et al.* (2020), α-guaiene (11.3 %) was the major volatile compound in TP, followed by *trans*-caryophyllene (9.5 %), γ-elemene (9.2 %). The qualitative and quantitative variability of plant secondary metabolite composition can be related to several factors like the stage of growth, the genetic pool, the state of plant material (dry & fresh), the geographical and environmental conditions including soil composition, climatic conditions with emphasis on stressful environmental conditions such as drought of semi-arid and arid zones, seasonal variations, and soils characteristics (Zouaoui *et al.,* 2020).

In our screening study, the botanical biodiversity and the high phenolic compounds content of aromatic plants of the Algerian Aurès mountains have been confirmed. AC, TA, AH, and RO contained the highest levels of phenolic compounds. AC was the plant with the highest concentration (100 mg/g DM) of phenolic compounds, flavonols being the major family (51.5 mg/gDM, 5 peaks) followed by cinnamic acid derivatives (34.8 mg/gDM, 15 peaks). Our finding is in agreement with those Bourgou *et al.* (2014) and Sebai *et al.* (2014) who found that flavonols were the major class of phenolic compounds of AC. However, these authors found mainly kaempferol, quercetin, and myricetin as flavonols, whereas in this work rutin was the major flavonol and, at a lower concentration, kaempferol-3-O-rutinoside (15 and 0.4 mg/g DM respectively). Chlorogenic acid has been identified as another major phenolic compound, in accordance with other studies on AC from Algeria (Djeridane *et al.,* 2006), from Tunisia (Sebai *et al.,* 2014), and from Spain (Melguizo-Melguizo *et al.,* 2014). Unlike Dib et al. (2017) who observed a high amount of flavones in AC, we did not find any flavones.

TA presented the second highest level of phenolic compounds. Cinnamic acid derivatives and flavones were the most abundant (26 and 14 mg/g DM, respectively) while simple phenols accounted for 1.3 mg/g DM. Rosmarinic acid (14 mg/g DM) was the major compound, followed by an unclassified compound (11 mg/g DM). To our knowledge, no data on TA phenolic compounds have been reported in the literature, but other species of *Thymus* have been studied. Rosmarinic acid is invariably the dominant compound in *Thymus vulgaris* (Achour *et al.,* 2017; Gavaric *et al.,* 2015; Pereira *et al.,* 2016). Roby *et al.* (2013) also found cinnamic acid derivatives as dominant phenolic compounds in *Thymus vulgaris* L. extract, since it constituted 28 % of the total extracted compounds followed by the two flavones: apigenin (8 %), and luteolin-7-O-rutinose (7 %).

Cinnamic acid derivatives were detected as the major family class (35.7 mg/g DM) of AH, the first one being the same unidentified caffeic acid derivative as in AC (11.8 mg/g DM), chlorogenic acid being the second one (11 mg/g DM), followed by another unidentified cinnamic acid derivative (5.4 mg/g DM). Neochlorogenic acid (0.4 mg/g DM), caffeic acid (0.2 mg/g DM), ferulic acid (0.02 mg/g DM), and eight unidentified cinnamic acid derivatives were also detected. On the other hand, AH was poor in flavonoids (less than 4 mg/g DM). In agreement with our results, chlorogenic acid has also been reported as the major phenolic compounds in AH from Morocco (Mouhajir *et al.,* 2001), from Algeria (Seddik *et al.,* 2010), and from Romania (Ivanescu *et al.,* 2010). In addition, these latter authors indicated the presence of chlorogenic acid in several *Artemisia* species (*A. absinthium* L., *A. annua* L., and *A. vulgaris* L.).

Flavones and cinnamic acid derivatives constituted the major phenolic compounds in RO (16.9 and 15.4 mg/g DM, respectively) while simple phenols accounted for 1.5 mg/g DM. The main identified phenolic compounds were rosmarinic acid (12.2 mg/g DM), luteoline-7-O-glucoside (7.6 mg/g DM), and hesperidine (3.6 mg/g DM). In addition, three unidentified peaks presenting a theophylline-like UV spectrum were not taken into account in table 5. In theophylline equivalents, these possible alkaloids could represent 5.3 mg/g DM. Our finding is in agreement with those Achour *et al.* (2017) and Amaral *et al.* (2013) who found that rosmarinic acid was the major phenolic compounds of rosemary (12.2 mg/g DM and 38.5 mg/g DW, respectively). Unlike Wojdylo *et al.* (2007), Amaral *et al.* (2013) and (Proestos & Komaitis, 2008), we did not find chlorogenic acid, luteolin or ferulic acid among the main phenolic compounds of RO. The composition of the phenolic compounds depends on the nature of genotypes, environment, harvesting season, dry processing, and storage conditions (Mishra *et al.,* 2018).

MV was among the species with the lowest concentrations of phenolic compounds (17.5 mg/g DM). The most abundant was an unidentified rosmarinic acid-like compound (4.5 mg/g DM). Dicaffeoyl quinic acid and an unidentified caffeic acid-like compound were also observed (2.7 and 1.8 mg/g DM). Several other cinnamic acid derivatives like neochlorogenic acid, chlorogenic acid, caffeic acid, verbascoside, and four unidentified cinnamic acid derivatives were present at lower concentrations. Boulila et al. (2015) detected caffeic acid, ferulic acid, 2-hydroxy cinnamic acid, rosmarinic acid, and *trans*-cinnamic acid as the main cinnamic acid derivatives in MV from Tunisia. However, unlike MV from Tunisia which contained some flavone derivatives like apigenin, luteolin, kaempferol, and quercetin (Boulila *et al.,* 2015), MV from Aurès mountains contained very few flavonoids. Boudjelal *et al.* (2012) have identified chlorogenic acid, luteolin-O-glucoside, luteolin-O-glucuronide, apigenin-O-glucuronide, apigenin-O-glucoside, and chrysoeriol-O-glucuronide in MV from Algeria.

Most of TP phenolic compounds were cinnamic acid derivatives exhibiting rosmarinic acid-like spectra for a total amount of 19.4 mg/g DM: three unidentified peaks (7, 5, and 2 mg/g DM), verbascoside (2 mg/g DM), and twelve other cinnamic acid derivatives present at low concentrations. Low levels of flavonoids were also present (3 mg/g DM, 4 peaks).

JP was the species with the lowest concentrations of phenolic compounds (11.42 mg/g DM). JP contained one major compound with a benzoic acid-derivative spectrum (5.4 mg/g DM) and small amounts of flavanols, flavones and cinnamic acid (3.4, 1, and 0.5 mg/g DM respectively). Phenolic contents of some *Juniperus* species have been reported in some literature. Taviano *et al.* (2013) identified apigenin, rutin in JP from Italy and Sahin Yaglioglu and Eser (2017) identified rutin (147 mg/g DW) in JP from Turkey.

Finally, TA and AH were both the most abundant plants in the Aurès mountains and the most grazed by goats. TA and AH were also the plants with the lowest sesquiterpenes to monoterpenes ratios (0.16 and 0.13 respectively), and were both rich in phenolic compounds. JP and MV had high sesquiterpenes to monoterpene ratios (0.53 and 0.59, respectively) and the lowest phenolic compounds' contents.

CONCLUSION

As a conclusion, the information gathered through this study confirms the importance of the use of aromatic plants in the Aurès mountains as feed for goats. Some of the aromatic plants identified in the survey have never been mentioned in the literature as ruminant feed. The most cited aromatic plants (with a higher Frequency of Citation (FC)) as goats' feed were TA, AH, RO, JP, AC, and MV. TA and AH were both the most abundant plants in the Aurès mountains and the most grazed by goats. Further work could be performed about the effects of these plants' secondary metabolites on ruminants and on their milk and meat products.

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