Nutritional value of pastoral species indigenous to Eastern Moroccan rangelands

Aboukhalid Kaoutar [1], Maâtougui Abdesselam [1], Chiboub Basma [1,2], Bahnini Mohamed [1,2] and Houmy Nadia [1]

Kaoutar.aboukhalid@inra.ma

1: Regional Center of Agricultural Research of Oujda, National Institute of Agricultural Research, Avenue Ennasr, BP 415 Rabat Principale, 10090 Rabat, Morocco

2: Laboratory Observatory of the Marchica Lagoon of Nador and Limiting Regions, Multidisciplinary Faculty of Nador, Mohamed 1st University, B.P 300, 60700 Nador, Morocco

Abstract

In Eastern Morocco, rangelands constitute an important feed resource for livestock. Therefore, determining the nutritional value of pastoral species is useful for efficient and sustainable management of these arid areas. This study aims to determine the chemical composition and nutritional value of 20 native pastoral species collected from different localities of Eastern Morocco. Nutritional composition of species was estimated by determining levels of dry matter, mineral matter, organic matter, total nitrogenous matter, neutral detergent fiber, acid detergent fiber and lignin detergent fiber. Results show that there were a highly significant differences among the species for all chemical compositions ($P<0.001$). *Asphodelus fistulosus*, *Peganum harmala*, *Suaeda vera*, *Atriplex halimus*, *Anabasis aphylla* and *Atriplex semibaccata*, were highly nutritious, containing high concentrations of total nitrogen matter (9.87 to 25.49% DM), digestible organic matter (up to 69.92 gr /kg DM), high energy value (up to 0.83 UF/Kg DM) and low lignin (2.80 to 9.50 % DM) and crude cellulose contents (7.70 to 19.19% DM). In contrast, *Stipa tenacissima, Launaea arborescens, Deverra scoparia, Salsola tetragona* and *Lygeum spartum* are less nutritious and show the lowest total nitrogen matter content (3.80 to 6.73% DM) and relatively high crude cellulose content (36.57 to 44.33 % DM). This study reveals that indigenous species could offer considerable potential as a fodder resource for livestock and constitute an alternative for the diversification of the introduced pastoral species in these degraded rangeland areas.

Keywords: Pastoral species; Rangelands; Nutritive value; Biodiversity; Eastern Morocco.

Valeur nutritive des principales espèces pastorales autochtones du Maroc oriental

Résumé

Dans les hauts plateaux steppiques du Maroc oriental, les terres de pâturages satisfont une partie importante des besoins alimentaires des ruminants. Ainsi, la détermination de la valeur nutritive des espèces pastorales est un préalable indispensable en vue de mettre en place des stratégies de gestion rationnelle et durable de ces écosystèmes. L'objectif de cette étude est de contribuer à une meilleure connaissance des valeurs nutritives de 20 espèces pastorales collectées dans différents pâturages du Maroc oriental. L'analyse de la valeur nutritive a porté sur la détermination des teneurs en matière sèche, matière minérale, matière organique, matière azotée totale, fibre de détergent neutre, fibre de détergent acide et fibre de détergent lignine. Les résultats obtenus montrent que les espèces sont différentes entre elles pour plusieurs constituants nutritifs (P<0.001). *Asphodelus fistulosus*, *Peganum harmala*, *Suaeda vera*, *Atriplex halimus*, *Anabasis aphylla* et *Atriplex semibaccata* recèlent des potentialités nutritionnelles eu égard à leur richesse en matières azotées totales (entre 9.87 et 25.49% MS), matière minérale (jusqu'à 22% de MS), matière organique digestible (jusqu'à 69.92 gr /kg MS), énergie (jusqu'à 0.83 UF/Kg MS) et leur faible teneur en lignine (entre 2.80et 9.50 % MS) et cellulose brute (entre 7.70 et 19.19 %). En revanche, *Stipa tenacissima, Launaea arborescens, Deverra scoparia, Salsola tetragona* et *Lygeum spartum* présentent les concentrations les plus importantes en cellulose brute (entre 36.57 et 44.33 % de la MS) et des teneurs relativement faibles en matières azotées totales (entre 3.80 et 6.73%) et sont, donc, de valeur nutritive médiocre. L'étude a révélé que les espèces pastorales autochtones pourraient offrir un potentiel considérable en tant que ressource fourragère, et constituent une alternative pour la diversification du matériel végétal utilisé dans tout programme de réhabilitation des pâturages dégradés.

Mots clés : Espèces pastorales ; Parcours ; Valeur nutritive ; Biodiversité ; Maroc oriental.

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القيمة الغذائية للأصناف الرعوية المحلية في شرق المغرب

أبوخالد كوثر، معتوكي عبد السلام، شيبوب بسمة، باحنيني محمد، هومي نادية

ملخص

في شرق المغرب، تلبي المراعي جزءا كبيرا من الاحتياجات الغذائية للماشية. لذلك، فإن تحديد القيمة الغذائية للأصناف الرعوية هو شرط أساسي لوضع استراتيجيات الإدارة الرشيدة والمستدامة لهذه المناطق القاحلة. أجريت هذه الدراسة لتحديد القيمة الغذائية لعشرين صنفا رعويًا محليًا تم جمعها من مواقع مختلفة في شرق المغرب. أظهرت النتائج التي ثم الحصول عليها أن الأصناف تختلف عن بعضها البعض بالنسبة للعديد من العناصر الغذائية. *Asphodelus fistulosus* و *Peganum Harmala* و *Suaeda vera* و *Atriplex halimus* و *Anabasis aphylla* و *Atriplex semibaccata* لها قيمة غذائية مهمة نظرًا لاحتوائها على تركيزات عالية من إجمالي المواد النيتروجينية (9.87 إلى 25.49٪ من المادة الجافة)، المواد العضوية القابلة للهضم (حتى 69.92 gr/kg من المادة الجافة)، طاقة عالية (تصل إلى 0.83 UF/Kg من المادة الجافة) ومحتوى منخفض من اللجنين (2.80 إلى 9.50٪ من المادة الجافة) و السليلوز الخام (7.70 إلى 19.19٪ من المادة الجافة). من ناحية اخرى، تمتلك *Stipa tenacissima* و *Launaea arborescens* و*Deverra scoparia* و *Salsola tetragona* و *Lygeum spartum* قيمة غذائية منخفضة و أقل محتوى من إجمالي المواد النيتروجينية (3.80 إلى 6.73٪ من المادة الجافة) ومحتوى عالي نسبيًا من السليلوز الخام (36.57 إلى44.33٪ من المادة الجافة). كشفت هذه الدراسة أن الأصناف المحلية يمكن أن توفر إمكانات كبيرة كمصدر علف للماشية وتشكل بديلاً هاما لتنويع الأصناف الرعوية التي يتم استعمالها لتأهيل المراعي المتدهورة.

الكلمات المفتاحية : الأصناف الرعوية، المراعي، القيمة الغذائية، التنوع البيولوجي، المغرب الشرقي

Introduction

Rangelands cover about 82% of the Moroccan arid lands and constitute natural ecosystems, used mainly for livestock production. These areas are an essential resource for maintaining biodiversity conservation and play a key role in domestic livestock feeding during grazing periods (Mahyou, 2010).

In Morocco, rangeland desertification is one of the most serious problems threatening the ecological environment and socio-economic development of semiarid and arid regions, in particular the Eastern Morocco, Pre-Sahara and Sahara, which are in an advanced state of degradation (Mahyou, 2010; Maâtougui *et al*., 2011). In these areas, degradation has reached such an alarming level that their capacity to provide sustainable livelihoods for pastoralists has been drastically reduced (Bechchari, 2001; Mahyou *et al*., 2005 ; Snaibi, 2020).

In the last decades, the carrying capacity of grazing lands and nutritional quality of the pastures, have been deteriorated due to the interaction between continuous over-grazing and recurrent droughts. The highly palatable and productive pastoral species have been replaced by unpalatable and low quality annual species. This resulted in a simultaneous loss of soil fertility and imbalance between livestock feed supply and demand. Indeed, dominant perennial species, such as alfa grass (*Stipa tenacissima* L.) and white wormwood (*Artemisia herba-alba* Asso), have declined and been replaced by invading species such as *Anabasis aphylla* L., *Noaea mucronata* Asch. & Schweinf., *Atractylis serratuloides* Sieb, *Peganum harmala* L. and *Thymelaea microphylla* Coss. and Durieu. In extreme situations, sand dunes expanded leading to desertification and a loss of biological diversity (Aidoud and Touffet, 1996 ; De Soyza *et al*., 1998 ; Wang *et al*., 2015).

Faced with this situation of continuous degradation, many efforts have been devoted to restore degraded rangelands and improve pastoral production in Morocco. For exemple, the study of germination characteristics of promising pastoral species, establishment of artificially planted vegetation in drylands and areas affected by desertification and enclosure treatments to restore degraded rangelands by restraining grazing and therefore contributing to the regeneration of vegetation, etc. (Maâtougui and Homrani., 2020 ; Homrani *et al*., 2020 ; Acherkouk *et al*., 2017 ; Hachmi *et al*., 2015 ; Homrani, 2015). However, *Atriplex nummularia* Lindl, which is an exotic plant, was systematically used in the majority of rangelands rehabilitation programs and little interest was given to indigenous species, in spite of their adaptation abilities to local biotopes (Maâtougui *et al*., 2011).

In the last years, awareness of the importance of diversification of the introduced pastoral species has received increasing attention, leading to the collection of major indigenous plant species from their native habitats and storing the seeds in gene banks to establish a reference collection for Morocco's arid and desert areas (Maâtougui *et al*., 2011). However, there is limited information about the nutritional value of these indigenous species. The main objective of this study is to determinate the nutritive value of some rangelands species indigenous to Eastern Morocco.

Experimental Section

The study area

The study area is located in the high plateaus of eastern Morocco. It is one of the most important pastoral zones in the country. The area is characterized by a semi-arid and arid Mediterranean climate in the north and an arid climate in the Saharan region to the south, with a rainfall average ranging from 100 to 360 mm from the south to the north (Benmostafa, 2002 ; Jorion, 2009). The annual average temperature is 19 °C, ranging from 4 °C in winter to 42.5 °C in summer (Le Houérou, 2001 ; Benmostafa, 2002). In summer, hot dry winds from the east and south are frequent and lead to strong sand storms. Potential evapotranspiration is about 1400 mm per year (Le Houérou, 1995). Soils are mainly silty to sandy loam in the north, with low organic matter content (less than 1%) (Benmostafa, 2002). In the south, most soils are sandy loam and are susceptible to wind erosion. The terrain is relatively flat, with an elevation of 1000 to 1400 m above sea level.

Pastoralism, based mainly on sheep, is the main livelihood and economic activity in these areas. The rangelands are characterized by species typical of land degradation such as *Noaea mucronata*, *Peganum harmala* and *Anabasis aphylla*.

Collection of samples of pastoral species

Samples of pastoral species have been collected from different areas in Eastern Morocco. For each sample, the location was recorded using a Global Positioning System (GPS). The spatial distribution of investigated species was illustrated on a geographic information system map using ArcGis 10.1 software (Figure 1).

The aerial parts were collected from 20 pastoral species belonging to 8 different families: Amaranthaceae (35%), Fabaceae (15%), Asteraceae (15%), Solanaceae (10%), Poaceae (10%), Liliaceae (5%), Apiaceae (5%) and Nitrariaceae (5%) (Table 1). The 20 studied pastoral species are among the most common in these drylands. The samples were harvested during the period between May and June 2021. Aerial parts (a mixture of leaves, tender stems and eventually flowers) were harvested from at least 5 randomly selected plants per species.

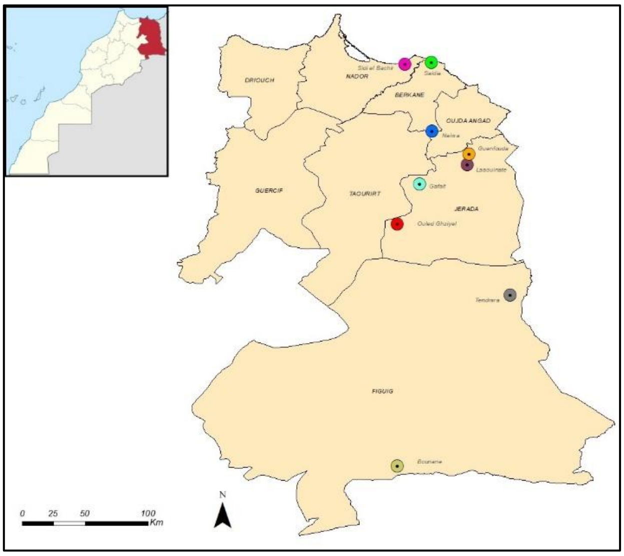

Figure 1. Geographical distribution of sampled pastoral species.

Table 1. The studied pastoral species, their sampling location and GPS coordinates.

Species	Family	Sampling Location	Latitude (N)	Longitude (W)	Altitude (m)
Atriplex semibaccata R. Br.	Amaranthaceae	Gafait	34°13'19.9''	2°23'24.4''	806
Atriplex halimus L.	Amaranthaceae	Saidia	35°5'26.06''	2°18'20.54''	1070
Anabasis aphylla L.	Amaranthaceae	Naima	34°36'59.35''	2°18'8.05''	232
Hammada articulata (Moq.) O. Bolòs & Vigo	Amaranthaceae	Bouânane	32°12'33.6''	2°32'55.3''	996
Noaea mucronata (Forssk.) Asch. & Schweinf	Amaranthaceae	Naima	34°36'59.35''	2°18'8.05''	232
Salsola tetragona Delile	Amaranthaceae	Tendrara	34°56'12.4''	2°00'55.8''	860
Suaeda vera Forssk. ex J.F.Gmel.	Amaranthaceae	Saidia	35°5'26.06''	2°18'20.54''	1070
Astragalus armatus Willd.	Fabaceae	Naima	34°36'59.35''	2°18'8.05''	232
Genista scorpius (L.) DC.	Fabaceae	Naima	34°36'59.35''	2°18'8.05''	232
Anthyllis cytisoides L.	Fabaceae	Sidi elbachir	35°4'44.21''	2°29'37.12''	1178
Launaea arborescens (Batt.) Murb.	Asteraceae	Bouânane	32°12'33.6''	2°32'55.3''	996
Artemisia herba-alba Asso	Asteraceae	Laâouinate	34°36'59.35''	2°18' 8.05''	1203
Atractylis serratuloides Sieber ex Cass.	Asteraceae	Naima	34°36'59.35''	2°18' 8.05''	232
Lycium intricatum Boiss.	Solanaceae	Saidia	35°5'26.06''	2°18'20.54''	1070
Withania frutescens (L.) Pauquy	Solanaceae	Sidi Elbachir	35°4'44.21''	2° 29'37.12''	1178
Stipa tenacissima L.	Poaceae	Guenfouda	34°21'49.0''	2°02'53.9''	832
Lygeum spartum L.	Poaceae	Bouâarfa	33°56'12.4''	2°00'55.8''	1276
Asphodelus fistulosus L.	Liliaceae	Naima	34°36'59.35''	2°18' 8.05''	232
Deverra scoparia Coss. & Durieu	Apiaceae	Bouânane	32°12'33.6''	2°32'55.3''	996
Peganum harmala L.	Nitrariaceae	Ouled Ghziyel	34°36'59.35''	2°18' 8.05''	1141

Physico-chemical analysis

Dry, mineral and organic matter

Collected samples were weighed (fresh weight) and dried at 55°C in a ventilated oven until reaching constant weight to obtain the dry weight (DM). Once dried, samples were milled with a sieve mesh size of 1 mm for analysis. The mineral content was obtained after calcination of the powders at 550 °C in a muffle furnace. The organic matter (OM) content is determined by the following formula: % OM = 100 - % MM.

Total nitrogenous matter content

The total nitrogen matter (TNM) was determined using the Kjeldahl method. The samples are mineralized with sulfuric acid (density: 1.84 g/cm3, purity 98%) and hydrogen peroxide in the presence of a catalyst. Organic nitrogen is converted to ammonia nitrogen (NH_4^+). The latter is displaced by 80 mL of 40% NaOH, vaporized in the form of ammonia (NH_3), and recovered in a solution of boric acid (4%) containing Tashiro indicator. Finally, the homogenate is titrated with a solution of sulfuric acid (0.1 N). Total nitrogen matter, reported on dry matter (DM) basis, was estimated by

multiplying the nitrogen level by the factor 6.25. All samples were analyzed in three replicates.

Analysis of parietal constituents

The parietal constituents were determined according to the analytical model of Van Soest et al. (1991). The NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber), and ADL (Lignin Detergent Fiber) values were expressed inclusive of residual ash. The content of crude cellulose was estimated using the difference between ADF and ADL. All samples were analyzed in three replicates.

Nutritive value

The prediction of nutritive value was carried out according to the following formulas (Demarquilly et Weiss, 1970):

- Digestible Organic matter:

DOM (gr /kg MS): = OM x dOM
dOM : Apparent digestibility coefficient of organic matter

- Indigestible Organic Matter:

IOM (gr/kg MS): = OM - DOM

- Energy:

UF = (2.36 DOM - 1.18 IOM) /1650 (UF/kg DM) (Breirem, 1939).

Statistical analysis

Analysis of variance (Student-Newman-Keuls test) was applied to test the significance of differences between species for all studied components. Analysis of data was performed in three replicates using the SPSS Software, with *p*-values < 0.05 as statistically significant and *p*-values< 0.001 as very significant.

Results

The chemical composition of the studied pastoral species is summarized in Table 2. DM results shows a highly significant variability among species (P<0.001). *Atractylis serratuloides*, *Stipa tenacissima*, *Salsola tetragona, Noaea mucronata* and *Astragalus armatus* recorded the highest value in DM, ranging from 72.18 to 78.22%, while *Asphodelus fistulosus* contained the lowest DM content (20.85%).

The analysis of mineral and organic matter showed a highly significant variability between species (P<0.001). *Atriplex semibaccata* showed the highest content of MM (24.36% DM) and the lowest level of OM (75.64% DM). On the other hand, *Genista* scorpius showed the lowest content in MM (3.76% DM) and the highest OM value (96.24% DM).

There was a wide variation in the TNM content of the studied species (P<0.001). The highest TNM values were observed in *Atriplex halimus*, *Atriplex semibacatta* and *Anabasis aphylla* (25.49% DM; 24.92% DM and 24.88% DM respectively), while the lowest value was detected in *Deverra scoparia* (2.80% DM) (Table 2; Figure 2).

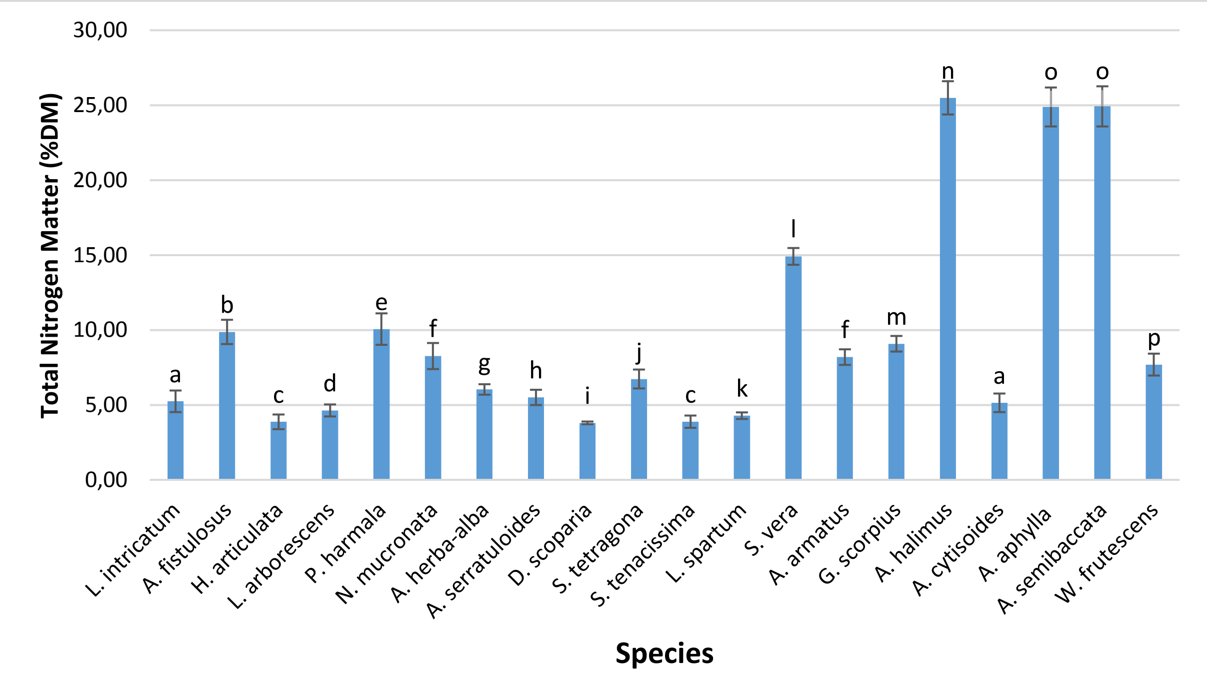

Figure 2. Total Nitrogen Matter of studied pastoral species. Different letters indicate a significant difference (p<0.05) between the values based on Student-Newman-Keuls test.

The results of NDF, ADF and ADL are shown in Table 2 and Figure 3. NDF concentration in DM varied drastically between species, ranging from 27.25% DM to 77.28% DM. The highest values were detected in *Salsola tetragona* (77.28 %DM), followed by *Lygeum spartum* (75.49% DM) and *Stipa tenacissima* (75.13% DM), while *Asphodelus fistulosus* showed the lowest NDF value (27.25% DM). We found a highly

significant difference (P<0.001) between the species in terms of lignocellulose fraction content. The highest ADF contents were observed in *Salsola tetragona* (54.70% DM), *Launaea arborescens* (52.88% DM) and *Stipa tenacissima* (52.54% DM). However, the lowest ADF content was recorded in *Peganum harmala* (14.03 %DM) and *Atriplex halimus* (15.79% DM). The lignin content showed a significant species-dependent variation (P<0.001). The highest contents were obtained for *Astragalus armatus* (20.56% DM) and *Lycium intricatum* (20.23 % DM). However, the lowest ADL contents were registered in *Peganum harmala* (2.82 % DM) and *Anabasis aphylla* (4.45 % DM).

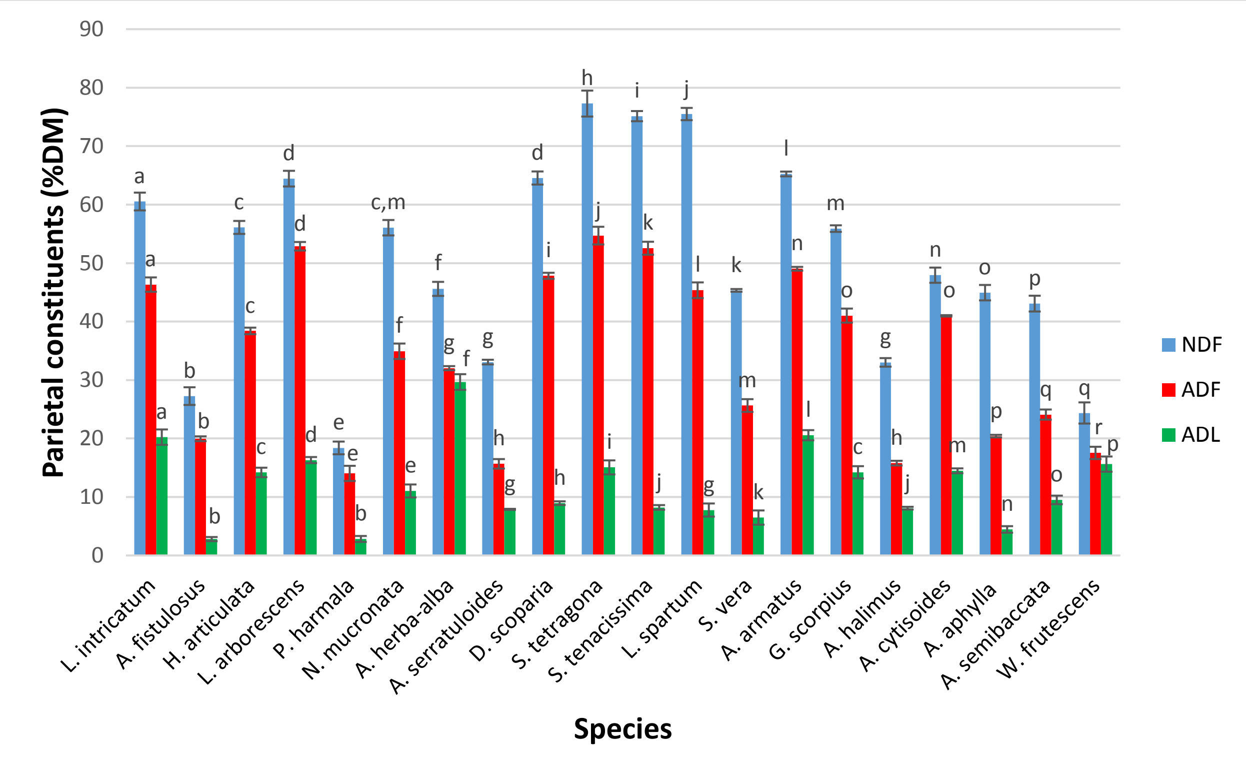

Figure 3. Parietal constituents (NDF, ADF and ADL) of studied pastoral species. Different letters indicate a significant difference (p<0.05) between the values based on Student-Newman-Keuls test.

Concerning crude cellulose contents, *Stipa tenacissima*, followed by *Lygeum spartum* and *Launaea arborescens* showed the highest values (44.33 %DM; 37.59% DM and 37.57 % DM respectively). Digestibility of Organic matter ranged from 55.71gr/kg DM (*Atriplex semibaccata*) to 69.92gr/kg DM (*Atriplex halimus*).

The energy value of studied ranges pastoral species varied from 0.64 to 0.83 UF/ kg DM and *Atriplex halimus* presents the highest value.

The energy value varied widely among the studied pastoral species (P<0.001), ranging from 0.64 to 0.83 UF/ kg DM and *Atriplex halimus* presents the highest value.

Table 2. Chemical composition of studied pastoral species. Values with different letters indicate a significant difference ($p<0.05$) between species components concentration.

Species	**DM (%)**	**MM (%DM)**	**OM (%DM)**	**TNM**	**NDF (%DM)**	**ADF (%DM)**	**ADL (%DM)**	**CC (%DM)**	**dMO**	**DOM (gr/kg DM)**	**IOM (gr/kg DM)**	**UF/Kg DM**
Lycium intricatum	47.90^{a}	13.43^{a}	86.57^{a}	5.24^{a}	60.53^{a}	46.32^{a}	20.23^{a}	26.09^{a}	0.70^{a}	60.94^{a}	25.63^{a}	0.69^{a}
Asphodelus fistulosus	20.85^{b}	6.75^{b}	93.25^{b}	9.87^{b}	27.25^{b}	19.96^{b}	2.80^{b}	17.16^{b}	0.72^{a}	66.79^{b}	26.46^{b}	0.77^{a}
Hammada articulata	56.13^{c}	9.27^{f,g}	90.73$^{f.g}$	3.57^{c}	56.10^{c}	38.40^{c}	14.20^{c}	24.20^{c}	0.70^{a}	63.84^{c}	26.89^{c}	0.72^{a}
Launaea arborescens	38.38^{d}	4.93^{c}	95.07^{c}	4.63^{d}	64.44^{d}	52.88^{d}	16.31^{d}	36.57^{d}	0.70^{a}	66.10^{d}	28.97^{d}	0.74^{a}
Peganum harmala	23.90^{e}	13.06^{d}	86.94^{d}	10.06^{e}	18.39^{e}	14.03^{e}	2.82^{b}	11.21^{e}	0.72^{a}	62.68^{e}	24.26^{e}	0.72^{a}
Noaea mucronata	75.46^{f}	20.63^{e}	79.36^{e}	8.26^{f}	56.05^{c,m}	34.92^{f}	11.03^{e}	23.89^{f}	0.71^{a}	56.28^{f}	23.08^{f}	0.64^{a}
Artemisia herba-alba	53.32^{g}	9.37^{f}	90.63^{f}	6.03^{g}	45.59^{f}	32.03^{g}	29.66^{f}	2.37^{g}	0.72^{a}	65.49^{g}	25.14^{g}	0.76^{a}
Atractylis serratuloides	78.22^{h}	9.13^{g}	90.86^{g}	5.50^{h}	33.07^{g}	15.67^{h}	7.88^{g}	7.79^{h}	0.72^{a}	65.23^{h}	25.63^{a}	0.75^{a}
Deverra scoparia	61.32^{i}	4.18^{h}	95.81^{h}	2.80^{i}	64.55^{d}	47.82^{i}	8.94^{h}	38.88^{i}	0.69^{a}	66.35^{i}	29.46^{h}	0.74^{a}
Salsola tetragona	76.40^{j}	6.75^{b}	93.25^{b}	6.73^{j}	77.28^{h}	54.70^{j}	15.06^{i}	39.64^{j}	0.70^{a}	64.86^{j}	28.39^{i}	0.72^{a}
Stipa tenacissima	76.42^{j}	6.34i	93.66^{i}	3.58^{c}	75.13^{i}	52.54^{k}	8.21^{j}	44.33^{k}	0.69^{a}	64.49^{k}	29.17^{j}	0.71^{a}
Lygeum spartum	59.10^{k}	7.34j	92.66^{j}	4.28^{k}	75.49^{j}	45.36^{l}	7.77^{g}	37.59^{l}	0.69^{a}	64.32^{l}	28.34^{i}	0.72^{a}
Suaeda vera	31.10^{l}	22.00^{k}	78.00^{k}	14.91^{l}	45.33^{k}	25.64^{m}	6.48^{k}	19.16^{m}	0.72^{a}	56.23^{f}	21.77^{k}	0.65^{a}
Astragalus armatus	72.18^{m}	10.68^{l}	89.32^{l}	8.19^{f}	65.24^{l}	49.03^{n}	20.56^{l}	28.47^{n}	0.71^{a}	63.03^{m}	26.29^{l}	0.71^{a}
Genista scorpius	63.25^{n}	3.76^{m}	96.24^{m}	9.08^{m}	55.90^{m}	41.02^{o}	14.22^{c}	26.80^{o}	0.71^{a}	68.14^{n}	28.10^{m}	0.77^{a}
Atriplex halimus	46.66^{o}	5.82^{n}	94.18^{n}	25.49^{n}	33.02^{g}	15.79^{h}	8.09^{j}	7.80^{h}	0.74^{a}	69.92^{o}	24.26^{e}	0.83^{a}
Anthyllis cytisoides	40.44^{p}	12.47^{o}	87.53^{o}	5.14^{a}	47.93^{n}	40.98^{o}	14.48^{m}	26.50^{p}	0.70^{a}	61.57^{p}	25.96^{n}	0.70^{a}
Anabasis aphylla	42.71^{q}	17.63^{p}	82.37^{p}	24.88^{o}	44.94^{o}	20.41^{p}	4.45^{n}	15.96^{q}	0.74^{a}	60.58^{q}	21.79^{k}	0.71^{a}
Atriplex semibaccata	49.31^{r}	24.36^{q}	75.64^{q}	24.92^{o}	43.07^{p}	24.09^{q}	9.50^{o}	14.59^{r}	0.74^{a}	55.71^{r}	19.93^{o}	0.65^{a}
Withania frutescens	33.00^{s}	14.30^{r}	85.70^{r}	7.69^{p}	24.37^{q}	17.54^{r}	15.62^{p}	1.92^{s}	0.72^{a}	62.13^{s}	23.57^{p}	0.72^{a}

Discussion

In the present study, we evaluated the nutritive value of 20 pastoral species indigenous to Eastern Morocco. The DM was relatively high for *Atractylis serratuloides*, *Stipa tenacissima*, *Salsola tetragona, Noaea mucronata* and *Astragalus armatus*. The high DM content in these species results in an increased needs of water for ruminants consuming these shrubs. Furthermore, high DM content is a limiting factor for the digestibility of these fodder resources (Arab *et al*., 2017). The content of DM can vary due to different factors such as age of plants, phenology and association with other species (Gallego-Castro *et al*., 2017; Moore and Jung, 2001).

Concerning MM content, significant differences have been found between the studied species, MM content was significantly higher (P<0.001) for *Atriplex semibaccata* and *Suaeda vera*, and conversely, the OM content is lower for these shrubs (P≤0.001). In accordance with these findings, several studies demonstrated the high mineral content of *Atriplex* species (Abd El-Rahman *et al*., 2009 ; Andueza *et al*., 2005 ; Abu-Zanat *et al*., 2009).

Atriplex halimus, *Atriplex semibaccata* and *Anabasis aphylla*s howed high TNM concentrations. TNM is the major limiting nutrient in the diets of livestock in drylands. Identifying alternative sources of TNM is essential to improve livestock nutrition and hence productivity in the pastoral drylands. Conversely, TNM was lower in the grasses *Stipa tenacissima* and *Lygeum spartum*. These results are consistent with the findings of Hussain and Durrani (2009), Mahmoud et al. (2017), and Julian et al. (2020) who emphasized that shrubs contained significantly greater TNM content than grasses. The differences in TNM content between pastoral species may be attributed to the inherent characteristics of each species ability to take up nutrients from the soil and store them in their tissues (Amiri *et al*., 2012 ; Njidda, 2010). Furthermore, the variability of TNM contents between species may result from differences in the accumulation of nitrogen in these plants during different growth periods.

In the present study, the TNM values detected for *Anabasis aphylla*, *Salsola tetragona*, *Atriplex halimus* are within range of the TNM values reported for similar species from Algeria, Tunisia and Iran (Rad *et al*., 2015 ; Chehma and Youcef, 2009 ; Selmi *et al*., 2013). However, the TNM value obtained for *Stipa tenacissima* and *Lygeum spartum* in our study was lower than that previously reported by Zirmi-Zembri and Kadi (2016). The difference in the TNM value could be attributed to varied stages of maturity of these species at sampling.

Cellulose, hemicellulose, and lignin are components of the cell wall, which differ in the degree of digestibility. While cellulose presents a low digestibility, hemicellulose is classified as a carbohydrate of moderate digestibility, and lignin is practically indigestible (Guerra *et al*., 2019). The NDF and ADF values of grass species were higher than those of other species, which agrees with findings reported by several authors (Hussain *et al*., 2009 ; Tufarelli *et al*., 2010 ; Elgersma and Soegaard, 2016). This is due to the fact that grasses have more stems and higher stem to leaf ratios, which results in greater concentrations of fibrous tissues compared to other pastoral species (Amiri *et al*., 2012). Ayeb et al. (2019) revealed that the mean NDF and ADF concentrations present in *Stipa tenacissima* collected in Southern Tunisia are 85.0 and 55.51% DM respectively, which was relatively greater than our values (75.13 and

52.54% DM respectively). This might be attributed to the different stages of maturity of plants at sampling, age or soil characteristics (León *et al*., 2012). Generally, higher fiber concentrations result in low nutritional feed value for sheep. This high content of NDF tends to limit the intake and degradability of DM and therefore, these grass species may offer poor quality forage compared to other species. Furthermore, the increase of fibers level in the fodders is negatively correlated with the digestibility of DM and NDF is the fraction that determines forage intake in ruminants, so that, at higher NDF values, lower feed intake occurs (Milad *et al*., 2011).

Concerning the NDF content of *Anthyllis cytisoides* (47.93% DM), *Stipa tenacissima* (75.13 %DM) and *Lygeum spartum* (75.49% DM), our values are close to those reported by Zirmi-Zembri and Kadi, (2016) and Robles and Bonza, (1993). Robles and Bonza, (1993) showed that *Anthyllis cytisoides* from Spain contained an NDF value of 54.8% of DM, higher than lignocellulosic fraction content (ADF = 33.6 % DM). Moreover, Zirmi-Zembri and Kadi (2016) reported that NDF values of *Stipa tenacissima* and *Lygeum spartum* collected in Algeria are 79.25 % DM and 80.1 % DM respectively. On the other hand, *Peganum harmala*, *Withania frutescens*, *Asphodelus fistulosus, Atriplex halimus* and *Atractylis serratuloides* displayed the lowest NDF values. Low fiber contents improve digestibility, intake and animal performance (Klopfenstein *et al*., 2001).

Unlike the NDF and ADF concentrations, the ADL values tended to be greater in shrubs than grasses. These findings are in line with those of Louhaichi *et al*., (2021) and Hussain and Durrani (2009) who detected higher lignin concentrations in shrubs compared to grasses.

Atriplex halimus presents the highest energy value. This can be explained by its high nutritional value (TNM=25.49 %DM ; dMO=0.74; DMO=69.92 gr/kg DM). It is worth noting that *Anthyllis cytisoides* showed a surprisingly low nutritive value, even though it is heavily consumed by livestock. However, some species like *Anabasis aphylla* and *Asphodelus fistulosus* showed high nutritional value in spite of they are little consumed by ruminants.

The moderate to high TNM and low fiber concentrations found in *Atriplex halimus*, *Atriplex semibaccata* and *Asphodelus fistulosus* suggest that these shrub species have a higher nutritive value than the highly fibrous *Salsola tetragona* and the grass species *Stipa tenacissima* and *Lygeum spartum*, suggesting that these species are promising for maintaining and enhancing livestock productivity. Therefore, *Atriplex halimus*, *Atriplex semibaccata* and *Asphodelus fistulosus* present suitable options for inclusion in livestock production systems to improve the nutrition of livestock. However, further research on domestication and multiplication of these pastoral species is essential due to the degree of vulnerability of these species in their natural ecosystems.

These wide variations on the nutritional proprieties of plant species could be explained by soil fertility (Milad *et al*., 2011; Wang *et al*., 1998), environmental conditions, age of plants, stage of growth and/or stem-leaf ratio differences of the collected species (Then *et al*., 2004 ; Saxena *et al*., 2012).

Conclusion

In Eastern Morocco, rangelands are characterized by unfavorable climatic conditions for the development of fodder plants, which are of great importance in supporting the basic nutritional requirements of ruminants in this region. In our study, the results indicate that the nutritional quality varies according to species. Indeed, *Atriplex halimus* and *Atriplex semibaccata* contained high amounts of TNM and DNM, *Suaeda vera* and *Atriplex semibaccata* are rich in MM, *Withania frutescens* and *Artemisia herba-alba* contained the lowest CC content. Therefore, it is possible to use mixed diets composed of different complementary species. These fodder resources present suitable options for inclusion in livestock production systems with an aim of improving the nutrition of livestock, while at the same time promoting sedentarisation of the pastoralists. Unfortunately, these species are undergoing a regressive evolution because of the interaction of several factors, mainly overgrazing, drought and rangeland cultivation. Therefore, it is recommended to reduce human disturbances through overgrazing or cultivation to preserve these valuable pastoral species in their natural habitats. Furthermore, it will be necessary to enforce policies that promote sustainable grazing management and ban cultivation in these fragile and disturbed ecosystems.

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