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ORIGINAL PAPER

A survey of chemical and nutritional characteristics of halophytes plants used by camels in Southern Tunisia

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Abstract The camel (*Camelus dromedarius*) is well adapted to the utilization of vegetation of low nutritional value in its natural habitat zone, thanks to its aptitude to vary food and to search plants that are rich in water content and that can make up for its nutritional deficits, particularly as concerns mineral elements. Therefore, a survey was carried out to determine camels pasture quality, dietary preference and to characterize the chemical characteristics and nutritional value of different halophytes plants in a region of Southern Tunisia during spring season. Laboratory analysis were conducted on fourteen vegetable species appertained to seven different botanical families: *Chenopodiaceae*, *Graminaceae*, *Tamaricaceae*, *Zygophyllaceae*, *Asteraceae*, *Frankeniaceae* and *Plumbaginaceae*. Data obtained indicate an high variability of nutritional content of halophytes plants preferred by camels, specially for dry matter, crude protein, fiber fractions, ash and mineral elements.

Keywords Camel · Pasture quality · Halophytes plants · Dietary preference · Tunisia

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Introduction

The national herd of dromedary camels (*Camelus dromedarius*) in Tunisia dropped from around 250,000 in 1956 to 70,000 in 1984; there are currently about 1.60 camels/km^2 in Tunisia (Gallacher and Hill 2006). In contrast, the population of goats, sheep and dairy cattle increased over the period from 1961 to 2004. However, only camels are allowed to wander freely throughout the desert to graze. The camel has specific anatomical and digestive characteristics which facilitate the valorisation of the great arid and desert regions, characterized by scarce resources and unfavourable to produce milk and meat and where other species can not compete.

In Tunisia, studies related to the ingestion and digestion in camel on rangelands are relatively recent (Abdouli et al. 1992; Khorchani et al. 1992; Hammadi 1996). Such research should be continued to develop appropriate methods for the estimation of the average intake and digestibility taken vegetation during the year to share periods of complementation for the safeguarding and/or improve the production of this species. In the other hand, this could encourage farmers that are responsible for rational and sustainable management of the rangelands to preserve this threatened area from desertification (Ben Arfa et al. 2004).

Camels take as much as 90% of their diet under semi-natural condition from browse plants. Some grazing may be required to maintain plant biodiversity and maximize biomass production (Oba et al. 2000; Zaady et al. 2001). Knowledge of the quality of feeds selected by the camel, its behavioural activities and feed preferences are important to the understanding of the forage-camel relationship (Dereje and Udén 2005). Effective management of grazing animals requires adequate knowledge not only on the influence of the animals on the pasture and environment but also on the influence of the pasture and environment on the animals (Kassilly 2002).

The impact of the camel on the range environment is dependent on its behaviour and the manner in which it utilised the available forage, hardly any study has addressed itself to camel behaviour on the Tunisian rangelands (Khorchani et al. 1992; Kassilly 2002). Little is known about the quality of the feeds selected, dietary preferences, and the behaviour of free ranging camels.

Therefore, the objective of this study was to increase knowledge of camels facilitate sustainable utilisation of arid and semi-arid eco-zones. The specific objectives were to generate information on dietary preferences of camel and to determine the nutritive characteristics of preferred plants.

Materials and methods

Study area

Samples of fourteen spontaneous vegetable species were collected during spring 2006 (March to June) from about 500 ha halophyte rangelands in Southern Tunisia. These species which include seven different botanical families are considered as the most appetite for the camel in one salt pasture usually used by the dromedary herd of the Arid Regions Institute of Medenine Tunisia (33°20′N and 10°29′E). This region is characterized by a mean altitude level of 116 m, a typical Mediterranean climate. The coldest month is December, with occasional freezing (down to -3°C) in January and February. The period between June and August is the warmest of the year, during which temperatures can reach as high as 48°C (in the shade). The temperature is affected by its proximity to the sea and altitude. The rainfall is characterized by low averages, high irregularity (both in time and space) and torrential downpours. It receives between 150 and 240 mm per year, with an average of thirty rainy days (Derouiche 1997). The prevailing winds affecting the plain are cool and humid eastern/north-eastern winds in winter and hot and dry south-eastern winds in summer.

Experimental animals

The study involved 25 adult camels which were selected from a herd of 70 animals and were appropriately marked for identification. The experimental animals were herded together with the rest of the herd. The whole herd of camels was released onto the pastures from about 07.00 to 19.00 h daily during the study period. At night, camels were kept in corrals made of thorny bushes and tree branches as protection from predators and did not have roofs. Camels were herded separately from other domestic ruminants and utilised communal rangeland for browsing/grazing.

Feeding behaviour study

For the preference and behavioural observations, a camel herd was escorted on foot while browsing and grazing. These observations were made during 10 days each in the spring season (March to June 2006). During this time, one camel was chosen each day randomly for a day-long data collection. Each camel was accompanied on foot and observed continuously and time spent on activities of browsing, walking, resting, ruminating and others (consisted of activities like playing, grooming, agonistic behaviour, rubbing against trees and wallowing in dust, etc.) were recorded. Plant preference data were compiled by randomly selecting a camel from the herd and, for 3 min, recording the time spent feeding on the preferred plants. The time period selected for the study was between 09.00 and 11.00 h and 13.00 and 15.00 h in the experimental period. Each camel was observed at a distance of 3–5 m to avoid interference with its activities. Time devoted to feeding on each plant was recorded, as were the names of the halophytes plants browsed. Two herdsmen and one plant specialist accompanied the researcher for identification of the preferred plants by their botanical names. During the experimental period, a total of fourteen halophytes plants were identified and collected.

Chemical analyses of forage samples

In order to characterize the plant parts selected by camels, samples of the 14 most preferred plants were hand plucked during each observation time. Samples were collected from different halophytes plants of the same species in the pasture to make the samples more representative. Before analyses the plant samples were dried for 48 h at 60°C and then dried samples were weighed and ground on a hammer-mill to pass through a 2 mm sieve and stored in plastic bags until analysed. The chemical analysis of plants were performed according to the methods of the Association of Official Analytical Chemists (AOAC 1990). The dry matter (DM) content of plants was determined by drying to constant weight at 105°C, and ash after heating at 550°C until a constant weight has been reached. In particular, were determined content of: crude protein (CP = 6.25 × nitrogen), crude fibre (CF), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) (Van Soest et al. 1991). Acid insoluble ash (AIA) was determined according to Van Keulen et al. (1977). On samples, after ashing, were determined the contents of calcium, magnesium, sodium and potassium by ionic chromatography. Iron, manganese, zinc and copper contents were obtained by atomic absorption spectrophotometry. Phosphorus content was determined by spectrophotometric method in ultraviolet (UV).

Results

Feeding behaviour study

The times spent by camels on the different activities expressed as a percentage of their total time at pasture was represented, on average, 60% of the time feeding, 23.4% walking, 2.6% ruminating, 6.2% idling and 7.8% on ‘other’ activities for the whole of the study period. It was observed that during their daily activities, the camels mostly walked or stood with their heads facing towards or and away from the sun. This orientation was irregularly maintained even during times when the animals were lying down. The least common position was the one with their sides towards the sun. The mechanisms used in food capture were mainly cutting and stripping. Leaves or shoots were removed from plants by being held firmly between the lower teeth and the upper palate with the help of the tongue and cutting was effected by the animals jerking their heads forwards. In other cases, an animal would trap a branch or shoot tightly in the mouth and with its head turned sideways leaves off the branch. Walking was slow and steady during normal feeding but was quicker on approaching water. Rumination and idling activities were observed to start after the animals had been on the pasture for some time. Before midday, the animals ruminated more while standing whereas afternoon rumination was mostly done with the animals lying down.

Plants species collected

The more represented families of halophytes plants in the pasture were *Chenopodiaceae*, with five botanical species: *Atriplex halimus* L., *Salicornia arabica* L., *Salsola tetragona* Del., *Salsola tetrandra* Forssk and *Suaeda mollis* (Desf.) Delile; the family of *Graminaceae*, with: *Aeluropus littoralis* (Gouan) Parl. and *Imperata cylindrica* L.; the family of *Tamaricaceae*: *Reaumuria vermiculata* L. and *Tamarix gallica* L.; the family of *Zygophyllaceae*: *Nitraria retusa* (Forssk) Asch and *Zygophyllum album* L. The remaining three botanical families were *Asteraceae*, *Frankeniaceae* and *Plumbaginaceae*, these represented by: *Artemisia campestris* L., *Frankenia thymifolia* Desf. and *Limoniastrum guyonianum*, respectively.

Chemical composition of forages

Chemical and nutritional composition of plants collected during experimental period are reported in Tables 1 and 2. As expected, the analysis of plot cover and chemical measurements showed clear differences between enclosures. The DM content of analyzed species varied between 13.5% for *Zygophyllum album* L. and 14.0% for *Salicornia arabica* L., until values of 45.3% for *Tamarix gallica* L. and 38.0% for *Limoniastrum guyonianum*. The CP contents of plants in spring season ranged from 4.1% for *Imperata cilindrica* L. and 6.5% for *Salsola tetrandra* Forssk, and 12.6% for *Salicornia arabica* L. and 16.5% *Suaeda mollis* (Desf.)

Table 1 Chemical composition (%) of halophytes plants on DM (mean ± standard deviation)

Chemical composition	Plant species[a]						
	AL	AC	AH	FT	IC	LG	NR
DM	32.5±3.0	35.6±3.4	30.2±3.0	40.1±4.00	31.2±3.1	38.0±3.8	23.2±2.3
CP	8.5±0.8	9.4±9.3	12.5±2.1	7.3±0.71	4.1±0.4	10.5±1.0	9.6±0.9
CF	28.8±2.6	16.9±1.6	20.3±2.0	16.5±1.64	38.5±3.8	9.5±0.9	6.7±0.6
EE	1.2±0.1	1.6±0.1	1.1±0.1	0.6±0.04	3.0±0.3	1.8±0.2	3.9±0.3
Ash	14.2±1.2	9.6±0.9	19.9±1.9	31.1±3.10	19.6±2.0	36.8±3.4	16.9±1.6
NDF	56.5±5.4	55.2±5.5	46.7±4.6	37.7±3.74	71.6±7.1	37.2±3.7	44.1±4.3
ADF	38.9±3.6	34.0±3.1	34.8±3.4	19.5±1.93	47.1±4.6	19.8±1.9	38.4±3.7
ADL	17.6±1.5	11.2±1.1	11.9±1.2	12.8±1.21	24.5±2.3	15.3±1.4	5.7±0.5
AIA	1.6±0.1	1.2±0.1	2.6±0.2	3.9±0.37	2.7±0.2	2.6±2.7	2.4±0.2
Hemicellulose	17.6±1.6	21.2±2.1	11.9±1.8	19.5±1.93	24.5±2.4	17.3±1.6	5.7±0.5
Cellulose	19.7±1.8	21.6±2.1	20.0±2.0	3.3±0.32	20.0±2.0	1.9±0.2	30.3±3.0

[a]AL- Aeluropus littoralis (Gouan) Parl; AC- Artemisia campestris L.; AH- Atriplex halimus L.; FT- Frankenia thymifolia Desf.; IC- Imperata cylindrica L.; LG- Limoniastrum guyonianum; NR- Nitraria retusa (Forssk) Asch.

Delile. NDF had an overall mean value of 44.0% and ranged from 23.8% for *Reaumuria vermiculata* L. to 71.6% for *Imperata cilindrica* L. The mean value for ADF content was 27.8% and varied between 15.7% for *Reaumuria vermiculata* L. to 47.1% for *Imperata cylindrica* L. ADL ranged from 5.7% for *Nitraria retusa* (Forssk) Asch to 24.5% in *Imperata cylindrica* L., with a mean value of 14.3%. Data obtained on EE content in plants showed a low mean values (2.0%), except for *Salsola tetragona* Del. (6.5%). The highest and lowest values of AIA were 3.9% in *Frankenia thymifolia* Desf. and 1.1% for *Salicornia arabica* L., respectively. The ash level of vegetation showed a high range of variability, between 14.16% for *Aeluropus littoralis* (Gouan) Parl. and 36.9% for *Limoniastrum guyonianum*, with mean value of 24.3%. Hemicellulose contents varied between 5.7% for *Nitraria retusa* (Forssk) Asch and 24.5% for *Imperata cylindrica* L., while mean values of cellulose ranged between 1.9% for *Limoniastrum guyonianum* to 30.3% for *Nitraria retusa* (Forssk) Asch.

Table 2 Chemical composition (%) of halophytes plants on DM (mean ± standard deviation)

Chemical composition	Plant species[a]						
	RV	SA	ST	STR	SM	TG	ZA
DM	20.4±2.0	14.0±1.4	20.9±2.1	29.0±2.9	14.7±1.4	45.3±4.5	13.5±1.3
CP	10.5±1.0	12.6±1.2	11.5±1.1	6.5±0.6	16.5±1.6	9.4±0.9	7.5±0.7
CF	11.2±1.1	16.6±1.6	17.1±1.7	18.1±1.7	23.0±2.2	28.2±2.7	17.8±1.8
EE	1.7±0.1	1.5±0.1	6.5±0.6	1.3±0.1	1.2±0.1	1.3±0.1	1.0±0.1
Ash	26.8±2.6	25.8±2.5	31.7±3.1	35.2±3.5	27.6±2.7	14.7±1.4	30.0±3.0
NDF	23.8±2.9	39.7±3.7	38.1±3.8	32.2±3.2	41.4±4.1	52.6±5.2	39.4±3.9
ADF	15.7±1.5	18.8±1.8	21.2±2.1	20.5±2.0	25.5±2.5	32.8±3.2	22.3±2.2
ADL	11.1±1.0	8.9±0.8	16.9±1.6	11.7±1.1	15.9±1.5	19.8±1.9	17.1±1.7
AIA	1.9±0.2	1.1±0.1	1.7±0.1	3.4±0.3	2.7±0.2	1.7±0.1	3.3±0.3
Hemicellulose	8.1±0.8	20.9±2.0	16.9±1.7	11.7±1.1	15.9±1.5	19.8±1.9	17.1±1.7
Cellulose	2.7±0.3	8.8±0.8	2.5±0.2	5.4±0.5	7.0±0.7	12.3±1.2	2.0±0.2

[a]RV- Reaumuria vermiculata L.; SA-Salicornia arabica L.; ST- Salsola tetragona Del.; STR- Salsola tetrandra Forssk.; SM- Suaeda mollis (Desf.) Delile.; TG- Tamarix gallica L.; ZA- Zygophyllum album L.

Table 3 Mineral composition of halophytes plants (mg/100 g DM)

Plant species[a]					Minerals				
	Calcium	Phosphorus	Copper	Zinc	Iron	Magnesium	Sodium	Potassium	Manganese
AL	1200	1752	3.6	9.1	<0.05	1053	1395	684	1.8
AC	1282	1105	2.0	1.5	18.8	129	307	848	3.1
AH	707	1129	1.7	1.7	0.05	906	4888	1134	<0.05
FT	5047	1834	2.7	1.7	38.9	804	1376	262	5.9
IC	222	1902	3.8	4.2	29.6	86	261	725	<0.05
LG	7185	1178	2.3	1.6	22.6	1445	2560	215	8.4
NR	1985	2064	2.2	1.5	13.5	1045	2434	492	2.9
RV	918	1457	2.5	2.1	10.7	331	7607	288	<0.05
SA	400	734	2.5	1.8	12.9	749	8710	390	<0.05
ST	1089	1176	2.6	0.9	0.05	62	9	628	<0.05
STR	937	1088	3.4	1.7	16.6	621	10	800	<0.05
SM	481	1488	2.9	2.7	<0.05	378	9237	678	<0.05
TG	1055	1056	1.7	1.7	<0.05	608	3181	330	<0.05
ZA	5116	1416	3.2	2.6	11.7	841	2768	500	<0.05
Mean	1973	1384	2.7	2.5	12.5	647	3196	570	1.6
s.e.m.[b]	578	103	0.2	0.5	3.3	110	859	70	0.7

[a] AL- Aeluropus littoralis (Gouan) Parl.; AC- Artemisia campestris L.; AH- Atriplex halimus L.; FT- Frankenia thymifolia Desf.; IC- Imperata cylindrica L.; LG- Limoniastrum guyonianum; NR- Nitraria retusa (Forssk) Asch.; RV- Reaumuria Vermiculata L.; SA-Salicornia arabica L.; ST- Salsola tetragona Del.; STR- Salsola tetrandra Forssk.; SM- Suaeda mollis (Desf.) Delile.; TG- Tamarix gallica L.; ZA- Zygophyllum album L.

[b] Standard error of mean

In the majority of species, calcium, phosphorus, magnesium, sodium and potassium contents are relatively high, while the micro-elements contents are low (Table 3). In particular, calcium and phosphorus contents (mg/100 g of DM) ranged from 222 for *Imperata cylindrica* L. to 7185 for *Limoniastrum guyonianum* and from 734 for *Salicornia arabica* L. to 2064 for *Nitraria retusa* (Forssk) Asch., respectively. Sodium and potassium values (mg/100 g of DM) ranged between 9 for *Salsola tetragona* Del. to 9237 for *Suaeda mollis* (Desf.) Delile and 215.45 for *Limoniastrum guyonianum* and 1134 for *Atriplex halimus* L., respectively.

Discussion

Feeding behaviour study

The percentage times spent on each activity by the camels are based on the assumption that the behaviour of the animal at the time of observation is representative of the interval time between observations (Kassilly 2002). Ideally, behaviour calculations should be based on continuous observations. However, Hull et al. (1960) established that results on major animal activities (feeding, ruminating, idling/resting) for continuous and intermittent observations are similar to observations made up to 30 min intervals for at least four animals. Because of the small time interval, coupled with the large number of observations in this study, the predictive validity of the results is high. Results from this study compare with those of other workers. The recorded feeding and walking times were similar to those reported for camels in Central Baringo, Kenya (Kassilly 2002). In Eastern Ethiopia, Dereje and Udén (2005) reported that browsing/grazing of camels was the dominant daytime activity (from 63% to 68%) followed by walking (26%), resting (6%), other activities such as urinating, defecating, rubbing against trees, dust bathing, sexual activities (2.5%) and ruminating (2%). The behaviour of camel registered during grazing was similar to those observed by Matias (1998) on dairy cows under tropical conditions.

Chemical composition and nutritional value of forages

Through data analysis reported in the Tables 1, 2, and 3, it clearly deduces the non-existence of a relationship between CP contents of the halophytes plants and its structural carbohydrates content expressed both of the parameters CF and NDF. This could demonstrate that the values of CP were not influenced by the plants' vegetative stage at mowing, with the vegetative development, while the CP contents decreases progressively the structural carbohydrates one increases, which means the existence of an inversely proportional relationship between these two nutritive components of the plants. The structural carbohydrates contents varies significantly within the different species object of our survey, showing values that fluctuates from 12–15% in *Reaumuria vermiculata* L. and *Tamarix gallica* L. to rather high values in *Imperata cylindrica* L., that shows a high ADL contents which reduces very much the use of the structural carbohydrates through the ruminal fermentation of camels. The values related to the lipid contents are low, without significant variations between the different species that constitutes camels' base fodder under pastures conditions in Tunisia.

Ash contents of the plants object of the survey is in general high, which highlights through the laboratory analyses values higher than 30% of DM (*Frankenia thymifolia* Desf.*, Limoniastrum guyonianum, Salsola tetragona* Del., *Salsola tetrandra* Forssk*, Zygophyllum album* L.). Such aspect, never found in plants species pastured by animals in Mediterranean countries, is specific to the territories constituting the natural habitats of camel. The major part of these plants are, precisely, adapted halophytes species, meaning to live under saline soil conditions which are physiologically arid with sodium chloride (NaCl) concentrations higher than 1%. These values are toxics for most of the high plants that tolerate just values lowers that 0.5–1%. Halophytes species require, instead, to develop, a NaCl concentration of at least equals or higher than 1–2%, with optimal values between 2 and 6%. The adaptation solutions expressed by these species can be summarised in mainly three models: accumulation of sodium chloride inside cells vacuum, resistance towards the entry of NaCl in the cells, and dilution of sodium chloride after its absorption (Wang et al. 2004). The first phenomenon is a characteristic of *Chenopodiaceae* (*Salicornia arabica* L.*, Salsola tetragona* Del., *Salsola tetrandra* Forssk*, Suaeda mollis* Desf. Delile), which are with succulent stems and leaves plants. The transpiring area is very limited and the accumulation of sodium chloride to high concentrations (10% of NaCl in the tissue of *Salicornia arabica* L) allows to obtain the high absorption tension useful to absorb water from the soil (Tobe et al. 2000).

Two aliphatic compounds, proline and betaine, have a major importance for this aim. As the proline is present in huge quantity in the xerophytes in general, that is in the plants adapted to arid climatic and soil conditions, or saline soils, this second group of halophytes shows that the adaptation to the salty environments is a phenomenon derived directly from the general capacity of adaptation to a permanent water stress (Ashraf and Foolad 2007). A third group of halophytes is made by those plants that, though absorbing salts, do not accumulate them but eliminate them through numerous secretory cells of the stem and leaves (Glenn and Brown 1999). *Limoniastrum guyonianum* belongs to this group from which species are not only part of littoral saline soils but also those continentals, corresponding to a lot of deserts and steppes. The particular abundance of minerals, and especially sodium, in the plants that constitute the base fodder of the camels at pasture is suitable to the survival of this species under an environment so hostile such as the desert.

The contents of crude protein, crude lipid, structural carbohydrate and nitrogen-free extract indicate nutritional characteristics almost equal to those found in the essence of the typical pastures of the Mediterranean region and compatible with the digestive physiology of the ruminant species. The content of minerals of the botanic species pastured by the camels in the Southern Tunisia, if it supports on one hand the survival of this species in the desert, on the other hand it involves an trace elements deficiency that should be compensated by an adequate food integration.

Conclusions

In conclusion, a better knowledge of the food consumed by camels in pasture would allow the formulation of suitable rationing plans for this species within the different physiologic situations and mainly would give to us the possibility to integrate conveniently the ration so that to reduce the impacts of eventual deficiencies that can represent a limiting factor to the production performance of these animals, which in North Africa constitute a fundamental subsidy to the human activity.

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