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Nutritive Evaluation of Two *Acacia* Populations in Southwestern Saudi Arabia.

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Abstract: Shoots of *Acacia tortilis* subsp. *tortilis* (Forssk.) Hayne *and Acacia ehrenbergiana* Hayne were collected from four locations (Abha, Jizan, Najran and Farasan Islands) of the southwestern region of Saudi Arabia and analyzed for *in vitro* total digestible nutrients, nutritive value, gross energy and seasonal nutrient concentrations in order to evaluate their usage as local forage. Pronounced differences were recorded between the two species between all estimated variables. The average total digestible nutrient (TDN) of *Acacia tortilis* was 64.8 % and that of *Acacia ehrenbergiana* was 68.4 % of the dry matter. Average digestible crude protein (DCP) of *Acacia tortilis* was 3.4 % and that of *Acacia ehrenbergiana* was 4.6 % of the dry matter. Average gross energy (GE) of *Acacia tortilis* was 2.982 kcal kg^{-1} and that of *Acacia ehrenbergiana* was 4.268 kcal kg^{-1} of the dry matter. *Acacia tortilis* had lower in crude protein (CP) (6.2 %), neutral detergent fiber (NDF) (25.6 %) and total carbohydrates (TC) (15.6 %) than *Acacia ehrenbergiana* while *Acacia ehrenbergiana* had lower crude fiber (CF) (35.2 %) and ether extract (EE) (2.3 %). On the basis of digestibility, fiber content, protein, ash and forage quality were the highest in the spring. Winter forage samples were of a higher quality than those of summer samples. Total carbohydrates content was common throughout the year. The obtained results proved that the nutrient status of *Acacia ehrenbergiana* as good quality forage, and *Acacia tortilis* as fair quality forage with respect to the net energy estimate throughout the year.

Key words: *Acacia* species; total digestible nutrients; nutritive values; gross energy; Saudi Arabia.

INTRODUCTION

The use of browse species as fodder for ruminant is increasingly becoming important in many parts of the tropics. Generally, tree fodder is richer in crude protein (CP), minerals and digestible nutrients than grass fodder [45]. The use of tree legume fodder as supplement has improved intake, digestibility and animal performance [34]. Several studies have evaluated the nutritive value, productivity and biomass of range plants as well as the effect of grazing on species diversity, abundance and soil degradation in the rangelands of Saudi Arabia [5,9,7,39,11]. [12] indicated that over 30% of the range land in Arab Gulf countries is in depleted conditions due to large numbers of livestock, over grazing, destructive gathering of wood and dry farming.

Nutrient contents (protein, carbohydrates, minerals and vitamins) and metabolisable energy (ME) change in relation to season [44], stage of growth [21], time of day [30], soil fertility or fertilizer application rates particularly nitrogen [37] and probably soil moisture status. Thus, an awareness of the factors influencing nutrient content of forage is required to allow more efficient supplementation of animals.

Acacia trees dominate in many parts of the arid and semi arid areas of Sub-Saharan Africa, and have multiple uses. They provide food, medicine, fodder aside from being resistant to diseases and the harsh climatic conditions [29]. The presence of phenolic compounds in *Acacia* species has a negative effect on their nutritional value and also on their intake by livestock [16]. Tannins have been attributed to be one of the major causes of their limited use as livestock fodder [32]. Generally, tannins in fodder tree are known to have a negative effect on intake and digestibility [28]. Studies on some acacias have shown them to have either a positive [13] or a negative effect [16] on animal performance. This variable effect could be attributed to the type of species, season and nutritive value.

The main objective of this study was to assess the nutritive value of two selected species of acacia (*Acacia tortilis and Acacia ehrenbergiana*) naturally growing in four locations (Abha, Jizan, Najran and Farasan Islands) of the southwestern region of Saudi Arabia. Samples collected of these two species were analyzed for *in vitro* total digestible nutrients, nutritive value, gross energy and seasonal nutrient concentrations in order to evaluate their locally usage as forage. The seasonal trends in the chemical composition of the species were used to identify periods of maximum and minimum nutritional quality.

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The Study Area: The southwestern part of Saudi Arabia is a unique area due to its environment and plant life. It belongs to the greater Afro-Arabian shield, which is part of the Precambrian crystalline plate. [10], geomorphologically, the southwestern part of Saudi Arabia is divided into three main units: (a) mountains; E1-Sarwat mountains (Abha), (b) plains; 'Tihamah' coastal plains, including those between Najran and Jizan and (c) islands; including those between Jizan and Farasan Islands (Fig. 1). Mountains on the northwestern sides are generally discontinuous, less rugged and much drier. The east facing slopes decent gradually and end in a high plateau. On the western side, the mountains fall in a series of dramatic escarpments and finally merge with the Tihama coastal plain while the eastern sides slope more or less gradually towards the interior parts of the country. Tihama lies between the Red Sea and the escarpments. It is narrow in the northwestern side and wider in the southwestern side. Ecologically, [18], distinguished five ecosystems within the Tihama coastal plains namely: shore-line, sand formations, salt marshes, wadis and rocky hills. Farasan Islands, lies in the southern part of Red Sea, about 40 km away from the Jizan coast and attains a width of approximately 120 km in SE to NW direction. The altitude of these islands ranges from 20 to 70 m. The entire region is an uplifted coral reef, and is composed, mainly, of fossil, coral-surfaces along wadis and runnels and eroded coral cliffs or coral sands along coastal regions. However, soil formations like aeolian and alluvial soil deposits can also be seen in some areas such as in protected bays, sandy shores [15].

Climate: Environmental setting of the study area is reported by [20]. The climate of the southwestern region is generally arid to hyper-arid. It is influenced by Saudi Arabia's unique topography; mountains in the west bordering the Red Sea and desert land in the interior (Najran) eastwards. The sun-rays, as in other parts of Saudi Arabia, are intense and seldom diffused by clouds. The mountains on the western side, especially the Asir Mountains are characterized by cool climate, high precipitation and high humidity. The area is under the influence of the prevailing southwesterly winds during most of the year. These winds primarily originate in Africa and along the Arabian Sea and then pass over the Red Sea before reaching the Asir highlands. In general, the climatic conditions in Abha area is characterized by cool rainy summers and cooler, rainy and foggy winters. Abha had the highest value of annual rainfall (524.9 mm year^{-1}), while Najran was approximately rainless and had the lowest relative humidity (3.1 %). Abha had the lowest value of the mean air temperature (16.3° C), while Jizan and Najran had the highest values (32.5° C and 35.5° C, respectively) (Table 1).

MATERIALS AND METHODS

Forty permanent stands were selected in the study area to represent the four locations in the southwestern Saudi Arabia: (Abha (lat. 18° 13' N 42° 36' E), Jizan (lat. 16° 54' N, 42 ° 33' E), Najran (lat. 16° 58' N, 42° 43' E) and Farasan Islands, Red Sea ((lat. (16^0 20`-17$^0$ 20` N, 41^0 24`-42$^0$ 26` E) (Fig. 1). The selected stands for sampling of both species represented a wide range of environmental conditions. Each location was represented by ten stands. Three representative trees of each species in each stand were selected for sampling. Samplings were carried out in spring, summer, autumn and winter of 2006. A composite sample were collected from the shoots of each tree from stands of the study area, cleaned and dried at 65ºC, powdered in a grinding mill and kept in a small paper bags ready for analysis.

Na, K and Ca were analyzed using flame photometer, Mg by atomic absorption, and P and N by spectrophotometer. Ash content was estimated by ignition at 500 ºC for about 2 hours. Ether extract (crude fat) was estimated by Soxhlet extraction method [8]. Total carbohydrates were calculated following [29]: NFE (% in DM) = 100 – (CP + CF + Fat + Ash), where NFE: Nitrogen free extract (mainly carbohydrates). Crude protein was calculated following [35]**:** CP (% in DM) = Total nitrogen (% in DM) × 6.25. Digestible crude protein (DCP) was calculated according to the equation of [17]: DCP (% in DM) = 0.929 CP - 3.52, where CP = crude protein, this equation is only valid in case of nitrogen concentration from 0.6 - 3% (or CP = 3.81%). Total digestible nutrients (TDN) were estimated according to the equation applied by [4]: TDN (in % DM) = 0.62 (100 + 1.25 EE) – CP 0.72, where EE is % of ether extract, and CP is percentage of crude proteins. Nutritive value (NV) was calculated following [4]: NV (% in DM) = TDN/CP. Gross energy (GE) was calculated following [31]: GE (kcal g/DM) = CAR (4.15) + CP (5.65) + CF (4.25) + EE (9.0), where CAR = carbohydrates content in g/DM. The studied species were evaluated as forage plants following [14].

Data were analysed using a factorial analysis model. A simple linear correlation coefficient was calculated between the concentration of different constituents, and between the TDN and nutritive values. All applied statistical analyses was according to the Stat-ITCF program [22].

RESULTS AND DISCUSSION

The general trend of nutrient variation among both species is *Acacia ehernbergiana* > *Acacia tortilis*. Exception, are EE, CF and Ash (*Acacia tortilis* > *Acacia ehernbergiana*). Factorial analysis of variation in contents of *Acacia tortilis* and *Acacia* *ehernbergiana* indicated that the interaction between location and species is highly significant ($P \leq 0.001$) for most of the estimated variables, while the interaction between the season and species is significant ($P \leq 0.01$) regarding Mg, CP and TC. On the other hand, the interaction between the location, season and species is highly significant ($P \leq 0.001$) for most of the estimated variables (Table 3). For both species the correlation coefficient between the P and CP, EE and Ash, P and NDF and CF and CF and NDF are significant negative (Table 4). Meanwhile, there is a moderate positive correlation between the following pairs: P-CF, EE-NDF and EE-CF for *Acacia ehernbergiana*.

Acacia ehernbergiana in the four locations had the highest concentration of Na, K, Mg, Ca and P. On the other hand, *Acacia tortilis* had the lowest concentration of Na, Ca and P in location 3, and K and Mg in location 1 (Fig. 2). *Acacia ehernbergiana* had the highest concentration of CP (10.1 %), NDF (33.2 %) and TC (22.8 %) in location 1 and 3 (Fig 3), while *Acacia tortilis* had the highest concentration of EE (3.5 %), CF (38.6 %) and Ash (15.1 %) in the same locations. On the other hand, *Acacia tortilis* had the lowest of CP (5.1 %), Ash (11.2 %), CF (32.4 %) and TC (13.5 %) in locations 2 and 4, while *Acacia ehernbergiana* had the lowest of EE (2.1 %) in location 3.

In spring, *Acacia ehernbergiana* had the highest concentration of all elements, except the Mg in winter. On the other hand, *Acacia tortilis* at autumn had the lowest concentration of all element contents, except the Ca in winter (Fig. 4). In winter, *Acacia ehernbergiana* had the highest concentration of CP (9.1 %), NDF (33.2 %) and TC (22.4 %), while *Acacia tortilis* had the highest concentrations of EE (3.5 %) in spring, CF (40.1 %) and Ash (15.9 %) in summer. In autumn, *Acacia ehernbergiana* had the lowest of EE (2.1 %), CF (32.1 %) and Ash (11.4 %) (Fig. 5).

In winter, *Acacia ehernbergiana* had the highest value of GE (4.268 kcal kg^{-1}) in location 4, while *Acacia tortilis* had the lowest value GE (2.986 kcal kg^{-1}) in location 4 in summer (Fig. 6). The relationship between the total digestible nutrients (TDN) and nutritive values of *Acacia tortilis* and *Acacia ehernbergiana* (Fig. 7) indicated a nearly linear relationship for both species ($r = 0.087$ and $r = 0.852$, respectively).

Discussion: The chemical compositions of the two species (*Acacia tortilis* and *Acacia ehernbergiana*) were consistent with what has been reported in other works with *Acacia* [38]. The comparison between the nutrient contents of the two species of the present study and that vegetation in the other related studies may evaluate their nutrient status as forage. [33] reports that the minimum proteins in the animal diet ranges between 6 and 12 % depending on the animal type. The present study indicates that the protein content of most sampled species approaches the minimal requirements for the animal diet. Low protein levels efficiency is associated with a relatively low voluntary feed consumption with protein deficient diet. The metabolism of the rumen micro-biota may be depressed by a deficiency in rumen nitrogen. This limitation will retard the rate of removal of organic matter from the rumen which, in turn, may reduce intake. Low protein levels will affect the wool growth, which is determined by protein absorbed in the intestine, which in turn lends on ingested nitrogen sources [19].

The present study indicates that the evaluated two *Acacia* species have relatively low P, K, Na and Fe; but high Ca, Mg and Mn comparing with many of the Egyptian Mediterranean range plants [19], and with the range plants in central Arabia as reported by [41] (Table 5). Information about minerals in browse species, particularly about microelement is very limited. However, the values obtained in this study were consistent with the wide range of data reported on *Acacia seyal, Acacia nubica* and *Acacia tortilis* [2] and those of *Acacia rigidula* and *Acacia farnesiana* [36]. Low values of phosphorus were similar to those of *Acacia aneura* [6]. Similarly, [45] reported low values of phosphorus for most of the tree legume forages. Factors such as soil, climate, stage of maturity and season contribute to variations in the concentration of minerals in forages ([29,43].

It is of interest to compare between the nutrient contents of the individual species in the present study and some of the related studies. There are differences in some constituents for the same species. [19] reported low values of carbohydrate and K for *Haloxylon salicornicum*. On the other hand, the study of [29] in the tropical West Africa, reported higher levels of proteins and crude fibers in three out of four compared species (*Acacia ehrenbergiana, Acacia seyal* and *Ziziphus spina-christi*). These differences may be related to the effect of variation in certain environmental factors in the study area, and/or genetically variation of the same species (e.g. different ecotypes, varieties or sub-species).

Comparing with the forage species currently used for pasture, the two study *Acacia* species contain less crude protein than *Bassia scoparia* (L) A. Scott. syn. *Kochia scoparia* (L) Schrad. (8.9 %), *Panicum miliaceum* (L) (13.1 %) and *Medicago sativa* (L) (20.3 %) [46]. The shortage in the nutrition status of the forage may be attributed mainly to the high stocking rate. If the stocking rate in the area is lower than that used in the calculation, most of the animal $^{-1}$.

Table 1: Long-term averages of some meteorological records (1980-1995) for four locations distributed in the study area [20].

	Location			
Climatic factor	Abha	Jizan	Najran	Farasan Islands
Max. air temp. (°C)	25.6	40.5	47.3	40.5
Min.air temp. (°C)	9.3	17.4	23.6	15.5
Mean air temp. (°C)	16.3	32.5	35.5	29.3
Relative humidity (%)	70.1	71.9	44.9	76.4
Evaporation (mm day^{-1})	6.8	8.1	3.1	7.8
Rainfall (mm $year^{-1}$)	524.9	99.4	33.6	56.7

Table 2: Forage quality according to [14].

Nutritional ratio *FU/kg	Digestible protein (%)	Net energy(MJ/kg)	Forage quality
< 55	< 2.5	< 3.10	Poor
55 - 68	2.5 - 3.4	3.10 - 3.45	Fair
68 - 88	3.4 - 5.3	3.45 - 4.15	Good
> 88	> 5.3	> 4.15	Excellent

*FU: food unit and one FU = 6.9 MJ = 1650 kcal

Table 3: Variation in the mean content of different nutrients in the shoots of *Acacia tortilis* and *Acacia ehrenbergiana*. F-LXS = F-value of interaction between location and species. F-LXSNXS = F-value of interaction between location, season and species. CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; CF = crude fiber; TC = total carbohydrates. *** P ≤ 001; ** P ≤ 0.01; * P ≤ 0.05; ns = not significant (P > 0.05).

Variable	Na	K	Ca	Mg	P	CP	EE	NDF	CF	ASH	TC
					%						
Species											
A. tortilis	1.755	1.28	0.71	1.445	0.365	6.22	2.98	25.56	37.58	11.85	15.63
S.D	0.27	0.01	0	0.01	0.01	0.11	0.03	0.1	0	0.05	0
A. ehrenbergiana	2.195	1.38	1.165	1.575	0.4	8.45	2.255	29.7	35.22	12.78	20.86
S.D	0.04	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.08	0.02	0.03
F-value	2.9*	ns	ns	ns	2.6**	ns	ns	17.85***	11.7***	ns	16.33*
F-LXS	5.8**	5.5*	7.81*	6.90**	2.8**	9.6*	2.8*	23.12*	23.33**	ns	18.6**
F-SNXS	ns	3.12*	ns	5.34**	3.08*	5.04**	ns	ns	ns	ns	11.07*
F-LXSNXS	ns	2.11***	ns	4.44**	2.11***	4.09**	ns	ns	21.06*	ns	ns

Table 4: Simple linear correlation coefficient (r) between the contents of different elements and nutrient values of *Acacia tortilis* and *Acacia ehrenbergiana*. ns = not significant (P > 0.05); r = │31-38│, >0.05> P >0.001; r = │38│, P>0.01.

Variable		*Acacia tortilis*	*Acacia ehrenbergiana*
Na	NDF	-0.53	ns
K	Ca	ns	-0.41
Ca	Mg	ns	-0.46
	EE	ns	-0.32
	Ash	-0.42	ns
P	NDF	-0.41	-0.57
	CP	-0.81	-0.85

Table 4: Continue

	CF	ns	-0.38
CF	NDF	-0.82	-0.9
	CP	ns	-0.42
CP	EE	-0.52	ns
	NDF	-0.33	ns
EE	Ash	-0.51	-0.67
	NDF	-0.41	ns
	CF	ns	-0.31

Table 5: Comparison between the annual average of total digestible nutrients (TDN), digestible crude protein (DCP) and gross energy (GE) of *Acacia tortilis* and *Acacia ehrenbergiana* in the present study and those of the previous related studies. * Data are mean of the different species.

Location	References	DCP	TDN	GE
			%	kcal kg-1
The present study	*Acacia tortilis*	3.4	64.8	2.982
	Acacia ehrenbergiana	4.6	68.4	4.268
Aqaba Gulf Area Pasture* (Sinai)	[24]	4.6	66.5	4.100
Bisha area* (Saudi Arabia)	[25]	8.8	74.8	3.974
East of Matruh (23 species*)	[26]	5.7	67.0	3.993
Riyadh area (S.A) (5 *Acacia* trees*)	[41]	2.4	60.2	6.342
United Arab Emirates (97 species*)	[40]	9.1	54.2	2.430
Kenya (6 *Acacia* trees*)	[2]	8.7	70.9	4.451

Fig. 1: Map showing the four locations of the study areas in the SW region of Saudi Arabia from which plants were collected (Abha, Jizan, Najran and Farasan Islands).

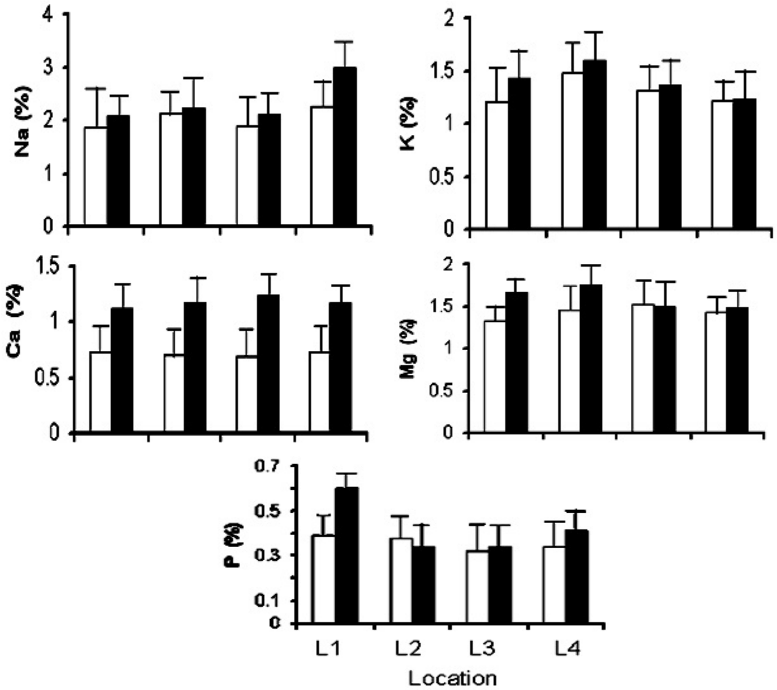

Fig. 2: Variations in the average nutrient contents of *Acacia tortilis* (□) *Acacia ehrenbergiana* (■) in the different locations (Abha (L1), Jizan (L2), Najran (L3) and Farasan Islands (L4)). Vertical bars indicated the standard deviations of the means.

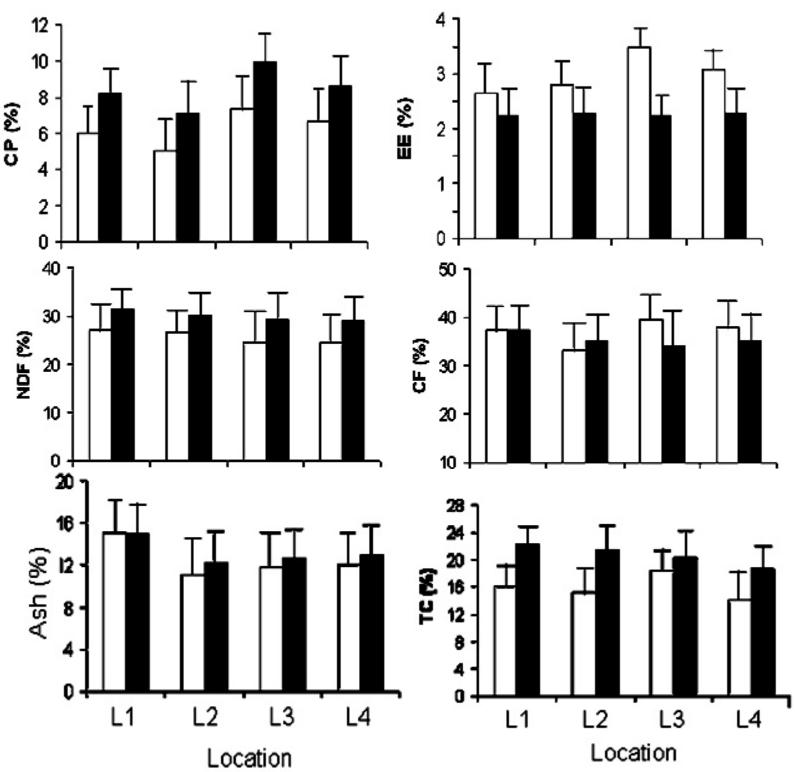

Fig. 3: Variations in the average nutrient contents of *Acacia tortilis* (□) and *Acacia ehrenbergiana* (■) in the different locations (Abha (L1), Jizan (L2), Najran (L3) and Farasan Islands (L4)). CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; CF = crude fiber; TC = total carbohydrates. Vertical bars indicated the standard deviations of the means.

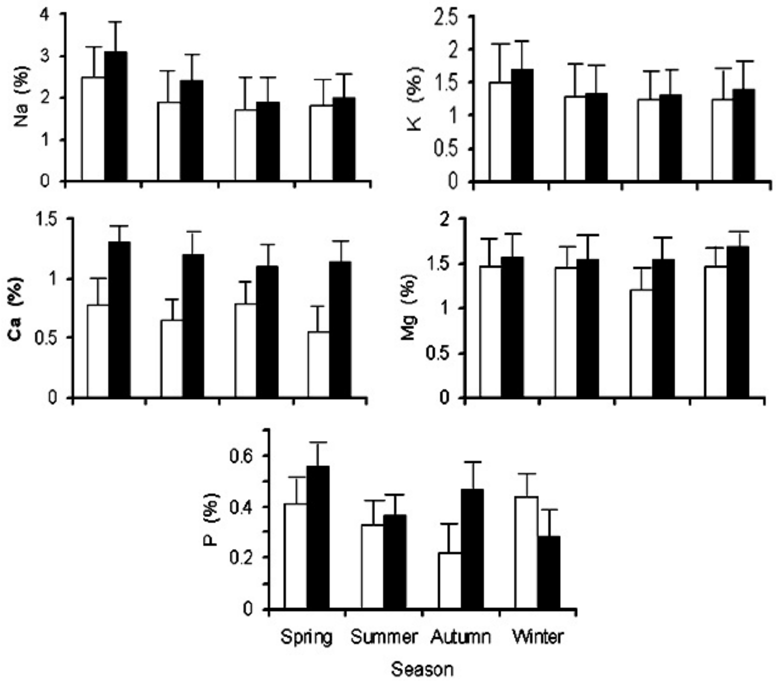

Fig. 4: Variations in the average nutrient contents of *Acacia tortilis* (□) and *Acacia ehrenbergiana* (■) in the different seasons (see Fig. 1). Vertical bars indicated the standard deviations of the means.

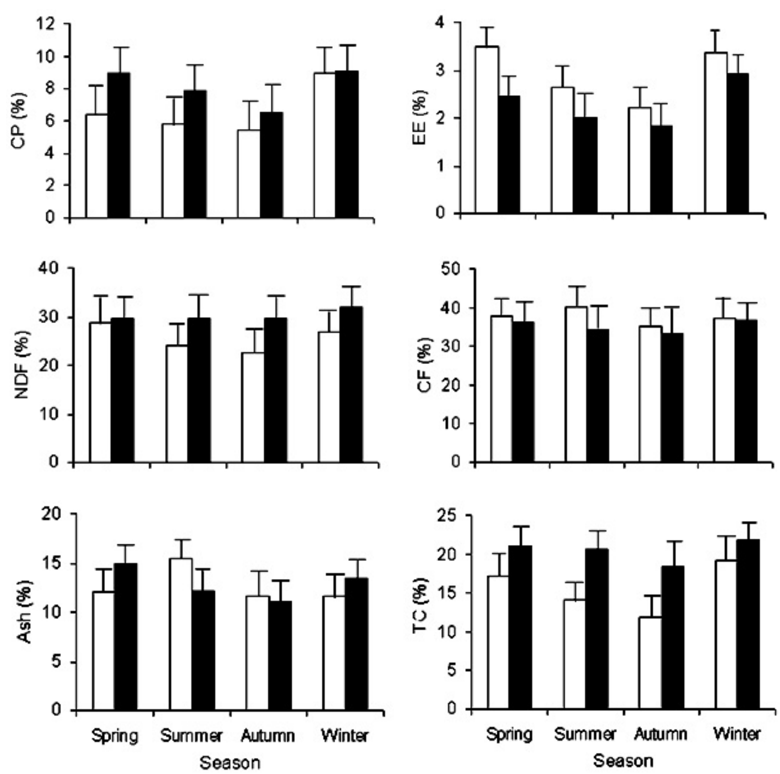

Fig. 5: Variations in the average nutrient contents of *Acacia tortilis* (□) and *Acacia ehrenbergiana* (■) in the different seasons (see Fig. 1). CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; CF = crude fiber; TC = total carbohydrates. Vertical bars indicated the standard deviations of the means.

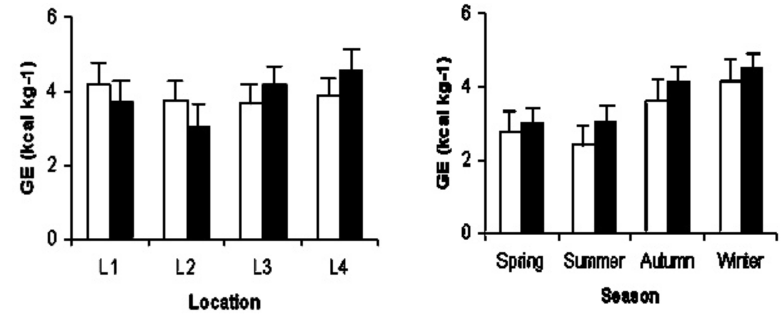

Fig. 6: Variation in the gross energy (GE) of the *Acacia tortilis* (□) and *Acacia ehrenbergiana* (■) in the different locations (Abha (L1), Jizan (L2), Najran (L3) and Farasan Islands (L4)) and different seasons. Vertical bars indicated the standard deviations of the means.

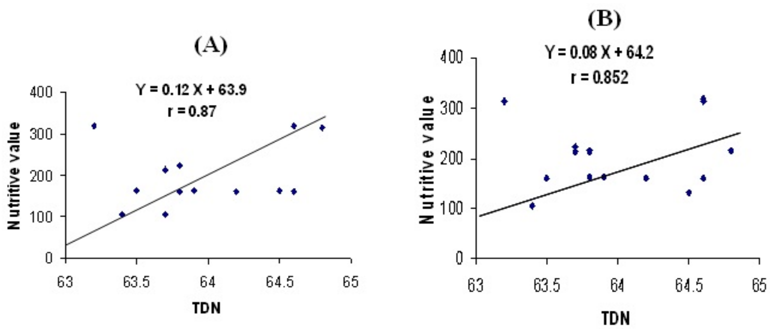

Fig. 7: Relationship between TDN (total digestible nutrients) and nutritive values of (A) *Acacia tortilis* and (B) *Acacia ehrenbergiana*.

requirements of energy and protein may met by the forage grown in the pasture. [23] concluded that the DCP in the forage of the western desert of Egypt is about 5.4%, and that the average DCP in the forage consumed is about 480 g /l00 kg^{-1} live weight/day, according to Damarqui1ly's equation. In the present study, the average DCP in the forage consumed in the area was calculated as about 164 g /l00 kg^{-1} live weight / day^{-1}, which is inadequate in meeting the protein needs of the grazing animals. The standard requirements of sheep as indicated by [3] are about 140 g/100 kg^{-1} live weight / day

In the present study the amount of total digestible nutrients (TDN) are about 53.8% on the average which is less than the average at Bisha area in Saudi Arabia (74.8%) as indicated by [25], Aqaba Gulf area of Sinai (66.5 %) as indicated by [24] (Table 5), on some supplementary feed (64.0 and 68.0 %)as reported by [42] and average of the Western Mediterranean vegetation (66% and 75%) [1], The obtained results of TDN in the present study is also higher than the average TDN (60.5 %) in Riyadh area in Saudi Arabia as reported by [41] and average TDN (54.2 %) of *Acacia nilotica* in United Arab Emirates as reported by [40]. However, [2] reported that the average of TDN in Kenya is 70.9 %.

The proportion of NDF-N and ADF-N was higher in *Acacia tortilis* and *Acacia ehernbergiana* than in *Acacia cyanophylla*[13]. On the basis of their potential degradability, the two species could be ranked as *Acacia ehernbergiana* > A. *tortilis*. A positive relation between in situ parameters, voluntary feed and digestibility have been reported[27] suggesting that *Acacia ehernbergiana* had a good potential for small ruminant feeding in Saudi. However, it is important to note that other factors such as the protein concentrations, seasonal variability and agronomic characteristics will contribute to the selection of the browses to be incorporated in the farming system.

A net energy ranged from 1.3 to 3.4 and 2.7 to 4.5 MJ/kg for *Acacia tortilis* and *Acacia ehernbergiana*, thus the forage quality of both species are ranked as having good energy content according to the scale suggested by [14]. The results have shown that the CP content of the studied Acacia species were sufficiently high to warrant consideration of their use as protein supplement to low quality diets. The potential nutritive values of the studied *Acacia* species were comparable to the other browsers and that the species were rich in most minerals. However, *Acacia tortilis* and *Acacia ehernbergiana* showed less promising potential than the rest. However, more work especially on animal responses, is needed to affirm the nutritional values of both *Acacia* species: *Acacia tortilis* is considered fair for grazing animals compared to *Acacia ehernbergiana* which is good for grazing animals.

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