Voluntary Intake and Digestibility of Saltbush by Sheep

M. M. W. Abu-Zanat*
Department of Animal Production, Faculty of Agriculture, The University of Jordan, Amman 11942, Jordan

ABSTRACT : The study was conducted to compare the dry matter intake and digestibility of *Atriplex halimus* (AH) and *Atriplex nummularia* (AN) and determine the proper proportion of saltbushes for partial replacement of alfalfa hay in the diets of Awassi sheep. The foliage of AH and AN were hand-plucked, air-dried in shade and then chopped mechanically similar to alfalfa hay. Two trials were conducted separately to determine voluntary feed intake and digestibility of saltbush browse. In the first trial, fifteen 8 month old Awassi lambs were distributed into 3 equal groups, and each animal was housed in individual pen. Each group received one of three dietary treatments: chopped alfalfa hay (H), dried foliage of *Atriplex nummularia* or foliage of *Atriplex halimus*. In the second trial, twenty-seven 12 months old Awassi male lambs were randomly selected, distributed into nine equal groups, and housed into metabolic crates. Each group of animals received one of nine dietary treatments: alfalfa hay, AN, AH and different proportions (25, 50 and 75%) of AN or AH mixed with alfalfa hay. Forage type had a significant ($p<0.001$) effect on dry matter intake (DMI) and growth rate of lambs of the voluntary feed intake trial. Lambs receiving the alfalfa hay diet showed high DMI and high growth rate compared to those fed the diets containing saltbush. In the digestibility trial, dietary treatments had significant ($p<0.05$) effect on DMI, dry matter digestibility (DMD) ($p<0.01$) and organic matter digestibility (OMD) ($p<0.01$). The inclusion of AN in the diet up to 50% had no significant effect on DMI and DMD, whereas the inclusion of AH above 25% reduced DMI, DMD and OMD. The treatments had significant ($p<0.05$) effect on water intake and on live weight changes of lambs. Except for the diet containing 25% of AN browse, all lambs fed diets containing the saltbushes exhibited loss in body weight. The nutritive value of *Atriplex nummularia* foliage is better than that of *A. halimus* and it is possible to replace up to 50% of alfalfa hay by *A. nummularia* without negative effects on intake and digestibility of dry matter. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 2 : 214-220)***

Key Words : Awassi Sheep, *Atriplex*, Dry Matter Intake, Digestibility, Growth Rate

INTRODUCTION

Extensive areas of rangelands in West Asia and North Africa (WANA) region are degraded through activities associated with dryland farming, uncontrolled grazing and mining (Le Houerou, 1990). Serious declines in productivity have occurred over extensive areas of lands where less productive, less palatable and less nutritious plants replaced key forage species. Rehabilitation of degraded rangelands is generally limited by low rainfall and unfavorable soil physical conditions. Because of drought and scarcity of precipitation, fodder shrubs are preferred to herbaceous species for rangeland revegetation. *Atriplex* species commonly known as saltbush are strong candidates for plant establishment in desert rangelands because of their salt tolerance and high productivity (Squires and Ayoub, 1992; Le Houerou, 2000).

In Jordan, the common fodder shrubs that are used for revegetation of rangelands are *Atriplex halimus* L. and *A. nummularia* L. *Atriplex halimus* is native to Jordan and represents 65% of saltbush plantations in Middle East region whereas; *Atriplex nummularia* is an introduced species from Australia (Le Houerou, 1994). The nutritional properties of these two fodder shrubs, acceptance by animals and adoption by pastoral communities are critical before launching large-scale plantations in the desert and steppe rangelands of Jordan.

In arid areas where the lack of water resources limits the production of alfalfa and other irrigated forage crops, the drought tolerant fodder shrubs may be used to partially substitute the alfalfa hay in the diets of small ruminants. Proper integration of fodder shrubs in the feeding calendar of grazing animals requires understanding of animal responses when fed these types of fodder plants. Several studies were conducted to assess the validity of these two shrub species as promising feeds for small ruminants in the low rainfall zone of Jordan. These studies included oxalate and tannins assessment as anti-nutritional compounds (Abu-Zanat et al., 2003a), mineral composition of *Atriplex* foliage (Abu-Zanat et al., 2003b), concentration of minerals in blood serum of ewes feeding on saltbushes (Alazzeh and Abu-Zanat, 2003), dry matter accumulation and chemical composition (El-Shatnawi and Mohawesh, 2000; El-Shatnawi and Turk, 2002), and effect of feeding foliage of these two shrub species on milk yield of Awassi ewes and growth of lambs.

The objectives of this study were to compare the dry matter intake and digestibility of *Atriplex halimus* and *Atriplex nummularia* and determine the proper proportion of saltbushes for partial replacement of alfalfa hay in the diets of Awassi sheep.

* Corresponding Author: M. M. W. Abu-Zanat. Tel: +962-6-5355000 (3011), Fax: +962-6-5355577, E-mail: Mahfouz@ju.edu.jo
Received February 4, 2004; Accepted August 9, 2004

MATERIALS AND METHODS

The study was conducted at the Agricultural Research Station of Jordan University for Science and Technology (JUST) located in Irbid, Jordan. The foliage of *Atriplex halimus* (AH) and *A. nummularia* (AN) were hand-plucked from range reserves belonging to the Ministry of Agriculture. The collected browse of each species was air-dried in shade after discarding the twigs having diameters >5 mm, and then chopped mechanically similar to alfalfa hay (H) that purchased from local market. The chopped browse contained 65% leaf material.

Voluntary intake trial

Fifteen Awassi lambs of nine months old and weighing between 30 to 35 kg were divided into 3 equal groups of five animals each. The animals were housed in individual pens (1.0 m×1.25 m) and left to accommodate for 3 weeks before starting the experiment. During this period the usual station's feed (concentrate ration and alfalfa hay) was gradually replaced by the experimental diets. The 3 dietary treatments were chopped alfalfa hay (H), foliage of *Atriplex nummularia* (AN) and foliage of *Atriplex halimus* (AH). The diets were provided to each animal separately; five replicates for each dietary treatment. The amounts of offered diets were 15 to 20% higher than the estimates of feed intake during adaptation period. Diets were provided at 9:00 am and refusals were collected 24 h later. Fresh water was available to animals at all times. Daily feed intake of diets (difference between the offered feeds and refusals) for each animal was recorded for 17 days and representative samples of diets were taken daily and the composite samples were analyzed for chemical composition.

Digestibility trial

Twenty-seven Awassi male lambs of twelve-months old and weighing between 49 to 53 kg were selected and housed in individual shaded pens (1.0 m×1.25 m) for 14 days before moving animals into metabolic crates to conduct the digestibility trial. During the 14-days adaptation period, feeding of penned animals was gradually shifted from the station's ration to the experimental diets. The animals were left for 14 days to adapt to metabolic crates and experimental diets before starting the fecal collection period. The nine dietary treatments were allocated randomly and each treatment was allocated to one group of three animals. The dietary treatments were T1 (100% H), T2 (75% H, 25% AN), T3 (50% H, 50% AN), T4 (25% H, 75% AN), T5 (100% AN), T6 (75% H, 25% AH), T7 (50% H, 50% AH), T8 (25% H, 75% AH) and T9 (100% AH). Daily feed intake of diets (difference between the offered feeds and refusals) and daily fecal output for each animal were recorded throughout the experiment. The excreta were sampled for dry matter determination. The fecal collection period lasted for 7 days. Digestibility of dry matter (DMD) was calculated using the equation:

$$\frac{\{(DMI)-(FDM)\}}{DMI} \times 100\%$$

where DMI is dry matter intake and FDM is fecal dry matter. Body weights of animals were recorded before and after the experiment. The same feedstuffs were used in the voluntary intake and digestibility trials.

Chemical analysis

The collected feed and refusals samples were placed in an oven at 100±5°C for 48 h for dry matter determination (AOAC, 1990). The dried samples were ground to pass a 2 mm screen. Representative samples of oven-dried and ground foliage weighing 0.5 g were placed in a muffle furnace at 500°C for six hours for total ash determination. The ash was wet with sulfuric and perchloric acids and diluted with distilled water (AOAC, 1990). Sodium concentration was determined by flame photometry (Corning 410), phosphorus by absorption spectro-photometry (KONTRON UVIKON 810, Tegimenta industries, Switzerland), and Calcium was determined by atomic absorption spectroscopy (Perkin-Elmer 7000, USA). Crude protein (N%×6.25) was determined by Kjeltec Auto 1030 Analyzer, Tecator Company, Sweden. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) of the composite samples were performed as described by Georing and Van Soest (1970). Organic matter was calculated as the difference between dry matter and ash contents.

Statistical analysis

The analysis of variance was performed on voluntary feed intake data using SAS General Linear Model (GLM) procedure for a complete randomized design (SAS, 1994). The feed intake model included treatment, replicate within treatment, day, treatment day interaction and residual error. Factors considered in statistical analysis were feed intake and body weight changes. For the digestibility trial, analysis of variance was performed on data using the SAS General Linear Model (GLM) procedure for a complete randomized design. The digestibility model included treatment, replicate within treatment, day, treatment day interaction and residual error day. Factors considered in statistical analysis were dry matter intake, dry matter digestibility, organic matter digestibility, water consumption and live weight changes. Treatment means were separated by least significant difference at $p<0.05$. The weight change model included forage type, proportion of saltbush in the diet, the interaction of forage type and proportion of saltbush in the

Table 1. Chemical composition of alfalfa hay, *Atriplex nummularia* and *A. halimus* fed to Awassi lambs at Agricultural Research Station

	Alfalfa hay	*A. nummularia*	*A. halimus*
Dry matter (%)	96.7	92.62	92.51
Ash (%)	11.0	23.80	25.16
Ca (%)	1.20	1.21	1.19
P (%)	0.20	0.11	0.18
Na (%)	0.15	5.94	6.31
Organic matter (%)	89.0	76.20	74.84
Crude protein (%)	16.1	13.75	12.84
Ether extract (%)	1.6	1.8	1.4
Nitrogen free extract (%)	41.1	38.45	35.3
Crude fiber (%)	30.2	22.2	25.3
Neutral detergent fiber (%)	46.0	34.70	40.72
Acid detergent fiber (%)	35.3	22.31	27.45

diet, and residual error. Factors considered in statistical analysis were weight changes, initial body weight and final body weight.

RESULTS

Chemical composition

Chemical composition of alfalfa hay, browse of *Atriplex halimus* and *A. nummularia* are presented in Table 1. The values of dry matter contents of the three forage types were relatively close, but the two *Atriplex* species contained lower levels of organic matter compared to alfalfa hay. The foliage of *A. halimus* contained a higher level of ash (25.16%) than that of *A. nummularia* (23.80%). Crude protein contents of the two shrub species were lower than that of AH. In general, the proximate composition of AH and AN was similar with a tendency for higher NDF and ADF in the browse of AH than that of AN. Plants of AH and AN contained higher concentrations of Na compared to alfalfa hay.

Voluntary feed intake trial

Means of daily feed intake, dry matter intake per kg metabolic weight and growth rate of Awassi lambs are given in Table 2. Forage type had a significant ($p<0.001$) effect on voluntary feed intake and growth rate of lambs ($p<0.001$). The lambs receiving alfalfa hay consumed higher amounts of feed compared with those fed the saltbushes. There were no significant differences in feed intake between lambs fed the two types of saltbushes. Relative intakes of saltbushes to alfalfa hay averaged 62% and 52% for *A. nummularia and A. halimus*, respectively. Lambs receiving the alfalfa hay gained weight whereas those fed saltbushes lost weight that ranged from 0.33 to 1.08 kg per animal at the end of experiment.

Table 2. Daily feed intake and growth rate of Awassi lambs fed alfalfa hay, *Atriplex nummularia* and *A. halimus* at Agricultural Research Station

	Alfalfa hay	*A. nummularia*	*A. halimus*
Feed intake			
g per day	$1{,}345^{*a}\pm278$	$830^{b}\pm133$	$699^{b}\pm164$
g DM per day	$1{,}301^{a}$	769^{b}	647^{b}
g kg $W^{0.75}$ per day	97^{a}	57^{b}	48^{b}
Growth rate (g per day)	121 ± 100^{a}	-86 ± 110^{b}	-89 ± 100^{b}

* Means±standard deviation.
Means in the same line with different letters are different ($p<0.05$).

Digestibility trial

The results of dry matter intake (DMI), dry matter digestibility (DMD) and organic matter digestibility (OMD), water intake and live weight changes of animals are presented in Table 3. The dietary treatments had a significant ($p<0.01$) effect on DMI, DMD and OMD. The DMI of alfalfa hay, AN at proportions of 25%, 50% and AH at 25% were not significantly different. The lowest DMI was obtained when AN and AH were fed solely to lambs, and when AH was fed at 75% in the diet. There were no significant differences in DMD between alfalfa hay and the two species of *Atriplex* when the browse was included at 25% in diet, and when AN browse was included at 50%. The inclusion of AN browse at 50% and 75% in the diet resulted in higher DMD as compared with AH at similar proportions. The DMD of AN was significantly higher than

Table 3. Means of dry matter intake (DMI), dry matter digestibility (DMD), organic matter digestibility (OMD), water intake and live weight of lambs fed different proportions of alfalfa hay and saltbush browse at Agricultural Research Station

	Ratio of alfalfa hay to saltbush browse									LSD
	Atriplex nummularia					Atriplex halimus				
	100:0	75:25	50:50	25:75	0:100	75:25	50:50	25:75	0:100	
DMI (g DM/kg $LW^{0.75}$)	68^{a}	66^{a}	70^{a}	59^{ab}	48^{b}	67^{a}	58^{ab}	47^{b}	40^{b}	10.5
DMD (%)	55.5^{a}	52.8^{a}	51.4^{a}	50.7^{ab}	36.4^{cd}	53.9^{a}	45.4^{abc}	38.1^{bcd}	30.4^{d}	13.3
OMD (%)	66.0^{a}	55.3^{ab}	53.8^{ab}	54.3^{ab}	40.1^{cd}	56.0^{ab}	49.7^{bc}	47.3^{bcd}	35.5^{d}	13.5
Water intake (L per day)	7.4^{c}	8.7^{abc}	10.6^{a}	10.9^{a}	9.9^{ab}	8.2^{bc}	8.7^{abc}	10.0^{ab}	10.6^{a}	2.3
Lamb live weight (kg)										
Initial	53.1	52.3	51.8	52.4	52.4	49.5	50.8	50.8	50.8	8.5
Final	53.3	52.3	51.5	51.6	51.5	49.2	50.3	50.0	49.7	8.5
Weight change	0.25^{a}	0.08^{ab}	-0.33^{abc}	-0.83^{bc}	-0.92^{bc}	-0.33^{abc}	-0.50^{abc}	-0.83^{bc}	-1.08^{c}	1.0

Means in the same line with different letters are different ($p<0.05$).

that of AH when fed solely to animals. Dry matter digestibility of alfalfa hay and AN mixed diets was maintained slightly above 50% before it dropped to 48% when the AN was fed exclusively to lambs.

The diets containing saltbushes showed lower digestibility of organic matter compared to alfalfa hay. There were no significant differences in OMD between AN at 25, 50 and 75% and AH at a proportion of 25% in diet. The OMD of AH declined steadily as the proportion of browse in diet increased from 25 to 100%. Overall percentages of DMD and OMD averaged 50.9 and 46.1, respectively.

The treatment diets had a significant ($p<0.05$) effect on water intake. Lambs receiving diets containing saltbush drank more water than those that received alfalfa hay diet. Water consumption averaged 10.0 and 9.4 liters per animal for diets containing AN and AH browse, respectively. Animals feeding solely on AN or AH diets exhibited the maximum water intake.

The dietary treatments had a significant effect on live weight changes of lambs. Lamb receiving alfalfa hay diet maintained a body gain of 0.25 kg, whereas lambs fed diets containing saltbushes exhibited losses in body weight, except for lambs on AN 25% diet, which ranged from 0.33 to 1.08 kg per animal.

DISCUSSION

Chemical analysis

The chemical analysis of the *Atriplex* browses used in this study is in close agreement with the study of Sotomayor and Correal (2000) and Bensalem et al. (2004). The crude protein values of the two shrub species are within the range of values (13-17%) reported by Chriyaa and Boulanouar (2000) and Munoz et al. (2000). The saltbushes are rich in nitrogen and should be used as alternative supplements to improve low quality feeds such as straws (Rubanza et al., 2003). The browse of AH and AN contained lower values of NDF compared to those reported by Munoz et al. (2000). The slight variation in the chemical composition of saltbushes among the different studies could be attributed to differences in soil characteristics and growth stages of plants at sampling (Karimi and Ungar, 1986).

Intake of saltbushes

The lower dry matter intakes of saltbushes as compared with those of alfalfa hay could be associated with high salt content and low organic matter digestibility of the consumed saltbushes. Dry matter intakes of saltbushes in the present study (48 to 57 g DM/kg $W^{0.75}$) were lower than those reported by other researchers (Le Houerou, 1991; Correal and Sotomayor, 2000; Sotomayor and Correal, 2000). The daily intake of Barbarine ewes were 117 and 90 g DM/kg $W^{0.75}$ for fresh shrubs of *Atriplex nummularia* and *A. halimus*, respectively (Le Houerou, 1991). In Spain, daily intake of *Atriplex nummularia* and *A. halimus* by Segurena ewes under pen feeding conditions averaged 1.5 kg or 88 g DM/kg $W^{0.75}$ for *A. nummularia* (Correal and Sotomayor, 2000) and 1.4 kg or 73 g DM/ kg $W^{0.75}$ for *A. halimus* (Sotomayor and Correal, 2000). In both studies, the saltbush browse (leaves and twigs <10 mm) was harvested twice weekly and chopped before group feeding of dry ewes. However, Wilson (1977) reported that daily dry matter intake of *Atriplex nummularia* by sheep averaged 550 g, which is lower than the values obtained in our study.

The variations in dry matter intake of saltbushes could be attributed to many factors including ratio of leaves to twigs, twig size, digestibility, salt content, previous exposure of animals to saltbush, and animal condition (Allison, 1985). The browse consists of leaves and twigs and substantial number of studies suggested that the diameters of twigs should be less than 5 mm to be grazable by animals (Roundy et al., 1989). Twigs having diameters more than 10 mm are largely indigestible. A large proportion of this indigestible material in the diet could be accumulated in the animals' gut and consequently limited their feed intake (Rehman, 1994).

Previous experience and adaptation of animals to saltbushes considerably affect the intake of browse (Correal and Sotomayor, 1997). Le Houerou (1992) reported that sheep become adapted to saltbush and increased their intake of forage over a 3-5 month period. During the first two weeks of the experiment that was conducted by Correal and Sotomayor (2000), Segurena dry ewes lost weight on saltbush diet (*Atriplex nummularia*) and then live weight improved in the third week; this suggests that during the first two weeks of the experiment, ewes went through an adaptation process. In our study, the animals were adapted to the experimental diets for 14 days before the start of measurements.

Animal condition is an important factor that determines the nutrient requirements and hence the dry matter intake of the animal. In our study, growing Awassi lambs were used compared to unmated and pregnant Barbarine ewes in Le Houerou (1991) study, whereas Segurena dry ewes were used in the two studies that were conducted in Spain (Correal and Sotomayor, 2000; Sotomayor and Correal, 2000). The large variations in the chemical composition and intake among the different *Atriplex* species in addition to differences in breeds, body weights and body condition of animals are major factors contributing to variability in dry matter intakes of saltbushes in the different studies.

Intake of saltbush and salt content

The reported intakes of saltbushes in this study suggested that the daily salt consumption was around 43 g per sheep, which could have limited feed intake. Leaves of saltbushes, particularly *Atriplex* species, contain high amounts of salts and suggested that the feed intake of sheep feeding solely on saltbush was limited by high salt concentrations (148 g NaCl/kg DM) (Malcolm et al., 1988). Mixing the browse of saltbushes with other conventional feeds such as straws increased feed intake of diet mainly due to dilution of salt content (Warren et al., 1990). It seems that the dry matter intake was limited by the animals' ability to ingest and excrete salt rather than the palatability of diets. The high salt content of saltbushes necessitates continuous accessibility to drinking water in areas where they are planted.

Live weight changes

Saltbushes are well known for their low energy value, particularly *Atriplex* species, which ranges between 3.0 and 5.0 MJ/kg DM (Kearl et al., 1977; Le Houerou, 1991). Animals feeding solely on saltbushes cannot maintain their body weight. In our experiment, the lambs receiving the browse of *Atriplex nummularia* and *A. halimus* exhibited some losses in body weight during the 17-day experiment. It seems that the lambs did not consume enough dry matter and most likely because of high ash content, which is mainly common salt (sodium chloride). A sheep weighing 45 kg should consume 1.4 to 1.6 kg DM of *Atriplex* per day in order to maintain its weight, and daily intakes of saltbushes below 90 g/kg $W^{0.75}$ are not expected to maintain body weight (Le Houerou, 1991). However, Correal and Sotomayor (2000) fed the browse of *Atriplex nummularia* with or without barley straw to dry Seurena ewes. Ewes on the saltbush diet consumed a mean of 1.5 compared to 1.8 kg DM per head per day on saltbush and straw diet. All the ewes ended up with higher live weights and better body condition during a six-week experiment under pen feeding conditions and indicated that the browse of *Atriplex nummularia* meets the maintenance requirements of ewes when fed either alone or with barley straw.

Sheep could maintain live weight for quite long periods feeding saltbush and these gains in body weight could be illusory because of increased water intake by the animals. The deuterium labeling technique showed that live weight comparisons for animals feeding on saltbushes were a misleading indicator of sheep condition (Warren and Casson, 1994). In order to maintain body weight or allow some gain, the foliage of *Atriplex* browse should be used as alternative supplements to low quality feeds such as straws (Ben Salem et al., 2004).

Intake and digestibility

The feed quality determines the relationship between digestibility and intake. The digestibility and intake are inversely related in high quality feeds (Hicks, 1990) and directly related in low and medium quality roughage (Weston, 1984). In high quality feeds, it was proposed that with an increase in intake, digestibility would decrease due to accelerated rate of passage. The intake of low and medium quality roughage such as the browse of saltbushes is mainly limited by its low digestibility.

The values of DMD and OMD in our study are well below those reported in literature. Wilson (1977) reported that the OMD of *A. nummularia* browse averaged 72% and Nefzaoui (2000) indicated that the OMD averaged 68% for *A. nummularia* and cactus mixed diet (3:1). However, other studies showed that the digestibility of saltbush diets (leaves and twigs <2 mm diameter) is below 55% indicating that saltbush is only maintenance feed (Rehman, 1994).

The inclusion of *Atriplex nummularia* browse up to 75% in diets maintained DMD and OMD slightly above 50% whereas increasing the proportion of *A. halimus* above 25% reduced the digestibility substantially. The high DMD and OMD of *A. nummularia* as compared with those of *A. halimus* could be associated with high levels of secondary chemical compounds and ash in the browse of *A. halimus.* A study found that *Atriplex halimus* contained more total phenols (1.88% vs. 1.36%), tannic phenols (1.72% vs. 1.19%), condensed tannins (1.0% vs. 0.80%), hydrolysable tannins (0.6% vs. 0.3%) and oxalate (7.01% vs. 6.20%) than *A. nummularia* (Abu-Zanat et al., 2003a). Feeding diets rich in tannins to ruminant animals produced negative effects on the animal, inducing low feed palatability and inhibited digestion (Singleton, 1981; Kumar and Singh, 1984). The tannins bind proteins to form insoluble complexes and inhibit cellulolytic and protolytic enzymes and decrease the production of volatile fatty acids, microbial DNA and RNA in the rumen (Singleton, 1981). The foliage of *A. halimus* contained higher levels of ash (28.03%) than that of *A. nummularia* (23.11%) (Abu-Zanat et al., 2003b). In this study, the nutritive value of *A. nummularia* is better than that of *A. halimus*.

The low DMD and OMD observed in our study limited intake of saltbushes and resulted in body weight losses in all animals receiving alfalfa hay and saltbush mixed diets except for the diet containing 25% of *A. nummularia* browse. In general, ruminants require forage of greater than 55% dry matter digestibility to maintain body weight. To increase body weight they need a diet with DMD of more than 60-65% (Warren and Casson, 1992; Anigbogu, 2003).

Water intake

Water consumption was significantly increased as the proportion of saltbushes in the diets increased and reached

the maximum level when the lambs fed exclusively on saltbushes. Means of daily water consumption ranged between 7.4 and 10.9 liters per lamb and were in agreement with those of Wilson (1966) and Le Houerou (1991), but higher (6.3 liters per animal) than those reported by Correal and Sotomayor (2000). The high salt content of saltbushes necessitates continuous accessibility to drinking water for animals feeding on or grazing such type of forage.

CONCLUSION

In experiments dealing with feeding or direct grazing of saltbushes, it is important to report the percentage of leaves in the browse, the diameter of twigs in the offered feed and refusals, and salt content in leaves and the whole browse. This information is helpful in making proper comparisons among the results of different experiments. Animals feeding exclusively on the foliage of *Atriplex* species cannot maintain their body weights because of low energy density. The saltbushes are rich in nitrogen and should be used as alternative supplements to improve low quality feeds such as straws. The nutritive value of *Atriplex nummularia* foliage is better than that of *A. halimus* and it is possible to replace up to 50% of alfalfa hay by *A. nummularia* without negative effects on intake and digestibility of dry matter.

Fodder shrubs, particularly *Atriplex* species, are well known for their tolerant to drought and salinity. In arid areas where the lack of water resources limits the production of alfalfa hay, these fodder shrubs may be used to partially substitute the alfalfa hay in the diets of small ruminants. *Atriplex nummularia* is an exotic species whereas *A. halimus* is a native species to the Mediterranean Basin; the decision to choose between the two species for revegetation of degraded rangelands depends on the economic feasibility of fodder plantations and the strategy of biodiversity conservation in the country.

ACKNOWLEDGEMENTS

Research was funded by the Government of Jordan and the European Commission as Project No: SEM/03/628/021 (Jordan Arid Zone Productivity Project: JAZPP).

REFERENCES

Abu-Zanat, M. W. M., F. M. Al-Hassanat, M. Alawi and G. B. Ruyle. 2003a. Oxalate and tannins assessment in *Atriplex halimus* L. and *A. nummularia* L. J. Range Manage. 56:370-374.

Abu-Zanat, M. W. M., F. M. Al-Hassanat, M. Alawi and G. B. Ruyle. 2003b. Mineral assessment in *Atriplex halimus* L. and *Atriplex nummularia* L. in the arid region of Jordan. African Journal of Range and Forage Science 20:1-5.

Alazzeh, Y. A. and M. M. W. Abu-Zanat. 2003. Impact of feeding saltbush (*Atriplex* sp.) on some mineral concentrations in the blood serum of lactating Awassi ewes. Small Rumin. Res. 54:81-88.

Allison, C. D. 1985. Factors affecting forage intake by range animals: A review. J. Range. Manage. 38:305-311.

Anigbogu, M. N. 2003. Supplementation of dry brewer's grain to lower quality forage diet for growing lambs in southeast Nigeria. Asia-Aust. J. Anim. Sci. 16:384-388.

Association of Official Analytical Chemists (AOAC). 1990. Official Methods of Analysis. 15th Edition. AOAC, Washington, DC.

Ben Salem, H., A. Nefzaoui and L. Ben Salem. 2004. Spineless cactus (*Opuntia ficus indica f. inermis*) and Oldman saltbush (*Atriplex nummularia* L.) as alternative supplements for growing Barbarine lambs given straw-based diets. Small Rumin Res. 51:65-73.

Chriyaa, A. and B. Boulanouar. 2000. Browse foliage as a supplement to wheat straw for sheep. In: Fodder Shrub Development in Arid and Semi-arid Zones. (Ed. G. Gintzburger, M. Bounejmate and A. Nefzaoui). Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, Vol. II, 27 October-2 November 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria, pp. 476-484.

Clarke, A. J. 1982. The grazing value of saltbushes. J. Agriculture of Western Australia. 23:7-9.

Correal, E. and J. A. Sotomayor. 1997. Sheep intake of *Atriplex* browse is influenced by previous adaptation of animals to this fodder. *Atriplex in vivo*. 5:2-4.

Correal, E. and J. A. Sotomayor. 2000. Effect of straw supplementation on intake and browsing of *Atriplex nummularia* (Oldman saltbush) by "Segurena" ewes under pen feeding and free grazing conditions. In Fodder Shrub Development in Arid and Semi-arid Zones. (Ed. G. Gintzburger, M. Bounejmate and A. Nefzaoui). Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, Vol. II, 27 October-2 November 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria, pp. 551-557.

El-Shatnawi, M. K. J. and Y. M. Mohawesh. 2000. Seasonal chemical composition of saltbush in semiarid grasslands of Jordan. Journal of Range Manage 53:211-214.

El-Shatnawi, M. K. J. and M. Turk. 2002. Dry matter accumulation and chemical composition of saltbush (*Atriplex halimus*) grown in Mediterranean desert shrublands. New Zealand Journal of Agric. Res. 45:139-144.

Georing, H. K and P. J. Van Soest. 1970. Forage fiber analysis. Agriculture Handbook, vol. 379. Agr. Res. Serv. USDA, Washington, DC, USA.

Hicks, R. B., F. N. Owens, D. R. Gill, J. J. Martin and C. A. Strasia. 1990. Effects of controlled feed intake on performance and carcass characteristics of feedlot steers and heifers. J. Anim. Sci. 68:233-244.

Karimi, S. H. and I. A. Ungar. 1986. Oxalate and inorganic ion concentration in *Atriplex triangularis* in response to salinity, light level and aeration. Botanical Gazzet. 147:65-70.

Kearl, L. C., M. F. A. Farid, L. E. Harris, M. F. Wardeh and H. Lioyd. 1979. Arab and the Middle East Tables of Feed Composition. Utah State University at Logan and Arab Center for the Studies of Arid and Dry Lands (ACSAD), Damascus, Syria.

Kumar, R. and M. Singh. 1984. Tannins: Their adverse role in ruminant nutrition. J. Agric Food. Chem. 32:447-459.

Le Houerou, N. H. 1986. Salt tolerant plants of economic value in the Mediterranean basin. Reclamation and Revegetation Research 5:319-341.

Le Houerou, N. H. 1990. Global change: vegetation, ecosystems and land use in the Mediterranean basin by the mid-21st century. In Greenhouse Effect, Sea Level and Drought. (Ed. R. Paepe, R. W. Faibridge and S. Jelgersma). Kulwer Academic Press, Dordrecht, The Netherlands, pp. 301-367.

Le Houerou, N. H. 1991. Feeding shrubs to sheep in the Mediterreanaean arid zone: intake, performance and feed value. In the IVth International Rangeland Congress, pp. 623-628. Montpellier, France.

Le Houerou, N. H. 1992. The role of saltbushes (*Atriplex* spp.) in arid land rehabilitation in the Mediterranean Basin: A Review. Agroforestry Syst. 18:107-148.

Le Houerou, N. H. 1994. Forage halophytes and salt-tolerant fodder crops in the Mediterranean Basin. In: Halophytes as a Resource for Livestock and for Rehabilitation of Degraded Lands. (Ed. V. R. Squires and T. A. Ayoub), pp. 123-137. Kulwer Academic Publishers, The Netherlands.

Le Houerou, N. H. 2000. Use of fodder trees and shrubs (trubs) in the arid and semi-arid zones of West Asia and North Africa: History and Perspectives. In: Fodder Shrub Development in Arid and Semi-arid Zones. (Ed. G. Gintzburger, M. Bounejmate and A. Nefzaoui). Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, Vol. I, 27 October-2 November 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria, pp. 9-53.

Malcolm, C. V., A. J. Clarke, M. F. D'Antuono and T. C. Swaan. 1988. Effects of plant spacing and soil conditions on the growth of five *Atriplex* species. Agriculture, Ecosystems and Environment. 21:265-279.

Munoz, F., J. D. Andueza, I. Delgado and M. J. Ochoa. 2000. Chemical composition and *in vitro* digestibility of browse plants in a semi-arid region of Spain. In Fodder Shrub Development in Arid and Semi-arid Zones. (Ed. G. Gintzburger, M. Bounejmate and A. Nefzaoui). Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, Vol. II, 27 October-2 November 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria, pp. 485-490.

Nefzaoui, A. 2000. Nutritive value of spineless cactus (*Opuntia ficus indica* var *inermis*) and *Atriplex* (*Atriplex nummularia*) based diets for sheep. In Fodder Shrub Development in Arid and Semi-arid Zones. (Ed. G. Gintzburger, M. Bounejmate, M. and A. Nefzaoui). Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, Vol. II, 27 October-2 November 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria, pp. 518-523.

Rubanza, K. D. C., M. N. Shem, R. Otsyina, T. Ichinole and T. Fujihara. 2003. Nutritive evaluation of some browse tree legume foliages native to semi-arid areas in western Tanzania. Asia-Aust. J. Anim. Sci. 16:1429-1437.

Rehman, A., J. B. Mackintosh, J. A. Fortune and B. E. Warren. 1994. Can the voluntary feed intake of wheat straw in sheep be improved by mixing with saltbush (*Atriplex amnicola*)? In Proceedings of the Australian Society of Animal Production pp. 175-177.

Roundy, B. A., G. B. Ruyle and J. Ard. 1989. Estimating production and utilization of Jojoba. J. Range Mange. 42:75-78.

SAS Institute, Inc. 1994. SAS/STAT User's Guide, Version 6, Fourth Edition, Vol. 2, SAS Inst., Cary, N.C., USA.

Singleton, V. L. 1981. Naturally occurring food toxin: Phenolic substances of plant origin common in foods. Adv. Food Res. 27:149-242.

Sotomayor, J. A. and E. Correal. 2000. Effect of straw supplementation on the *Atriplex halimus* diet consumed by Segurena ewes. In Fodder Shrub Development in Arid and Semi-arid Zones. (Ed. G. Gintzburger, M. Bounejmate and A. Nefzaoui). Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, Vol. II, 27 October-2 November 1996, Hammamet, Tunisia, ICARDA, Aleppo, Syria, pp. 558-563.

Squires, R. V. and T. A. Ayoub. 1994. Halophytes as a resource for livestock and for rehabilitation of degraded lands. Proceedings of the International Workshop on Halophytes for Reclamation of Saline Wastelands and as a Resource for Livestock: Problems and Prospects. Nairobi, Kenya, 22-27 November 1992. Kulwer Academic Publishers, London, UK.

Warren, B. E., C. L. Bunny and E. R. Bryant. 1990. A preliminary examination of the nutritive value of four saltbush (*Atriplex*) species. In Proceedings of the 1990 Australian Society of Animal Production pp. 424-427.

Warren, B. E. and T. Casson. 1992. Saltbush quality and sheep performance. In Proceedings of 3rd National Workshop on Productive Use of Saline Land (Ed. T. N. Herrmann). South Australian Department of Agriculture, Australia, pp. 79-86.

Warren, B. E. and T. Casson. 1994. Sheep and saltbush-are they compatible? In Proceedings of 3rd National Workshop on Productive Use of Saline Land. (Ed. M. A. Schulz and G. Petterson), pp. 125-129.

Wetson, R. H. 1984. Rumen digesta load in relation to voluntary feed consumption and rumination in rough-feed young sheep. Can. J. Anim. Sci. 64 (Suppl.):324-325.

Wilson, A. D. 1966. The tolerance of sheep to sodium chloride in food or drinking water. Aust. J. Agric. Res. 17:503-514.

Wilson, A. D. 1977. The digestibility and voluntary intake of the leaves of trees and shrubs by sheep and goats. Aust. J. Agric. Res. 28:501-508.