

Nutrient Composition of *Atriplex* Leaves Grown in Saudi Arabia

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Abstract

Leaves of 6 *Atriplex* species (saltbush) grown in Saudi Arabia were studied for their nutritive characteristics. Crude protein contents varied between 16.7 - 25.2%, crude fat between 1.0 - 1.6%, crude fiber between 7.8 - 10.4%, and ash between 18.5 - 27.2%, on a dry matter basis. *A. undulata* had the lowest and *A. nummularia* had the highest protein and fiber contents. Ash content was lowest in *A. canescens* and highest in *A. undulata*. The level of Na was extremely low (0.21%) in *A. canescens* compared to that in the other species (2.38 - 5.57%). The level of K (6.06%) was highest in *A. canescens* compared to 2.48 - 3.54% in other species. Ca content was significantly higher in *A. vesicaria* (2.48%) than that in the remaining species (1.12 - 1.50%). Variations in the levels of P, Mg, Fe, Zn, Cu, and Mn were only minor. Sulphur amino acids (methionine + cystine) were the most deficient essential amino acids in all species (chemical score = 45 - 61) while lysine contents were 75 - >100% of the FAO/WHO (1973) reference protein. Predicted digestible dry matter ranged between 74.5 - 78.8% and digestible energy (M Cals/Kg) between 3.215 - 3.399. These data suggest that *Atriplex* leaves as a range forage for livestock would have good nutritive value.

Atriplex species commonly known as saltbush are strong candidates for plant establishments in saline areas and for increasing productivity in arid or semiarid regions of the world because of their salt tolerance and high productivity (Kleinkopf et al. 1975). Hence these plants have been grown as a forage shrub for many years in marginal agricultural lands in South Africa, Australia, USA and the Middle East (Goodin and McKell 1970). In the Kingdom of Saudi Arabia, where prolonged drought and excessive salinity are common, several species of *Atriplex* were grown successfully on marginal agricultural lands (Hyder 1981). *Atriplex* species are reported to show considerable variation in their chemical composition (Smit and Jacobs 1978) and differ considerably in their responses to sodium salts (Goodin and McKell 1970). Considerable information on the chemical composition and nutritional characteristics of the *Atriplex* species is available in the literature (Beadle et al. 1957, Goodin and McKell 1970, Chatterton et al. 1971, NAS 1971, Welch 1978, Smit and Jacobs 1978, Davis 1981, Welch and Monsen 1981, McArthur et al. 1984). However, such information on *Atriplex* species grown in the Kingdom of Saudi Arabia was lacking except for the protein and ash contents of some species reported by Hyder (1981). The present investigation was undertaken in an attempt to characterize the forage value of the leaves of six *Atriplex* species grown under the environmental conditions of Saudi Arabia. *Atriplex* leaves alone were included in this study because goats, which along with sheep and camels are the major grazing animals, show unique preferences for shrub and tree leaves (NRC 1981). Moreover, compositional information on the leaves alone was scarce for most of the *Atriplex* species under study especially those grown in Saudi Arabia.

Materials and Methods

Preparation of Samples

Mature dry leaves were collected from 6 *Atriplex* species, *A. nummularia* Lindl., *A. rhagodioides* F. Muell., *A. vesicaria* Heward., *A. canescens* (Pursh) Nutt., *A. lentiformis* (Torr) S. Wats

and *A. undulata* (moq.) Dietr. The plants were exotic introductions from Australia and U.S.A. The seeds of *A. nummularia*, *A. rhagodioides* and *A. vesicaria* were supplied by C.V. Malcolm, Research Officer, Department of Agriculture, Perth, Western Australia. Seeds of the other *Atriplex* species were obtained from Dr. L.R. Green, range scientist, Forest Fire Laboratory, Riverside, California, U.S.A. Plants were grown at the Regional Agriculture and Water Research Center, Riyadh (Hyder 1981). Seeds were sown in the greenhouse in November 1977 in earthen pots (30 cm in diameter and 12 cm deep) with 1:1 mixture of sand and peat. Pots were watered regularly. All species germinated within 1 month. When large enough, individual seedlings were transferred to separate containers (12 cm diameter and 6 cm deep) having the same mixture of sand and peat. After 3 weeks in the greenhouse, the seedlings (12-16 cm in height) were transferred to the field plots in January 1978. The transplants were placed 1.75 m apart in rows which were 2 m apart and irrigated immediately. The plants were harvested in April 1980. All the plants had completed phenological stages of flowering, fruit, and seed production. Leaves were collected from 10-15 plants of each species, air dried and ground in a micro mill (Technilab Instruments, Pequannock, N.J., Model #502) to pass 1 mm-sieve, and stored in a freezer (-5°C) until analysed.

Chemical Composition

Analysis for moisture, crude protein (N × 6.25), crude fat, crude fiber, ash and nitrogen-free extract (NFE) (by difference) were done by methods of AOAC (1980). Acid detergent fiber (ADF) values were determined following the procedure by Goering and Van Soest (1970). For mineral analysis, the dry ash was dissolved in 20% HCl and necessary dilutions made with deionized water. Na and K were estimated with a flame photometer (Beckman, Klinia flame). Ca, Mg, Fe, Zn, Cu and Mn were determined with an atomic absorption spectrophotometer (Perkin-Elmer, Model 603). P was determined by the procedure of Watanabe and Olsen (1965). For Ca and Mg, the final diluted solutions contained 1% lanthanum to reduce interferences.

For amino acid analysis, duplicate samples containing 5 mg protein were hydrolysed with 6N HCl for 24 hours at 110°C. Cystine was determined as Cysteic acid (Moore 1963) and tryptophan by the alkaline hydrolysis procedure of Hugli and Moore (1972). All the hydrolysates were analysed with an automatic amino acid analyser (Beckman, 119 CL). The chemical scores were determined by dividing the contents of the essential amino acids in the *Atriplex* leaf proteins by the contents of the same amino acid in the FAO/WHO reference protein (FAO/WHO 1973).

Nutritional Characteristics

Digestible dry matter (DDM), digestible energy (DE), and metabolizable energy (ME) were calculated from the chemical data. DDM was calculated from the ADF values and DE from the DDM values using the following equations reported by Fonnebeck et al. (1984) for alfalfa hay:

$$\text{DDM}\% = 88.9 - 0.779 (\text{ADF})$$

$$\text{DE}\% = 0.628 + 0.984 (\text{DDM}\%)$$

$$\text{DE (M cals/kg)} = 0.027 + 0.0428 (\text{DDM}\%)$$

For the calculation of the ME, the following equation was used (Gonzalez and Everitt 1982):

$$\text{ME (M cals/kg)} = \text{DE (M cals/kg)} \times 0.8210$$

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Results and Discussion

Proximate Composition

Proximate analysis data are reported in Table I. Considerable variations in the crude protein, ash, and carbohydrate contents were observed among the leaves of the 6 *Atriplex* species. The percentage values of fat and fiber showed relatively small variations. The protein content varied from 16.7% in *A. undulata* to 25.2% in *A. nummularia*; mean was 19.4% for the 6 species. Smit and Jacobs (1978) also reported considerable variations in the

Table 1. Proximate composition¹ of *Atriplex* leaves.

<i>Atriplex</i> species	Protein (N×6.25)%	Fat %	Fiber %	Ash %	Nitrogen-free extract
<i>A. nummularia</i>	25.2	1.1	10.4	24.3	39.0
<i>A. canescens</i>	17.4	1.6	9.0	18.5	53.5
<i>A. vesicaria</i>	17.8	1.6	8.3	34.1	38.2
<i>A. rhagodioides</i>	17.2	1.0	10.2	22.8	48.8
<i>A. lentiformis</i>	21.9	1.1	8.0	22.0	47.0
<i>A. undulata</i>	16.7	1.3	7.8	27.2	47.0
Mean	19.4	1.3	9.0	24.8	45.6

¹Dry weight basis.

Table 2. Mineral element content¹ of *Atriplex* leaves.

<i>Atriplex</i> species	Na	K	Ca	P	Mg	Fe	Zn	Cu	Mn
	%					µg/g			
<i>A. nummularia</i>	4.85	2.49	1.44	0.24	0.76	420	54	24	74
<i>A. canescens</i>	0.21	6.06	1.31	0.19	0.72	370	59	20	84
<i>A. vesicaria</i>	4.95	2.86	2.48	0.18	0.84	350	58	23	78
<i>A. rhagodioides</i>	2.38	2.48	1.50	0.22	0.59	335	66	25	82
<i>A. lentiformis</i>	4.91	2.76	1.12	0.28	0.79	250	59	26	75
<i>A. undulata</i>	5.57	3.54	1.45	0.24	0.66	485	70	26	89

¹Dry weight basis.

Table 3. Amino acid composition of *Atriplex* leaves (g amino acid/100 g protein).

Amino acid	<i>Atriplex</i> species						FAO/WHO (1973)
	<i>A. nummularia</i>	<i>A. canescens</i>	<i>A. vesicaria</i>	<i>A. rhagodioides</i>	<i>A. lentiformis</i>	<i>A. undulata</i>	
Aspartic acid	5.96	4.83	6.52	5.68	5.01	4.81	—
Threonine	2.90	2.52	3.27	2.90	2.57	2.50	4.0
Serine	3.12	2.56	3.61	3.05	2.62	2.85	—
Glutamic acid	6.89	5.62	7.28	6.69	5.54	5.33	—
Proline	3.22	2.62	2.47	3.68	2.13	2.08	—
Glycine	3.54	2.96	3.75	3.39	2.86	3.09	—
Alanine	3.79	3.03	3.99	3.68	3.26	3.25	—
Valine	3.65	2.84	4.04	3.39	2.83	3.16	5.0
Methionine (M)	0.87	0.91	0.94	0.85	0.80	0.80	—
Cystine (C)	0.69	0.74	0.85	1.18	0.80	1.32	—
M + C	1.56 ¹	1.65 ¹	1.79 ¹	2.03 ¹	1.60 ¹	2.12 ¹	3.5
Isoleucine	3.27	2.42	3.34	2.87	2.30	2.38	4.0
Leucine	5.04	4.00	5.41	4.97	4.14	4.02	7.0
Tyrosine (T)	1.99	1.58	2.15	1.93	1.59	1.67	—
Phenylalanine (P)	3.20	2.60	2.55	3.15	2.53	2.55	—
T + P	5.19	4.18	4.70	5.08	4.12	4.22	6.0
Lysine	5.44	4.22	5.71	5.04	4.08	4.09	5.5
Histidine	1.53	1.15	1.53	1.12	0.91	0.93	—
Arginine	5.30	2.50	3.57	2.79	2.63	2.27	—
Tryptophan	0.62	0.60	0.77	0.93	0.79	0.74	1.0
NH ₃	2.53	2.86	2.70	1.14	1.22	1.37	—
Chemical score	45	47	51	58	46	61	100

¹First limiting essential amino acid.

protein content among *Atriplex* species, as well as seasonal variations within species. Welch and Monsen (1981) reported winter crude protein levels of 6–14% of dry weight in 43 accessions of fourwing saltbush (*A. canescens*) and indicated that genetic variation plays an important role in determining the level of protein in this *Atriplex* species. McArthur et al. (1984) reported seasonal variations in the protein content of 'Rincon' fourwing saltbush (*A. canescens*) ranging from 17.9% in November to 26.5% in June in the leaves with intermediate values for other seasons. Goodin and McKell (1970) indicated a decrease of approximately 2% in the protein content of *A. lentiformis* and 3% in *A. polycarpa* between the first and second harvest separated by 1-month intervals. The National Research Council (NRC 1976) recommended 9.2% and 5.2% crude protein for lactating and dry beef cows, respectively. The protein content of the dry leaves of the 6 *Atriplex* species exceeded these requirements. Moreover, the data suggest that these leaves could be used as a protein supplement with other forage crops such as dormant grasses which usually are deficient in this nutrient (Gonzalez and Everitt 1982). The crude protein content of the leaves of *Atriplex* species was also higher than the requirements for sheep (8.9–16%, NRC 1975). Similarly, it exceeded the protein needs suggested for maintenance, live weight gain of goats, and for pregnant and lactating does (NRC 1981).

The percentage of fat varied between 1.0–1.6%. The fat values

are slightly lower than those of NAS (1971) for *Atriplex* leaves (1.9–2.7%) and 2.5–3.5% reported by Chatterton et al. (1971) in the leaves of *A. polycarpa*. The ash contents varied between 18.5% in *A. canescens* to 34.1% in *A. vesicaria*. These values are in agreement with those reported by NAS (1971). Chatterton et al. (1971) reported considerable variation in the total ash content of *A. polycarpa* leaves (15–20%) with the highest value during late summer.

The crude fiber content was highest in *A. nummularia* (10.4%) and lowest in *A. undulata* (7.8%). These values are comparable to those reported for *A. polycarpa* leaves by Chatterton et al. (1971). The fiber as well as ash content showed large seasonal variations in *Atriplex* species (Chatterton et al. 1971, Davis 1979). However, these seasonal variations in fiber content were lowest in the leaves compared to the stems or whole plant (Chatterton et al. 1971). NFE varied from 38.2% in *A. vesicaria* to 53.5% in *A. canescens*. These values are close to 40–45% reported by Chatterton et al. (1971) in the leaves of *A. polycarpa* and compare favorably with the values of NAS (1971).

Mineral Contents

Data on the mineral element contents are shown in Table 2. All the mineral elements showed a wide range of variation except Cu, which differed over a narrow range. The concentration of Na was lowest in *A. canescens* (0.21%) and highest in *A. undulata* (5.57%). Other investigators have also reported much lower Na levels in *A. canescens* compared to the Na levels in the leaves of other *Atriplex* species (Wallace et al. 1973, Smit and Jacobs 1978). Richardson (1982) showed that distinct biotypes of *A. canescens* exist with regard to Na accumulation. Na levels in all the species were well above the 0.06% level considered adequate for beef cattle (NRC, 1976). It was also much higher (except *A. canescens*) than 0.5% level considered adequate for goats (NRC 1981) and 0.04–0.1% of diet dry matter considered adequate for sheep (NRC 1975). Goats in particular can consume Na in excess of their requirements with no apparent ill effects (NRC 1981).

In contrast to Na, the concentration of K was maximum in *A. canescens*, and relatively much lower in other species. High levels of Na in the leaves tend to depress the K levels (Wallace et al. 1982). Richardson (1982) reported large ecotype differences in the leaves of *A. canescens* for K accumulation. K concentrations in leaves were high when Na concentrations were low. The K levels in all the species were well above the (0.6–0.8%) minimum requirement range for cattle (NRC 1976) and 0.5%–0.8% range for goats and sheep (NRC 1975, 1981).

The Ca content varied from 1.12 to 2.48%, with *A. vesicaria* containing significantly higher amounts of Ca compared to the other species. All species had Ca levels that exceeded the requirements (0.18%–0.44%) for beef cattle (NRC 1976), 0.138% for goats (NRC 1981), and 0.21–0.52% for sheep (NRC 1981). The levels of P (0.18–0.28%) were satisfactory in comparison to 0.18% considered adequate for dry cows (NRC 1976) but were below the 0.39% level considered adequate for lactating cows (NRC 1976). A similar situation existed for sheep with requirements of 0.16–0.37% (NRC 1975). This was also true for goats (NRC 1981). The concentration of Mg was lowest in *A. rhagodioides* (0.59%) and highest (0.84%) in *A. vesicaria*. The range of Mg was well above the Mg requirements (0.04–0.18%) of beef cattle (NRC 1976), sheep and goats (0.04–0.08%) (NRC 1975, 1981).

Among the micro-elements, the level of Fe ranged between 250–485 µg/g dry leaves, which is higher than the values reported for some *Atriplex* species (Wallace et al. 1982). Although minimal requirement for Fe has not been established, 80–100 µg/g feed is considered ample for beef cattle (NRC 1976) and 30–50 µg/g dry matter for sheep and goats (NRC 1975, 1981). *Atriplex* leaves are, therefore, adequate in Fe for beef cattle, sheep, and goats. In contrast to Fe, the contents of Zn and Cu tended to be lower than the values of Wallace et al. (1982). Only Mn levels were relatively comparable with the data of above authors. The level of Zn in

Atriplex leaves was well above the suggested requirement level (20–30 µg/g of diet dry matter) for beef cattle (NRC 1976), 10 µg/g for goats (NRC 1981) and 35–50 µg/g for sheep (NRC 1975). Cu content was also well above the 4 µg/g of diet dry matter suggested as a requirement for beef cattle (NRC 1976) and 5 µg/g feed suggested for sheep (NRC 1975). Similarly, the Mn level exceeded the 1–10 µg/g requirement for beef cattle (NRC 1976) and 20–40 µg/g for sheep (NRC 1975).

Amino Acid Composition

The amino acid contents of *Atriplex* leaves have been studied as a possible source of plant protein (Silva and Pereira 1976) and for providing information for taxonomic studies (Cozic-Trichet and Goas 1969). In general, there is very limited information on the amino acid profile of *Atriplex* leaf protein. Because of these reasons, the amino acid composition of the 6 *Atriplex* leaf proteins was studied and the results are shown in Table 3. Considerable variations in the concentrations of some amino acids were observed. Total sulphur amino acids (methionine + cystine) were the first limiting essential amino acids in all the *Atriplex* species. The chemical score (FAO/WHO 1973) ranged between 45–61, with *A. undulata* showing the highest chemical score. Lysine, which is the most deficient essential amino acid in cereal proteins, was present in levels higher than those of cereal protein. However, it was slightly lower than the FAO/WHO reference protein (1973), except *A. vesicaria* protein, which contained slightly higher lysine than that in FAO/WHO (1973) pattern. In general, the lysine contents were between 75–>100% of the reference protein. These results indicated that *Atriplex* leaf protein has a good amino acid profile and these proteins could supplement those of cereal proteins. In general, these findings are similar to those of Silva and Pereira (1976).

ADF, DDM, DE and ME

The ADF values (Table 4) ranged from a minimum value of 13.0% in *A. undulata* to a maximum value of 18.5% in *A. lentiformis*. The DDM values ranged between 74.5%–78.8%. Data on the

Table 4. Acid Detergent Fiber (ADF), Digestible Dry Matter (DDM), Digestible Energy (DE) and Metabolizable Energy (ME) of *Atriplex* leaves (dry weight basis).

<i>Atriplex</i> species	ADF ¹ %	DDM ² %	DE ²		ME ³ (M cal/Kg)
			%	(M cal/Kg)	
<i>A. nummularia</i>	15.5	76.8	74.9	3.314	2.717
<i>A. canescens</i>	14.1	77.9	76.0	3.361	2.756
<i>A. vesicaria</i>	13.8	78.2	76.3	3.373	2.765
<i>A. rhagodioides</i>	15.2	77.1	75.2	3.326	2.727
<i>A. lentiformis</i>	18.5	74.5	72.6	3.215	2.636
<i>A. undulata</i>	13.0	78.8	76.9	3.399	2.787

¹ADF determined following the procedure of Goering and Van Soest (1970).

²Calculated by the prediction equation of Fomesbeck et al. (1984).

³Calculated by the equation, ME (M cal/Kg) = DE (M cal/Kg) × 0.82 (Gonzalez and Everitt 1982).

DDM values for *Atriplex* leaves alone is scarcely reported in the literature. However, values for total digestible nutrients (TDN %) in *Atriplex* leaves are reported to be 40.2% and 45.5% for cattle and sheep, respectively (NAS 1971). The DDM values were comparable to in-vitro dry matter digestibility values (66.8%–77.0%) for moth bean plant (*Vigna aconitifolia*), a forage crop of the arid and semiarid areas (Arora et al. 1975). The DE (M cal/Kg) levels of all the species were higher than 2.20 and 2.50 M cal/Kg required to meet the needs of dry and lactating cows, respectively (NRC 1976) and approximate to the needs of sheep and goats (NRC 1975, 1981). The DE values, as expected, were generally higher than most other forage crops but comparable to that of prickly pear cactus (Gonzalez and Everitt 1982). The ME values were also higher than values, 1.82–1.86 ME/kg dry matter, for the whole browse (*Atriplex* species) (Gohl 1981). Although the methods used to estimate

energy value are based on an alfalfa equation, these data suggest that *Atriplex* leaves have good digestibility and energy values.

In conclusion, leaves of *Atriplex* species have a good nutritional potential as a feed for livestock. However, feeding trials are needed to determine their palatability and, if necessary, to ascertain means of increasing their palatability.

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