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Nutritive Quality of Some Salt-Tolerant *Atriplex* Species in Terms of Nutritional and Anti-Nutritional Components

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Abstract

The objective was to study the relationships between the cell-wall constituents (neutral detergent fiber NDF, acid detergent fiber ADF and lignin) and crude protein (CP), soluble nitrogen and anti-nutritional components of five Atriplex species grown on salty soil and irrigated with saline water. However, organic matter (OM), total carbohydrate (total CHO), non-fiber carbohydrate (NFC), nitrogen solubility and gross energy (GE) were also determined to evaluate the nutritive quality of the experimental species. The highest concentration (g/kg DM) of the CP was recorded in A. semibaccata, and the descending order was A. semibaccata 189>A. leucoclada and A. molles 175>A. canescens 128>A. halimus 105. Among the studied species, A. canescens had the highest contents of hemicelluloses, OM, total CHO, NFC and GE. The highest cell-wall constituents were observed in A. halimus and the lowest contents in A. molles. The highest concentrations of total phenols and tannins were noted in A. canescens, A. leucoclada and A. semibaccata and the lowest concentrations in A. halimus and A. molles. Soluble nitrogen and CP values were negatively correlated with cell wall constituents. Nitrogen solubility was negatively correlated with tannins. All species could be used as protein supplements for ruminants in dry regions and saline lands.

Keywords*: carbohydrate, fiber, forage, protein, salinity, tannin.*

1. Introduction

The dry season in the arid and semi-arid regions is the most demanding restriction, characterized by insufficient and poor-quality feed [1]. The grazing animals in these regions depend largely on annual herbaceous plants and crop residues containing poorer amounts of protein and other essential nutrients, so that a high rank of animal production is not forever achievable. Tree leaves have been used as protein and minerals supplements to the low quality roughages in the tropics during the dry period [2, 3, 4]. Perennial shrub species are important sources of feeds for small ruminants in these regions during the dry seasons and supply vegetation with superior nutritive value [5].These shrubs are tolerant to the harsh environmental conditions and have possibility for assuaging some of the feed lacks and deficiencies assayed [6, 7]. However, leaves of shrubs and trees provide the required “by pass” protein and some addition compounds which decrease enteric methane production, and therefore increase the animal productivity [8]. *Atriplex* species (salt-bush) are adapted to arid rangelands conditions and very imported feed reserve for ruminants, used as protein supplements to sheep and goats [9, 10], and could be utilized for range improvement in arid, semi-arid and saline lands and browsed nearly the year around [11].*Atriplex nummularia* was used with *Acacia cyanophylla* or spineless cactus hay for feeding sheep [9, 12] as nitrogen supplement for improving the nutritive value of the diets and therefore enhancing animal growth. Feeding of Damascus

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does on *Atriplex lentiformis* hay had no effects on their reproductive characteristics [13]. The nutrient costs for shrub production from *A. nummularia* were lower than those for alfalfa hay as a supplement for goat production [10]. Replanting of dry rangelands in the Syrian steppe with *Atriplex* species is recommended for rehabilitation, providing complementary feed sources and soil protection against wind erosion and the barley-*Atriplex* systems have potential to provide sustainable production in degraded steppe areas [14].

There is a dearth of information in the literature on the correlations of the nutritional components with anti-nutritional components of the *Atriplex* species grown in salty soil and irrigated with saline water, thus the studies on these correlations are necessary and valid to evaluate the quality of these salt-bushes. Therefore, the main objectives ware to determine the quality of some perennial *Atriplex* species grown in salty soil and irrigated with saline water in terms of their chemical composition, cell wall constituents, total carbohydrates, nitrogen solubility and anti-nutritional components and study the relationship between the nutritional and anti-nutritional components.

2. Materials and Methods

2.1. Tested plant materials

Five perennial species of *Atriplex* (*Atriplex halimus, A. canescens, A. leucoclada, A. semibaccata, A. molles*), grown on salty soils (EC = 31.7 dS/m, pH = 7.54, total carbonate = 21%, organic matter = 0.39%, Na =191 meq/L, Mg = 77.5 meq/L, Ca = 39.5 meq/L, CL = 280 meq/L at 25-50 cm depth; silt-loam texture) at the "Farm of 7th April" in north-eastern of Syria (39^{o} 41.3 E, 36.3^{o} 34.1 N, 203 m above sea level), with an average annual rainfall of 140 mm, and were irrigated bi-weekly from planting to harvest with saline water (EC = 15-22 dS/m, pH = 7.35-8.29, Na = 40-80 meq/L, Mg = 36-90 meq/L, Ca = 12.5-19.5 meq/L, CL = 76-165 meq/L) were selected.

Outside branches of the 5-year-old plants were cut at vegetative growth stage at 40 cm distance from the tip with 4 replicates (n = 4) (4 plants each) for each species.

The collected plants for each replicate of each species were mixed well, dried at 20-25 ^{o}C for one week, ground to pass through a 1-mm sieve and stored frozen at -20 ^{o}C in sealed nylon bags for later analyses.

2.2. Determination of components

Standard methods as described in AOAC [15] were used for determination of dry matter (DM), ash, ether extract (EE) and crude protein (CP). Nitrogen (N) concentration was measured by the Kjeldahl method, and CP concentration was calculated as N% x 6.25. Organic matter (OM) was calculated as: OM = DM – ash. Cell-wall constituents (neutral-detergent fiber, NDF; acid-detergent fiber, ADF and lignin) were analyzed [16].

Both NDF and ADF were not ash corrected. Acid-detergent residue was treated with H_2SO_4 for lignin estimation. Hemicellulose and cellulose were calculated from the differences between NDF and ADF and between ADF and lignin, respectively.

The total carbohydrate (CHO) was calculated according to Yisehak and Janssens [17] as:

$$\text{Total CHO (\%)} = 100 - (\%\ \text{CP} + \%\ \text{EE} + \%\ \text{ash} + \%\ \text{lignin})$$

Non-fiber carbohydrate (NFC) was calculated as:

$$\text{NFC} = \text{DM} - (\text{CP} + \text{NDF} + \text{fat} + \text{ash})$$ [18].

Gross energy (GE) was estimated by a calorimeter (CAL^{2K} Calorimeter). Buffer soluble nitrogen (BS-N), non-protein nitrogen (BS-NPN) and nitrogen solubility were determined according to Makkar and Becker [19]. Total phenols and tannins were determined by spectrophotometric methods [20].

2.3. Statistical analyses

A one-way variance analysis was used in this experiment to see the mean differences between the studied *Atriplex* species for nutritive and anti-nutrient contents. Data of chemical measurements were subjected to one-way analysis of variance (ANOVA) test, using a Statview-IV program (Abacus Concepts, Berkeley, CA, USA). Means were separated using the Fisher's least significant difference test at the 95% confidence level. Correlation coefficients between the studied parameters were calculated.

3. Results and discussion

In this study, it was found that the nutrient composition of the experimental salt-*Atriplex* species varied.

The changes in some nutritional components and cell wall constituents of the experimental species are illustrated in Table 1. The descending order in the crude protein values was *A. semibaccata*> *A. leucoclada and A. molles*> *A. canescens*> *A. halimus*.*A. molles*had the highest content of Ash.

The species *A. halimus* had the lowest ether extract content among the all studied species. The highest NDF, ADF and lignin contents were observed in *A. halimus* and lowest in *A. molles*. Lignin content in *A. cannescens*, *A. leucoclada* and *A. semibaccata*was similar. The results indicated that crude protein was negatively (r = -0.70, P < 0.001) correlated with cell wall constituents (NDF, ADF and lignin).

Table 1. Nutritive components and cell wall constituents of the experimental salt-*Atriplex* species (g/kg DM).

Species	CP	A	EE	NDF	ADF	L
A. halimus	105.4^{d}	253.8^{b}	2.39^{e}	494.1^{a}	331.5^{a}	81.7^{a}
A. canescens	127.5^{c}	193.8^{e}	3.67^{d}	450.5^{b}	267.2^{c}	56.1^{bc}
A. leucoclada	175.3^{b}	223.0^{d}	10.38^{b}	408.4^{c}	261.7^{d}	57.2^{b}
A. semibaccata	188.6^{a}	240.3^{c}	11.06^{a}	445.8^{b}	287.2^{b}	54.5^{c}
A. molles	174.6^{b}	263.1^{a}	5.54^{c}	372.6^{d}	221.2^{e}	47.7^{d}
SEM	0.21	0.38	0.15	2.47	1.08	0.79
P-*value*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

DM: dry matter; CP: crude protein; EE: ether extract; A: ash; NDF: neutral-detergent fiber; ADF: acid-detergent fiber; L: lignin.
SEM: standard error of the means.
$^{a,b,c,d...}$Means in the same column for each parameter with different superscripts are different at P< 0.05.

The changes in nitrogen forms, nitrogen solubility and anti-nutritional components of the studied species are illustrated in Table 2. BS-N and BS-NBN contents of the studied species ranged from 8.3-14.3 and 7.7-12.7, respectively. Among the experimental species, *A. molles* had the highest (P < 0.05) values of BS-N and the lowest tannins content. The results indicated that BS-N was negatively (r = -0.90, P < 0.0001) correlated with cell wall constituents (NDF, ADF and lignin).
The highest N-solubility was observed in *A. canescens* (58%) and followed by *A. molles* and *A. halimus* (average 50%), whereas the lowest N-solubility (41%) was recorded in *A. leucuclada* and *A. semibaccata* (average 41%).
Both tannins and total phenols have been demonstrated to be detrimental to normal protein degradation in the rumen. The highest total phenols and tannins contents were observed in *A. canescens*, *A. leucoclada* and *A. semibaccata* (average 11.5 and 1.9-5.0 g/kg DM, respectively), whereas the lowest (average 8.1 and 0.16-0.68 g/kg DM, respectively) were recorded in *A. halimus* and *A. molles* (Table 2).

Table 2. Nitrogen forms, nitrogen solubility and anti-nutritional components of the experimental salt-*Atriplex* species (g/kg DM).

Species	Total N	BS-N	BS-NPN	N-solubility (%)	% NPN	Total phenols	Total tannins
A. halimus	16.87^{d}	8.29^{e}	7.67^{e}	49.1^{c}	45.5^{a}	7.96^{e}	0.68^{d}
A. canescens	20.40^{c}	11.92^{c}	8.91^{d}	58.4^{a}	43.7^{b}	11.91^{b}	2.06^{b}
A. leucoclada	28.05^{b}	11.47^{d}	9.39^{c}	40.9^{e}	33.5^{c}	10.31^{c}	1.88^{c}
A. semibaccata	30.18^{a}	12.63^{b}	9.87^{b}	41.8^{d}	32.7^{d}	12.36^{a}	4.96^{a}
A. molles	27.94^{b}	14.34^{a}	12.70^{a}	51.5^{b}	45.5^{a}	8.21^{d}	0.16^{e}
SEM	0.03	0.02	0.03	0.10	0.14	0.02	0.02
P-*value*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

BS-N: buffer soluble nitrogen; BS-NPN: buffer soluble non-protein nitrogen.
SEM: standard error of the means.
$^{a,b,c,d...}$Means in the same column for each parameter with different superscripts are different at P< 0.05.

The results indicated that N-solubility was negatively correlated with tannins (r = -0.45, P = 0.044). The changes in the cellulose, hemicelluloses, organic matter, energy and carbohydrates of the experimental *Atriplex* species are shown in Table 3. The highest cellulose content was recorded in *A. halimus* and followed by *A. semibaccata*, whereas the lowest cellulose content was reported in *A. molles* followed by *A. canescens* and *A. leucoclada*. Among the experimental species, *A. canescens* had the highest content of hemicelluloses compared with other species (average 155 g/kg DM). However, *A. canescens* had the highest contents of OM, CHO, NFC and GE compared with other experimental species.

Table 3. Changes in the hemicellulose (HC), cellulose (CL), organic matter (OM), total carbohydrate (CHO) and non-fiber carbohydrate (NFC) (g/kg DM) and gross energy (GE; MJ/kg DM) of the experimental salt-Atriplex species

Species	HC	CL	OM	CHO	NFC	GE
A. halimus	162.6^{b}	249.8^{a}	676.8^{d}	631.3^{b}	74.9^{c}	13.79^{d}
A. canescens	183.4^{a}	211.1^{c}	725.4^{a}	706.8^{a}	143.7^{a}	15.21^{a}
A. leucoclada	146.8^{d}	204.5^{d}	696.6^{b}	621.6^{c}	102.5^{b}	14.49^{b}
A. semibaccata	158.6^{bc}	232.7^{b}	680.5^{c}	591.6^{e}	35.1^{d}	13.96^{cd}
A. molles	151.5^{cd}	173.5^{e}	647.5^{e}	607.3^{d}	94.7^{b}	14.35^{bc}
SEM	2.73	1.13	0.37	0.87	2.58	0.12
P-*value*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

SEM: standard error of the means.

$^{a,b,c,d,...}$Means in the same column for each parameter with different superscripts are different at $p< 0.05$

4. Discussion

Crude protein concentration ranged from 189-105 g/kg DM, with *A.semibaccala* having the highest content and *A. halimus* the lowest. El-Waziry [21] and Sallam *et al.* [22] reported that the crude protein contents in trefoil hay and alfalfa hay as commonly used forages for livestock were 145 and 182 g/kg DM, respectively. The minimum crude protein level of 80 g/kg DM is required for rumen microorganisms function [23]. Therefore, the experimental *Atriplex* species appear to be a good protein source for ruminants.

Ash concentrations in the experimental species were high and ranged from194-263 g/kg DM. The studied species are extremely tolerate the soil salinity [24], and could be provide the animal with necessary minerals. Kumara Mahipala *et al.* [2] and Haddi [25] reported that salt-tolerant species of *Atriplex nummularia, Rhagodia eremaea* and *Atriplex amnicola* and species of *Salsola vermiculata*, *Atriplex halimus* and *Sueada mollis* had high contents of ash (157-179 and 150-323 g/kg DM, respectively).

The NDF concentrations of all experimental species were fell below 600 g/kg DM, a level above which feed intake of ruminants is influenced [26]. Higher values of NDF and ADF result in lower digestibility [27]. The high structural carbohydrate content affects the number of nutrients consumed, thereby increasing feed digestibility [28, 29]. Alonso-Diaz *et al.* [30] indicated that NDF concentrations in tree leaves of *Lysiloma latisiliquum*, *Acacia pennatula*, *Piscidia piscpula* were negatively correlated with dry matter digestibly. However, Jung *et al.* [31] and Moore and Jung [32] reported that the lignin concentration of forages is negatively related to the extent of digestion. This inhibition likely results from a reducing in the microbial growth rate and microbial enzyme activity in the rumen [33].

The N-solubility values (41-58%) obtained from the experimental species were comparable with the reports of Al-Masri [34] (37-52%) for some range plants (*Artemisia herba-alba*, *Noaea mucronata*, *Lavandula officialis*, *Astragalus spinosus* and *Capparis spinosa*). Hussain *et al.* [35] reported that BS-N rates ranging between 25-40% of the total nitrogen in leaves of some *Sesbania* species. The content of crude protein in the studied species can be misleading, because up to 46% of this fraction can be non-protein nitrogen (NPN).

The experimental *Atriplex* species have low contents of total phenols and tannins (7.96-12.36 g/kg DM and 0.16-4.96 g/kg DM, respectively). Getachew *et al.* [36] indicated that plants containing total tannins and phenols levels up to 20 and 40 g/kg DM, respectively, are not anticipated to precipitate protein and, therefore, are not likely to adversely affect ruminant productivity.

5. Conclusion

Based on the results of this research it is concluded that the highest content of crude protein was observed in *A. semibaccata*. *A. canescens* had the highest values of N-solubility, hemicellulose, OM, CHO, NFC and energy. The highest contents of cell-wall constituents were observed in *A. halimus*. The studied species had low concentrations of anti-nutritional components (total phenols and tannins), and N-solubility was negatively correlated with tannins. The experimental *Atriplex* species grown on salty soil and irrigated with saline water are suitable as protein feed supplements for ruminants in arid and semi-arid regions and saline lands.

Compliance with Ethics Requirements. Author declares that he respects the journal's ethics requirements. Author declares that he has no conflict

of interest and all procedures involving human or animal subjects respect the specific regulation and standards.

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