

# Chemical composition, *in situ* ruminal degradability and post-ruminal disappearance of dry matter and crude protein from the halophytic plants *Kochia scoparia*, *Atriplex dimorphostegia*, *Suaeda arcuata* and *Gamanthus gamacarpus*

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## Abstract

Samples of *Kochia* (*K. scoparia*), *Atriplex* (*A. dimorphostegia*), *Suaeda* (*S. arcuata*) and *Gamanthus* (*G. gamacarpus*) were collected and analyzed for chemical composition including crude protein (CP), ether extract (EE), ash, neutral detergent fiber (NDFom), acid detergent fiber (ADFom), non-protein N (NPN), Ca, P, Na, K, Cl, Mg, Fe, Cu and Se. In addition, *in situ* ruminal degradability and post-ruminal disappearance of dry matter (DM) and CP of the samples using a mobile bag technique were determined. Results indicate that the chemical composition of *Kochia* and *Atriplex* was notably different from those of *Suaeda* and *Gamanthus*. All of these halophytic plants had high concentrations of Na, K, Cl, Cu and Se, and low levels of Ca, P and Mg. The rapidly degradable fractions of DM

*Abbreviations:* ADFom, acid detergent fiber; CP, crude protein; DM, dry matter; EDDM, effective ruminal degradability of DM; EDCP, effective ruminal degradability of CP; EE, ether extract; NDFom, neutral detergent fiber; NPN, non-protein N

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and CP (g/g) of *Kochia* (0.31 and 0.35, respectively) and *Atriplex* (0.39 and 0.50, respectively) were lower than for *Suaeda* (0.53 and 0.55, respectively) and *Gamanthus* (0.56 and 0.66, respectively). Ruminal DM and CP disappearance of *Kochia* (444 and 517 g/kg, respectively) and *Atriplex* (472 and 529 g/kg, respectively) were lower ( $P < 0.05$ ) than those of *Suaeda* (553 and 577 g/kg, respectively) and *Gamanthus* (663 and 677 g/kg, respectively) ( $P < 0.05$ ) using the mobile bag technique. *Suaeda* had the lowest ( $P < 0.05$ ) NDFom and ADFom disappearance (214 and 232 g/kg, respectively) in the rumen. *Kochia scoparia* and *Atriplex dimorphostegia* have more beneficial chemical nutritive components and digestible values versus *Suaeda arcuata* and *Gamanthus gamacarpus*.

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**Keywords:** Halophytic plants; Chemical composition; Degradability

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## 1. Introduction

Halophytes are plants that have the ability to survive in saline and alkaline soils and are drought resistant. In many areas of the world, native and introduced halophytes are forage resources, especially for sustaining grazing livestock when other feeds are scarce (Cohen et al., 1989; El-Shatnawi and Turuk, 2002; Ben Salem et al., 2004). Halophytic species within 26 families were identified in central Iran and more than 70% belonged to the *Chenopodiaceae* family (Rezvani Moghadam and Koocheki, 2003). There has been increased interest in planting halophytic plants as forage in the salt stressed agricultural regions to improve animal production. However, many factors affect their chemical composition and nutritive value (El Shaer, 1981; El-Shatnawi and Abdullah, 2003).

*Kochia* is a potentially valuable forage plant on arid and semiarid lands. Madrid et al. (1996) reported that *Kochia* could be substituted for barley straw in diets fed to goats during the warm season in Mediterranean regions. The chemical composition of *Kochia* changes with maturity (Cohen et al., 1989), but the crude protein (CP) content and its digestibility have been reported to be comparable with alfalfa in sheep (Sherrod, 1973).

Many species of *Atriplex* are excellent livestock feeds because of their relatively high CP content (El Shaer, 1981; El-Shatnawi and Abdullah, 2003). There is wide variation in the mineral content of *Atriplex* due to differences in species, geographical regions and stage of growth (Gihad and El Shaer, 1992). Hopkins and Nicholson (1999) reported that finishing lambs fed *Atriplex nummularia*, supplemented with either hay or grain, produced acceptable meat based on both objective and subjective criteria.

Biomass of *Suaeda* is able to replace conventional grass hay in fattening diets for sheep (Swingle et al., 1996). *Suaeda fruticosa* contains the lowest ash and silica, and the highest ether extract (EE), Ca, Na, K, and Mg, versus other halophytic plants, and it is palatable to sheep (El Shaer, 1981).

To the best of our knowledge, the nutritive value of *Gamanthus* and its chemical components have not been evaluated. Salts accumulate in the seeds of *Gamanthus* and traditionally the leaves and seeds are used in feeding sheep or goats in central Iran.

The objective of this study was to evaluate four Iranian halophytic plants (*i.e.*, *Kochia scoparia*, *Atriplex dimorphostegia*, *Suaeda arcuata* and *Gamanthus gamacarpus*) for their chemical composition and *in situ* ruminal and post-ruminal disappearance of DM and CP.

## 2. Material and methods

### 2.1. Sampling and chemical composition

This experiment was conducted using halophytic plants from the central Iran desert, where the climate is classified as dry arid with average annual rainfall of 169.4 mm and maximum annual temperature of 35 °C. In August 2003, within each sampling area, ten 100 m transects were randomly selected. On each transect, five shrubs for each halophytic plant were randomly selected and clipped. *Kochia*, *Atriplex* and *Suaeda* were harvested at mid-bloom stage as hay, and *Gamanthus* was harvested as leaves and seeds. Samples of each halophytic plant were dried in a forced-air oven (56 °C), ground to pass a 2 mm screen and analyzed for total N (Kjeldahl method, Kjeltac 2300 Autoanalyzer, Foss Tecator AB, Hogans, Sweden), neutral detergent and acid detergent fiber ([NDFom and ADFom], Van Soest et al., 1991), ether extract ([AOAC, 2000], ID 920.39), ash ([AOAC, 2000], ID 942.05), Ca, Cu, Fe, and Mg ([AOAC, 2000], ID 968.08), Na and K ([AOAC, 2000], ID 956.01), Cl ([AOAC, 2000], ID 943.01), P ([AOAC, 2000], ID 965.17), Se ([AOAC, 2000], ID 996.16). Sodium sulfite and an alpha amylase were not used in the NDFom assay (Udén et al., 2005). Non-protein N was chemically determined using trichloroacetic acid (1 g/100 mL) solution (Licitra et al., 1996).

### 2.2. In situ ruminal degradability of DM and CP

For *in situ* techniques, four Holstein steers (24 ± 3 months of age and 450 ± 11 kg of body weight) with ruminal fistula and T-shaped duodenal cannulae were used and housed individually in concrete floored pens. Table 1 shows the ingredient composition of the total mixed ration (TMR) offered to steers in two equal feedings at 08:00 and 16:00 h.

Dried samples (5 g) were weighed into 12 cm × 19 cm polyester bags (50 µm pore size), and 8 bags were prepared for each sample and each incubation time. Ruminal incubation times were 2, 4, 8, 16, 24, 48, 72 and 96 h. All bags were inserted at the same time, just before the morning feeding (*i.e.*, 08:00 h). Bags representing 2 and 4 h were soaked in water (39 °C for 15 min), before incubation. At the end of each incubation period, bags were rinsed

Table 1  
Ingredients of total mixed ration (TMR) diet (as fed)

	Per steer per day
Alfalfa hay	2.5 kg
Corn silage	7 kg
Barley straw	0.5 kg
Barley grain	1064 g
Corn grain	732 g
Wheat bran	168 g
Mineral and vitamin premix <sup>a</sup>	32 g

<sup>a</sup> Composition of mineral and vitamin premix: Ca, 196.0 g/kg; P, 96.0 g/kg; Mg, 19.0 g/kg; Fe, 3.0 g/kg; Na, 71.0 g/kg; Cu, 0.3 g/kg; Mn, 2.0 g/kg; Zn, 3.0 g/kg; Co, 0.1 g/kg; I, 0.1 g/kg; Se, 0.01 g/kg and Vitamin A, 500,000 IU/kg; Vitamin D, 100,000 IU/kg; Vitamin E 100 IU/kg.

with cold tap water until the rinse water was clear. Zero time disappearance was obtained by washing unincubated bags in a similar way. All washed bags were dried in a forced-air oven at 56 °C for 48 h. Disappearance of DM and CP at each incubation time was calculated from the proportion remaining after incubation in the rumen. The N concentration of sample residues was determined by a Kjeldahl method (Kjeltec 2300 Autoanalyzer, Foss Tecator AB, Hogans, Sweden).

### 2.3. *In situ* ruminal disappearance of NDFom, ADFom, ash and EE

Samples (1.2 g) were weighed into 3 cm × 6 cm of polyester bags (50 µm pore size). The bags (8 bags/sample) were placed into plastic mesh cylinders (26 cm × 8 cm, 0.57 mm pore size) and incubated in the rumen for 16 h. After incubation, bags were rinsed with cold tap water until the rinse water was clear and dried for 48 h in a 56 °C forced-air oven. Dried samples were analyzed for NDFom and ADFom ([NDFom and ADFom] Van Soest et al., 1991), EE ([AOAC, 2000], ID 920.39), and ash ([AOAC, 2000], ID 642.05).

### 2.4. *In situ* ruminal and post-ruminal disappearance of DM and CP using the mobile bag technique

Ruminal and post-ruminal disappearance of DM and CP of the halophytic plants was determined by incubation of the 28 bags for each sample in the ventral sac of the rumen for 12 h. After incubation, 12 bags for each sample were used to determine ruminal disappearance and 16 bags for each sample were introduced into the small intestine through the duodenal cannulae at a rate of one bag per 30 min. Upon recovery from the rumen and feces, bags were rinsed with cold tap water until the rinse water was clear and dried for 48 h in a 56 °C forced-air oven (De Boer et al., 1987). Dried bags were weighed to determine ruminal DM disappearance. The N concentration of sample residues was determined by the Kjeldahl method (Kjeltec 2300 Autoanalyzer, Foss Tecator AB, Hogans, Sweden).

### 2.5. Calculations and statistical analysis

Degradation of DM and CP was calculated using the equation of Ørskov and McDonald (1979) as:  $P = a + b(1 - e^{-ct})$ , where  $P$  is the disappearance rate at time  $t$ ,  $a$  the rapidly degradable DM or CP fraction,  $b$  the slowly degradable DM or CP fraction in the rumen,  $c$  the rate constant of degradation of  $b$ , and  $t$  is the time of incubation.

Effective degradability of DM (EDDM) and CP (EDCP) was calculated using the equation of Ørskov and McDonald (1979) as:  $EDDM$  or  $EDCP = a + [b \times c/(c + k)]$ , where  $k$  is the fractional outflow rate from the rumen (per hour) and  $a$ ,  $b$ , and  $c$  are as described above. The  $k$  values used to calculate EDM and EDCP were 0.02, 0.04, and 0.06 h<sup>-1</sup>, which is a normal range of rates observed in ruminants fed forages (Ørskov and McDonald, 1979). Calculations as described by Subuh et al. (1996) were used for ruminal, post-ruminal and total tract DM and CP disappearance using the mobile bag technique.

Data of ruminal and post-ruminal disappearance were analyzed by SAS (1987) using the general linear models procedure as a completely randomized design with steers as replicates.

Statistical differences between the four halophytic plants were determined using Duncan's multiple range test.

### 3. Results

#### 3.1. Chemical composition

The CP content (Table 2) of Kochia (117 g/kg) was higher ( $P<0.05$ ) than Suaeda (75 g/kg), Gamanthus (68 g/kg) and Atriplex (62 g/kg). Suaeda had the highest ( $P<0.05$ ) EE at 24.1 g/kg, and all plants were relatively high in ash. Atriplex was highest ( $P<0.05$ ) in NDFom and ADFom (530 and 427 g/kg, respectively), however Atriplex was similar in NPN concentration (2.2 g/kg) to Suaeda (3.4 g/kg), and lower ( $P<0.05$ ) versus Kochia (4.8 g/kg) and Gamanthus (5.7 g/kg). The plants were high in Na, Cl, K, Cu and Se, but their Ca, Mg and Fe content was relatively low. Se concentration was highest ( $P<0.05$ ) in Gamanthus at 44.6 mg/kg while Cu and Fe concentrations were highest ( $P<0.05$ ) and lowest in Suaeda ( $P<0.05$ ) at 79.6 and 57.7 mg/kg, respectively.

#### 3.2. In situ ruminal degradability of DM and CP

The rapidly degradable DM fraction (Table 3) was highest ( $P<0.05$ ) for Gamanthus at 0.56 g/g. Suaeda had a lower ( $P<0.05$ ) slowly degradable DM fraction at 0.18 g/g compared with the other plants. The disappearance rate of DM was lowest ( $P<0.05$ )

Table 2  
Chemical composition (DM basis) of various halophytic plants ( $n = 3$ )

	Halophytes				S.E.M.
	Kochia	Atriplex	Suaeda	Gamanthus	
DM (g/kg)	338.0c	375.0b	310.0c	550.0a	14.6
CP (g/kg)	117.0a	62.0c	75.0b	68.0bc	6.1
EE (g/kg)	12.5b	9.2b	24.1a	13.3b	2.3
Ash (g/kg)	117d	169c	326b	414a	10.4
NDFom (g/kg)	427b	530a	287c	303c	12.9
ADFom (g/kg)	313b	427a	223c	83d	9.1
NPN (g/kg)	4.8ab	2.2c	3.4bc	5.7a	1.1
Ca (g/kg)	9.5b	6.8b	14.4a	16.6a	2.0
P (g/kg)	1.4ab	1.6a	0.8c	1.0bc	0.2
Na (g/kg)	17.7d	41.1c	68.3b	121.0a	5.1
Cl (g/kg)	23.7a	26.7a	29.3a	28.0a	3.5
K (g/kg)	9.0b	15.3a	13.7a	7.9b	1.3
Mg (g/kg)	1.4a	1.3a	1.7a	1.1a	0.3
Fe (mg/kg)	317.0a	333.0a	57.7b	333.0a	12.4
Cu (mg/kg)	30.1c	36.0c	79.6a	64.3b	4.1
Se (mg/kg)	5.4c	6.7c	22.3b	44.6a	2.9

Means in the same row with different letters differ ( $P<0.05$ ). DM, dry matter; CP, crude protein; EE, ether extract; NDFom, neutral detergent fiber; ADFom, acid detergent fiber; NPN, non-protein N.

Table 3

*In situ* DM degradation parameters and effective degradability of various halophytic plants

	Halophytes				S.E.M.
	Kochia	Atriplex	Suaeda	Gamanthus	
Parameters <sup>a</sup>					
<i>a</i> (g/g)	0.31d	0.39c	0.53b	0.56a	0.01
<i>b</i> (g/g)	0.37a	0.27b	0.18c	0.31b	0.02
<i>c</i> (h <sup>-1</sup> )	0.09a	0.09a	0.04b	0.07a	0.01
Effective degradability (g/g) <sup>b</sup>					
EDDM2	0.61b	0.61b	0.65b	0.80a	0.04
EDDM4	0.57b	0.58b	0.62b	0.76a	0.03
EDDM6	0.53b	0.55bc	0.60b	0.73a	0.04

Mean in the same row with different letters differ ( $P < 0.05$ ).

<sup>a</sup> *a*, rapidly degradable DM fraction; *b*, slowly degradable fraction; *c*, rate constant of degradation of *b* fraction.

<sup>b</sup> EDDM, effective degradability of DM. EDDM2, EDDM4 and EDDM6 were calculated as  $k = 0.02, 0.04, 0.06 \text{ h}^{-1}$  ruminal, respectively ( $k$  is the ruminal outflow rate).

for Suaeda at  $0.04 \text{ h}^{-1}$ . The EDDM calculated at  $0.02, 0.04$  and  $0.06 \text{ h}^{-1}$  outflow rates showed similar differences among the halophytic plants. The EDDM of Kochia was similar to that of Atriplex and Suaeda, but lower ( $P < 0.05$ ) than that of Gamanthus.

Table 4 shows that the rapidly degradable CP fraction (g/g) of Atriplex and Suaeda (0.50 and 0.55, respectively) was intermediate to Kochia and Gamanthus (0.35 and 0.66, respectively). There was no difference ( $P > 0.05$ ) between the slowly degradable CP fraction (g/g) for Atriplex, Gamanthus and Suaeda (0.23, 0.22 and 0.17, respectively) but it was greatest ( $P < 0.05$ ) for Kochia (0.49). The EDCP of Gamanthus was highest ( $P < 0.05$ ) at the three outflow rates.

Table 4

*In situ* CP degradation parameters and effective degradability of various halophytic plants

	Halophytes				S.E.M.
	Kochia	Atriplex	Suaeda	Gamanthus	
Parameters <sup>a</sup>					
<i>a</i> (g/g)	0.35d	0.50c	0.55b	0.66a	0.02
<i>b</i> (g/g)	0.49a	0.23b	0.17b	0.22b	0.03
<i>c</i> (h <sup>-1</sup> )	0.08a	0.09a	0.05a	0.07a	0.02
Effective degradability (g/g) <sup>b</sup>					
EDCP2	0.74b	0.69bc	0.67c	0.83a	0.03
EDCP4	0.68b	0.66b	0.64b	0.80a	0.03
EDCP6	0.63b	0.64b	0.63b	0.78a	0.03

Mean in the same row with different letters differ ( $P < 0.05$ ).

<sup>a</sup> *a*, rapidly degradable fraction; *b*, slowly degradable fraction; *c*, rate constant of degradation of the *b* fraction.

<sup>b</sup> EDCP, effective degradability of CP. EDCP2, EDCP4 and EDCP6 were calculated as  $k = 0.02, 0.04, 0.06 \text{ h}^{-1}$ , respectively ( $k$  is the ruminal outflow rate).

Table 5

*In situ* ruminal and post-ruminal disappearance of dry matter and crude protein (g/kg of DM and CP, respectively) of halophytes

	Halophytes				S.E.M.
	Kochia	Atriplex	Suaeda	Gamanthus	
<b>Ruminal<sup>a</sup></b>					
DM	444d	472c	553b	663a	7.8
CP	517c	529c	577b	677a	7.6
<b>Post-ruminal<sup>b</sup></b>					
DM	203a	194ab	168b	133c	10.3
CP	560c	628b	481d	696a	13.4
<b>Total tract</b>					
DM	568c	574c	626b	707a	12.5
CP	793c	821b	780c	901a	7.9

Means in the same row with different letters differ ( $P < 0.05$ ).

<sup>a</sup> DM and CP disappearance from polyester bags after 12 h incubation in the rumen of steers.

<sup>b</sup> Intestinal disappearance of the ruminal undegraded DM and CP.

### 3.3. *In situ* ruminal and post-ruminal disappearance

Mean ruminal DM disappearance of Kochia, Atriplex, Suaeda and Gamanthus was 444, 472, 553 and 663 g/kg (S.E.M. = 7.8), respectively (Table 5). Kochia had the lowest ruminal DM disappearance, while Gamanthus had the highest ( $P < 0.05$ ). Post-ruminal disappearance of ruminally undigested DM of Kochia was higher ( $P < 0.05$ ) than Suaeda and Gamanthus. Gamanthus had the highest ( $P < 0.05$ ) total tract DM disappearance (707 g/kg). Ruminal CP disappearance of Gamanthus and Suaeda (677 and 577 g/kg, respectively) was higher ( $P < 0.05$ ) than Atriplex and Kochia (529 and 517 g/kg, respectively). Mean post-ruminal CP disappearance of ruminal undigested CP of Kochia, Atriplex, Suaeda, and Gamanthus was 560, 628, 481 and 696 g/kg (S.E.M. = 13.4), respectively. The lowest ( $P < 0.05$ ) total tract CP disappearance was observed for Kochia and Suaeda (Kochia = 793, Atriplex = 821, Suaeda = 780, Gamanthus = 901).

Ruminal EE disappearance (Table 6) indicated that Kochia and Atriplex (480 and 480 g/kg, respectively) had lower values than Suaeda and Gamanthus (825 and 753 g/kg,

Table 6

Disappearance of EE, NDFom, ADFom, ash (g/kg of nutrient) from halophytic plants in the rumen using an *in situ* procedure

	Halophytes				S.E.M.
	Kochia	Atriplex	Suaeda	Gamanthus	
EE	480b	480b	825a	753a	31.35
NDFom	383b	473a	214c	519a	21.73
ADFom	362c	531b	232d	575a	9.56
Ash	849b	937a	875b	953a	9.30

Means in the same row with different letters differ ( $P < 0.05$ ). Disappearance from polyester bags after 16 h incubation in the rumen of steers.

respectively). Atriplex and Gamanthus had the highest ruminal NDFom disappearance (473 and 519 g/kg, respectively). Ruminal ADFom disappearance of Suaeda, Kochia, Atriplex and Gamanthus (232, 362, 531 and 575 g/kg, respectively) differed ( $P < 0.05$ ). Kochia and Suaeda (849 and 875 g/kg, respectively) had higher ruminal ash disappearance *versus* Atriplex and Gamanthus (937 and 953 g/kg, respectively).

## 4. Discussion

### 4.1. Chemical composition

The chemical composition of forages affects digestibility of nutrients. The CP of the halophytic plants evaluated in this study was lower than some previous reports (El Shaer, 1981; Cohen et al., 1989; Madrid et al., 1996; Swingle et al., 1996). Differences among studies may be related to stage of harvesting, leaf:stem ratio or genetic variation (Gihad and El Shaer, 1992; Benjamin et al., 1995; El-Shatnawi and Abdullah, 2003). In the present experiment, the EE of halophytic plants ranged from 9.2 to 24.1 g/kg, with Suaeda having the highest EE concentration, confirming findings of El Shaer (1981). Our halophytic plants were generally high in Na, K, Cl, Cu, Se, ash and NDFom, but low in Ca, P, and CP (Table 2), which is consistent with Swingle et al. (1996). Results show that our halophytic plants had a higher ratio of Ca:P than in previous studies (Cohen et al., 1989; Ben Salem et al., 2002; El-Shatnawi and Abdullah, 2003). Atriplex and Suaeda were high in K content and the K concentration of halophytic plants is generally more than that required by ruminants (Kearl, 1982). The Mg content of our halophytic plants ranged from 1.1 to 1.7 g/kg DM, which is lower than values previously reported (Cohen et al., 1989; Ben Salem et al., 2002).

The NDFom of Suaeda in the present study was lower than in other halophytic forages, which is consistent with observations of El Shaer (1981). Our halophytes varied in NPN content from 2.2 to 5.7 g/kg, and this is important because NPN content can influence CP quality of forages for ruminants (Cohen et al., 1989; Ben Salem et al., 2004). Copper requirements for ruminants were estimated to be 5–10 mg/kg of dietary DM (Kearl, 1982) and Cu concentrations of our halophytic plants indicate adequate concentrations.

### 4.2. *In situ* ruminal degradability of DM and CP

*In situ* digestion coefficients were used to develop a system to predict feed nutritive value and voluntary intake (Ørskov, 2000). Rapidly degradable fractions of DM and CP, determined in the current study, were similar to previous observations (Danesh Mesgaran and Stern, 2005). Kibon and Ørskov (1993) noted that Kochia and Atriplex were low in rapidly degradable fractions of DM, which can reduce voluntary DM intake. Low rapidly degradable DM fractions of Kochia and Atriplex could be due to their low ash and high NDFom and ADFom contents, as shown in Table 2. The DM degradability values for Atriplex in the current study are consistent with values of Ben Salem et al. (1985).

Concordant with Kaitho et al. (1998), Atriplex had a rapidly degradable CP fraction of about 500 g/kg but this contrasts to Ben Salem et al. (2002) who reported that about



700 g/kg of Atriplex N was rapidly degradable. The rate of CP degradation of Gamanthus and Suaeda was lower than Kochia and Atriplex, which could be due to differences in NPN content between species. Effective degradability of DM of Kochia, Atriplex and Suaeda was similar, but lower than in Gamanthus. Gamanthus had a higher EDCP than our other halophytic plants, which is consistent with Yan and Agnew (2004) who showed that EDDM and EDCP were negatively related to NDFom and ADFom concentrations.

#### 4.3. *In situ* ruminal and post-ruminal disappearance

Ruminal DM and CP disappearance varied, perhaps due to differences in NDFom, ADFom, lignin (Van Soest, 1994; Yan and Agnew, 2004) and ash (Benjamin et al., 1995). Within a halophyte, lower ruminal disappearance of DM was compensated by higher post-ruminal disappearance. The DM disappearance of Kochia was higher ( $P < 0.05$ ) than in Suaeda and Gamanthus, but there was no difference for Kochia and Atriplex or Atriplex and Suaeda. This may be because of the low CP content of the halophytic plants, low quality of the residues and partial microbial contamination of the samples collected in the feces (Woods et al., 2003).

A high ruminal disappearance of EE ( $P < 0.05$ ) for Suaeda, versus Kochia and Atriplex, may be related to its high EE content. In contrast, ruminal disappearance of NDFom and ADFom was lowest ( $P < 0.05$ ) for Suaeda. Smith et al. (1972) reported that the proportion of soluble DM, lignin and hemicellulose in forages may account for differences in their cell wall digestibility. It is noteworthy that more than 840 g/kg of the ash content of our halophytic plants disappeared in the rumen. This is important because minerals of feeds are mostly released in the rumen, affecting the buffering capacity of rumen contents (Emanuele et al., 1991).

Total tract DM disappearance of Kochia and Atriplex was lower ( $P < 0.05$ ) than in Suaeda and Gamanthus while total tract CP disappearance of Kochia and Suaeda was similar but lower ( $P < 0.05$ ) than in Atriplex and Gamanthus. Danesh Mesgaran and Stern (2005) determined ruminal and post-ruminal disappearance of CP for Kochia, Atriplex, and Suaeda using *in situ* and *in vitro* procedures, and reported that ruminal, post-ruminal and total tract disappearance of Kochia was higher than in Suaeda and Atriplex. The disparity between results in the current experiment with that of Danesh Mesgaran and Stern (2005) may be related to species of the halophytic plants, stage of harvesting and/or microbial contamination of the samples collected in the feces.

## 5. Conclusions

*Kochia scoparia* and *Atriplex dimorphostegia* appear to have more beneficial chemical nutrient components and nutritional values than *Suaeda arcuata* and *Gamanthus gamacarpus* for ruminants. In general, all of these Iranian halophytic plants had high concentrations of Na, K, Cl, Cu and Se, and low concentrations of Ca, P and Mg. *Kochia scoparia* had the lowest rapidly degradable DM and CP fractions, which may depress voluntary intake of this halophyte. Voluntary intake of Atriplex may be higher than Kochia because the rapidly

degradable DM and CP fractions of *Atriplex* were higher than that of *Kochia*. *Kochia scoparia* and *Atriplex dimorphostegia* had similar EDDM estimated at different outflow rates, but their EDDM was lower than in *Suaeda* and *Gamanthus*. These halophytes have potential to provide supplemental feed nutrients for ruminants.

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