Livestock Science 194 (2016) 1–6

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Recovered energy and efficiency of digestion in sheep and goats fed *Atriplex nummularia* compared to alfalfa hay

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ARTICLE INFO

Keywords:
Sheep
Goat
Forage quality
Digestion
Recovered energy

ABSTRACT

An experiment was carried out to examine differences between sheep and goats in utilizing forages varying in feeding value. Twenty four non-lactating females (Age=3.5 years; Barki sheep, n=12 and Balady goats, n=12) were individually housed in 1.0×1.5 m pens with sand floor for a 25-d period and then moved to metabolic cages. Animals of each species were offered either alfalfa hay or *Atriplex nummularia* foliage as sole diet for ad libitum consumption. Dry matter intake and digestibility were greater ($P < 0.001$) for animals fed alfalfa hay than *Atriplex nummularia*. Intake of organic matter (g/kg metabolic body weight ($BW^{0.75}$)/d) and gross energy (kJ/kg $BW^{0.75}$/d) was greater ($P < 0.05$) for goats than sheep. The significant interaction between forage type and animal species indicated that digestibility (%) of organic matter and energy was only greater for goats than sheep fed *Atriplex nummularia*, while no significant differences were observed between animal species when fed alfalfa hay. However, NDF digestibility was similar between both animal species fed either roughage. Energy expenditure (kJ/kg $BW^{0.75}$/d) was similar between goats and sheep, and greater ($P < 0.001$) for animals fed alfalfa hay than *Atriplex nummularia*. The significant interaction between forage type and animal species indicate that recovered energy (RE, kJ/kg $BW^{0.75}$/d) was similar for both animal species when fed alfalfa hay, while it was greater for goats than sheep when fed *Atriplex nummularia*. It is concluded that apparent digestibility and RE were practically similar in sheep and goats when they consumed the high quality forage (i.e. Alfalfa), while low quality forage (i.e. *Atriplex nummularia*) was better utilized by goats than sheep.

1. Introduction

Atriplex species are common fodder plants in arid and semi-arid regions (Hyder and Akil, 1987). Because of its tolerance to drought and salinity (Ben Salem et al., 2010) they grow or can be planted in saline soil and/or water and can play an important role in livestock feeding. *Atriplex* species remain green during the drought season and maintain a relatively moderate crude protein (CP, ranging 10.3–25.2% of dry matter, Ben Salem et al., 2010) content throughout the year albeit having a low energy content (Hassan et al., 1979). The high salt (NaCl, with an average content of 58.4 and 123.0 g/kg DM for Na and Cl, respectively) content in *Atriplex* and the limited availability of drinking water may restrict feed intake and lead to negative effects on animal performance (Benjamin et al., 1992; Ben Salem et al., 2010). Feeding *Atriplex* can be an alternative to minimize the need for protein supplements. Hence, studying its effects on grazing animals is of importance.

Local Barki sheep and Balady goats are raised in the desert areas of Egypt. They are generally well adapted to the desert climate conditions and can survive on poor quality forage (Farid et al., 1989; Helal et al., 2010; 2016). Goats are more efficient utilizers of tree and shrub vegetations than sheep (Merrill and Taylor, 1981). El-Meccawi et al. (2008) reported that digestibility of high quality forage was similar in sheep and goats, while low quality forages were better digested by goats than sheep. Valderrábano et al. (1996) reported better intake and utilization of *Atriplex* by goats than sheep.

Brosh et al. (1986) suggested that the type of diet influences the energy expenditure (EE) and that Bedouins goats adapted to desert conditions can reduce their metabolic rate when consuming low quality forage that is mainly due to the low feed intake level. This is in agreements with the findings of Askar (2015, 2016) who reported that Barki sheep and Balady goats have the ability to survive under harsh and desert condition by reducing their EE as a mechanism of adaptation when their intake is restricted to below maintenance energy requirements. Conversely, desert Barki sheep (Hassan and Abdel-Aziz, 1979; Kandil and El Shaer, 1989; Abou El Nasr et al., 1996) and Balady goats (Kandil and El Shaer, 1989) fed *Atriplex nummularia* as a sole diet failed to maintain their body weight and most of them had a

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http://dx.doi.org/10.1016/j.livsci.2016.10.009
Received 10 April 2016; Received in revised form 11 October 2016; Accepted 12 October 2016

negative nitrogen (and energy) balance, although Farid et al. (1989) and Askar (2015) reported the capacity of long-term adaptation of both animal species to protein and energy deficiency. Similar findings were reported with Barbarine (Ben Salem et al., 2005) and Marino (Wilson, 1966) sheep fed only *Atriplex nummularia*.

In the present study, it was intended to investigate differences between sheep and goats in intake, digestibility, and energy utilization when maintained on *Atriplex nummularia* compared to alfalfa hay as the sole diet.

2. Materials and methods

2.1. Animals and treatments

The experiment was carried out, during April and May 2012 at the Maryout Desert Research Station of the Desert Research Center, DRC, Egypt, about 35 km south-west of Alexandria and 180 km north of Cairo, at latitude 31° 13' N and longitude 29° 58′E. This area is classified as a semi-arid region with erratic rainfall averaging less than 150 mm/year, mostly in the winter. Average ambient temperatures were 26 °C and 13 °C while relative humidity values were 69% and 71%, in summer and winter respectively. The experimental procedures were approved by the Animal and Poultry Production Division of DRC committee and as followed by the Veterinary and Animal Care Department.

Twenty four non-lactating females (Age=3.5 years; Balady goats, n=12 and Barki sheep, n=12) were individually housed in 1.0×1.5 m pens with sand floor for a 25-d period and then moved to metabolic cages. Animals of each species were randomly distributed into two dietary treatments, alfalfa hay (4th cut *Medicago sativa*, control) or lush leaves and succulent stems of *Atriplex nummularia* offered for ad libitum consumption with at least 20% refusals as the sole diet. Alfalfa hay was cultivated in a normal fertile soil, while *Atriplex nummularia* was naturally growing at a salt affected soil around the Research Station and harvested daily for animals feeding during the experimental period.

2.2. Experimental procedures

Water was offered twice daily, at 08:00 and 14:00 h. Directly after the individual feeding period (25 days), animals were moved to 60×110 cm metallic metabolic crates in two sets of 12 each, with three animals per treatment and animal type for each set, for the collection of feces and urine. Ten days were then allowed for adjustment, followed by 7-d of collection period and calorimetric measurements. Feed regime and water were supplied in the same manner as in the individual feeding period. Feed intake and water consumption were measured daily. Feed and orts were sampled to get a proportional composite sample for each animal for a seven-day period starting 24 h prior to the collection of excreta. Feces and urine output were collected daily and a 10% sub-sample of each was taken and pooled in individual composite samples through the seven-day collection period. Urine was collected with the aid of funnels attached to the bottom of the cages and then draining into large bottles containing 20% sulfuric acid solution. Individual pooled samples for each animal were preserved by freezing for later analysis. At the end of the collection period, composite samples of forages, orts, and feces were oven-dried at 55 °C to reach a constant weight, ground to pass through a 1 mm mesh screen, and preserved in plastic bottles for later analysis.

2.2.1. Energy expenditure

The calorimetry system and its usage were described previously by Askar (2016) in which all animals were fitted with a face mask facilitating open-circuit respiratory system for measuring O_2 consumption (Sable Systems, Las Vegas, NV). Heart rate (HR) was simultaneously measured to determine the individual energy expenditure (EE)/HR ratio for each animal. Energy expenditure was estimated assuming a constant thermal equivalent of 20.47 kJ per liter O_2 (Nicol and Young, 1990). Human S610 HR (Polar, Lake Success, NY) monitors with infrared connections to the transmitters were used to collect HR data at a 1-min interval. Heart rate data were analyzed using Polar Precision Performance SW software provided by Polar. Heart rate was measured for each animal in elevated cages for at least 48 h. The daily HR and EE were determined from the EE: HR ratio for each animal.

2.2.2. Weather data

Ambient temperature (T °C) and relative humidity (RH%) were recorded daily at 20-min intervals with a Hobo® Temperature/RH Data Logger (Hobo Pro RH/Temp; Onset Computer Corp., Bourne, MA, USA). It was installed in the center of the barn area. A temperature-humidity index (THI) (Amundson et al., 2006) was calculated with the following formula:

$$THI = (0.8 \times T) + [(RH/100) \times (T - 14.4)] + 46.4.$$

2.2.3. Analytical procedures

Laboratory dry matter (DM) content of feeds, orts, and feces were determined by drying at 105 °C for 24 h, and the organic matter (OM) was determined by ashing at 550 °C in a muffle furnace for six hours. The CP was measured by Kjeldahl method described in AOAC (2005). Neutral detergent fiber (aNDF) content was determined according to Mertens (2002), and the acid detergent fiber (ADFom) content was analyzed as described in AOAC (2005) using the filter bag technique (ANKOM 200, ANKOM Technology Corp., Fairport, NY, USA). Acid detergent lignin (ADL, sa) content was determined by the method suggested by Robertson and Van Soest (1981).

Gross energy (GE) of feed, orts and feces were measured by bomb calorimeter (IKA, model C 200, Staufen, Germany), using benzoic acid as standard. Metabolizable energy (ME) was estimated as 82% of digestible energy (DE) intake (NRC, 2007). Recovered energy (RE) was calculated as the difference between ME intake (MEI) and total EE.

2.3. Statistical analyses

Data were analyzed by the GLM procedure of the SAS statistical package (SAS, 2000), with a model consisting of the effects of forage type, animal species, and the interaction between forage and animal species. Differences between means are significant when P-value is below 0.05, but considered tendency when P-value is comprised between 0.05 and 0.10.

3. Results

Composition of feeds is presented in Table 1. Alfalfa hay and *Atriplex nummularia* had similar gross energy content. Alfalfa hay had higher crude protein and lower fiber fraction contents than *Atriplex nummularia* (Table 1). In this regard, alfalfa hay is considered as a

Table 1
Chemical composition of alfalfa hay and *Atriplex nummularia* foliage.

Constituents	Alfalfa hay	*Atriplex nummularia*
Dry matter, g/kg	902	603
Gross energy, MJ/kg dry matter	16.3	15.9
Chemical composition, g/kg dry matter		
Organic matter	852	825
Crude protein	177	87
Neutral detergent fiber	509	749
Acid detergent fiber	315	475
Acid detergent lignin	113	179