

Effects of Feed Intake Level on Digestion and Energy Utilization in Desert Sheep and Goats

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Abstract: Twenty four adult local desert non-pregnant and non-lactating females, 12 Barki desert sheep and 12 Balady desert goats, were used to evaluate effects of long-term nutrient restriction on digestion and energy utilization. Animals were individually housed for a 3-month period and then moved to metabolic cages in two sets of 12 animals, three per treatment and species for each set. Six animals of each species were used as control and fed a concentrate mixture and alfalfa hay diet (50:50% as DM basis) at a level adequate for the metabolizable energy (ME) intake of maintenance (ME_m , control). The other six animals were used as restricted diet and fed 50% of the previous amount relative to actual BW (restricted). Total Energy expenditure (EE) was estimated by heart rate (HR) monitor for 48-h period after its individual calibration by oxygen consumption with a face mask open-circuit respiratory system. Similar digestible energy was observed between animal species at control level (63.7 vs. 63.2%, SEM = 1.53), while a greater ($P < 0.01$) digestibility was reported for sheep vs. goats at restricted feed intake level (60.8 vs. 50.9%, SEM = 1.53, respectively). Energy expenditure was greater ($P < 0.001$) for control vs. restricted intake level (420 vs. 338 kJ/kg $BW^{0.75}$ /day, SEM = 10.2, respectively) and tended to be higher ($P < 0.10$) for sheep vs. goats (394 vs. 364 kJ/kg $BW^{0.75}$ /day, SEM = 10.2, respectively). As a result, the energy balance was greater for control vs. restricted intake level (9.3 vs. -139.8 kJ/kg $BW^{0.75}$ /day, SEM = 8.27, respectively) and similar between both animal species (-62.4 vs. -68.0 kJ/kg $BW^{0.75}$ /day, SEM = 8.27, for sheep and goats, respectively). In conclusion, both desert Barki sheep and Balady goats are able to reduce their EE in order to improve their energy balance as a mechanism of adaptation when their ME intake is restricted below ME_m requirements.

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1- Introduction:

Metabolizable energy (ME) requirements for maintenance (ME_m) can be influenced by several factors, including animal species and feed intake level. AFRC (1998) summarized data suggesting that ME_m is greater for goats than sheep and similar to that of cattle, although CSIRO (1990) suggested that ME_m is similar for sheep and goats. On the other hand, feed intake level is considered one of the most important factors that affects ME_m (NRC, 2007; Helal et al., 2011; Askar, 2015). Small ruminants are able to adapt to restricted feed intake at level below ME_m by a reduction in basal metabolic rate (Asmare et al., 2006) and in energy used for the splanchnic tissues (Asmare et al., 2012) that account for a considerable portion of the fasting metabolic expenditure (NRC, 2007). However, effects of intake level on ME_m were not addressed by NRC (1985) for sheep or by NRC (1981), AFRC (1998), or Sahlou et al. (2004) for goats. In this concern, there have been several previous studies showing the effect of restricted feed intake level on nutrients requirements, particularly those regarding the desert animals, such as black Bedouin/Balady goats (Brosh et al., 1986; Askar, 2015; Askar et al., 2015) or Barki sheep (Farid, 1997; Farid et al., 1989; Askar et al., 2015). Choshniak et al. (1995) reported that a feeding level of Bedouins goats

on a half of a previous *ad lib* level of intake resulted in a reduction in heat production of a magnitude adequate to maintain body weight. Similar findings were observed with Asmare et al. (2006) with Boer/Spanish meat goat that indicated that the ability of goats to reduce ME_m with limited nutritional planes may not be unique to particular genotypes, such as the desert goat. Recently, Helal et al. (2011) concluded that the trend of change in heat production in response to feed restriction and re-alimentation was varied among different goat genotypes that consequently affecting the ME_m . However, long-term adaptation of Barki desert sheep to low protein intake has been previously studied by Farid (1997) and Farid et al. (1989) but a little or no information is available for the long-term adaptation of Barki sheep in comparison with Balady goats to low energy intake. The objective of the present experiment was to study effects of long-term restricted feed intake on digestion, energy expenditure, and energy balance by desert Barki sheep and Baladi goats.

2- Materials and Methods

2-1- Animals and Treatments

This experiment was carried out, from September 23 to the end of January 2014 at the Maryout Desert Research Station which belongs to

the Desert Research Center, DRC, some 35 km southwest of Alexandria, 180 km north of Cairo, Egypt, at latitude 31° 13' N and longitude 29° 58' E. It is a semi-arid region with low erratic rainfall averaging less than 150 mm/year mostly in the winter season. Average ambient temperatures were 26°C and 13°C, and relative humidity values were 69% and 71% for the summer and winter seasons, 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 adult local desert non-pregnant and non-lactating females, of which twelve Barki sheep and twelve Balady goats, were individually housed in 1.0 x 1.5m pens with sand floor for 3-month period then moved to metabolic cages in January to study effects of long-term restricted feeding regime on digestion and energy expenditure (EE) and energy and protein balance. Animals of each species were allocated to two levels of feed intake. Animals on a control feeding treatment were fed a diet with adequate energy of maintenance or at a level of feeding to meet approximately the metabolizable energy for maintenance requirement (ME_m) (control), while those on the other dietary treatment was fed almost 50% of these quantities on a BW basis, termed as the restricted treatment (restricted). Alfalfa hay and concentrate feed mixture (50:50%) were given based on requirement recommendations of Farid et al. (1983) and Helal et al. (2010). Barki sheep and Balady goats were fed approximately 453 and 429 kJ/kg $BW^{0.75}$, respectively, for mature animals fed a control treatment. The chemical composition of each feed ingredient is presented in Table 1.

Table (1). Chemical composition of alfalfa hay and concentrate supplement.

Constituents	Alfalfa hay	Concentrate supplement
Dry matter (DM), %	849	900
Gross energy, MJ / kg DM	17.1	18.0
Chemical composition, g / kg DM		
Organic matter	923	899
Crude protein	124	124
Neutral detergent fiber	560	515
Acid detergent fiber	323	290
Hemicellulose	237	225
Acid detergent lignin	113	98
Cellulose	210	192

2-2- Experimental procedures:

Animals stayed in individual pens for 3-month period on the feeding regimes of the control and restricted levels. Water was available free choice twice daily, at 08:00 and 14:00 h. Body weight was determined bi-weekly before the offer of feeds and

water, and feed offered was adjusted depending on body weight changes. However, the bi-weekly body weight changes and feed intake, and the corresponding EE will be published in another adjacent article.

Directly after the individual feeding period, animals were moved to metabolic crates in two sets of twelve, three animals per treatment and animal species for each set, for collection of feces and urine. It was lasted for 7-day collection period for each animal after feed intake establishment. Feed regime and water were followed the same treatments and trend of the individual feeding. Feed intake and water consumption were daily measured. Feed and orts were sampled to get a proportional composite sample per animal for a 7-day period starting 24 h in advance of the excreta collection period. Feces and urine output were daily collected and a ten percent sub-sample of each taken and pooled in individual composite samples for the 7-day collection period. Individual pooled samples for each animal were preserved frozen pending analyses. At the end of the collection period composite samples of forage and feces were oven-dried at 55°C to constant weight, ground to pass through a 1 mm screen, and preserved in plastic bottles for later analysis.

2-2-1- Energy expenditure

All animals were fitted with a face mask of an open-circuit respiratory system for O_2 consumption measurements. Heart rate (HR) was simultaneously determined at same time to get the individual EE/HR ratio for each animal. Measurements of O_2 consumption were made twice daily at the morning and afternoon as described by Landau et al. (2006). The concentration of O_2 was analyzed using a fuel cell FC-1B O_2 analyzer (Sable Systems, Las Vegas, NV) and EE was estimated assuming a constant thermal equivalent of 20.47 kJ per liter O_2 (Nicol and Young, 1990).

2-2-2- Heart rate

Heart rate was measured on animals fitted with Vermed Performance Plus ECG electrodes (Bellows Falls, VT) attached to the chest just behind and slightly below the left elbow and at the middle right side of the back. Electrodes were secured to skin with 5-cm wide elastic bandage (Henry Schein, Melville, NY) and animal tag cement (Ruscoe, Akron, OH). Electrodes were connected by ECG snap leads (Bioconnect, San Diego, CA) to T61 coded transmitters (Polar, Lake Success, NY). Human S610 HR (Polar Electro Oy, Kempele, Finland) monitors with infrared connections to the transmitters were used to collect HR data at a 1-min interval. Heart rate data was analyzed using Polar Precision Performance SW software provided by Polar Electro Oy. Heart rate was measured for each animal on elevated cages for

at least 48-h periods. The diurnal HR and EE were determined from the EE/HR ratio for each animal.

2-2-3- Weather data

Ambient temperature ($T^{\circ}\text{C}$) 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: $\text{THI} = (0.8 \times \text{Temp}) + [(\text{Hum} / 100) \times (\text{Temp} - 14.4)] + 46.4$.

2-2-4- Analytical procedures

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 6 h. The crude protein (CP) was measured by Kjeldahl method as described by AOAC (2005). The neutral detergent fiber (aNDF) content was determined according to Mertens (2002), and the acid detergent fiber (ADF) content was analyzed as described by AOAC (2005) using the filter bag technique (ANKOM Technology Corp., Fairport, NY, USA). The acid detergent lignin (ADL, sa) content was determined according to 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) intake was estimated as 82% of digestible energy (DE) intake (NRC, 1981). Energy balance (EB) 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 animal species, intake level, and animal species \times intake level. Means were presented in tables for animal species \times intake level regardless of the significance of the interaction effect. The least significant difference was used for comparing means. Differences among means with $P < 0.05$ were accepted as statistically significant differences and those with $0.05 < P < 0.10$ were accepted as representing tendencies to differences.

3- Results and Discussion:

3-1- Climate conditions

Daily mean T, RH, and THI for 20-min interval measurements were determined throughout the month of January in which the digestion and energy utilization parameters were estimated on metabolic cages (Figures 1, 2, and 3). Apparently, animals were exposed to moderate cold conditions for the Egyptian species in winter season.

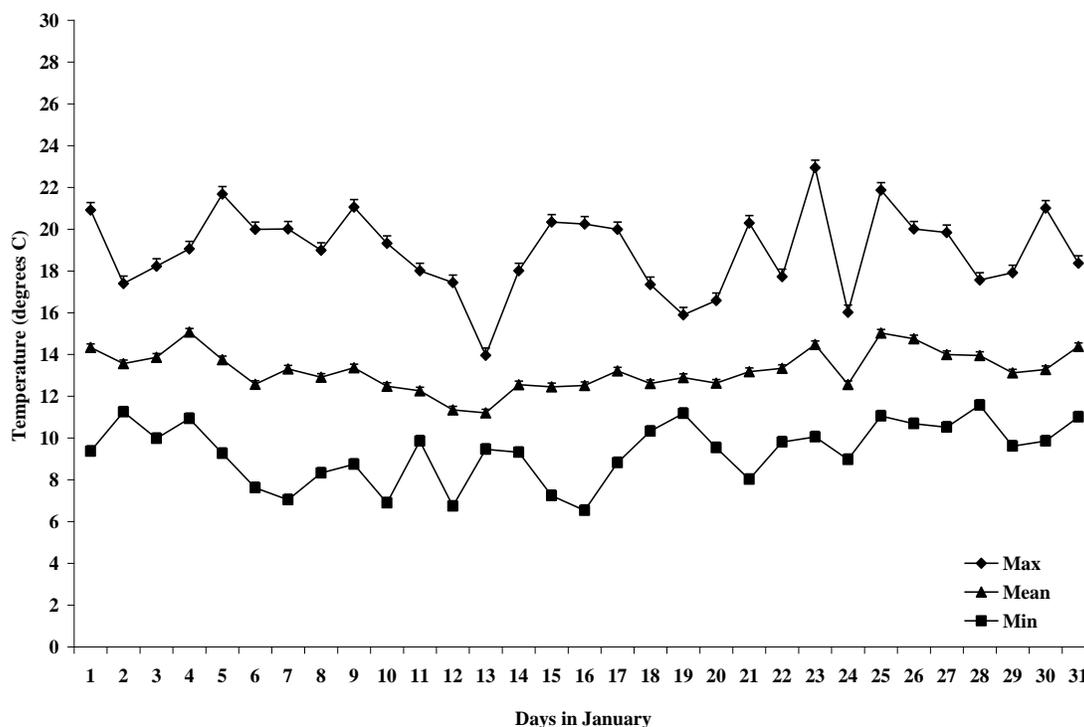


Figure (1). Daily mean, maximum, and minimum ambient temperature throughout the experimental time (January, 2012) that animals were exposed to.

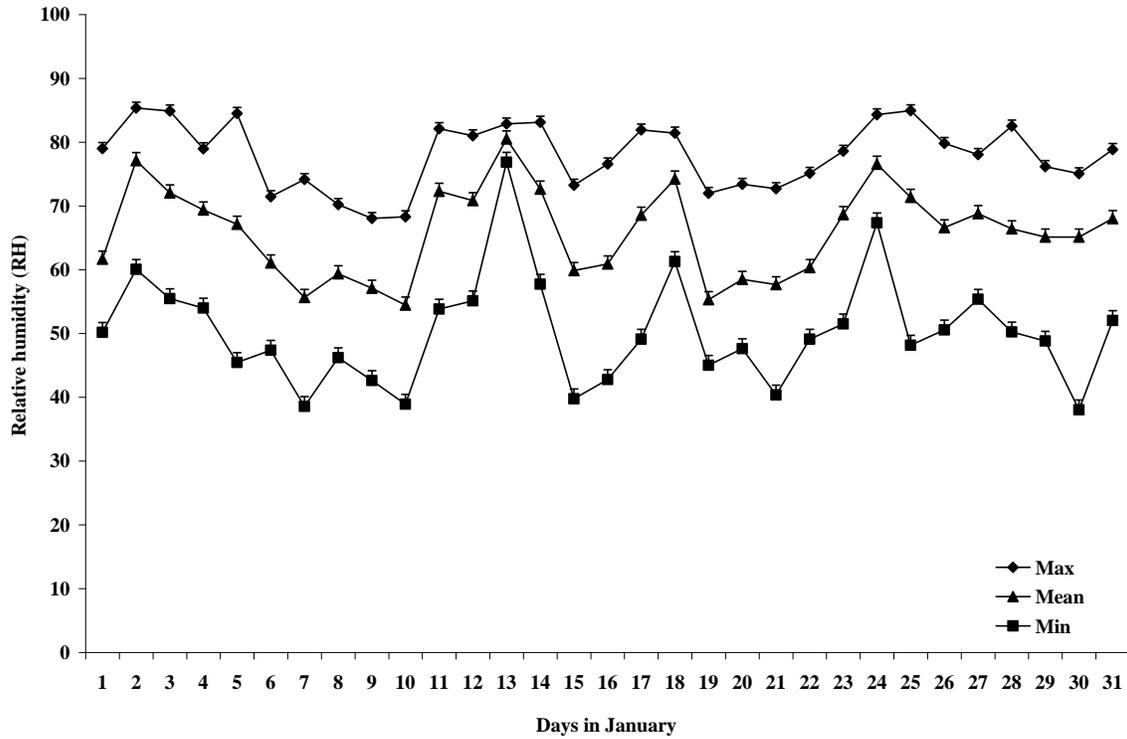


Figure (2). Daily mean, maximum, and minimum relative humidity (RH, %) throughout the experimental time (January, 2012) that animals were exposed to.

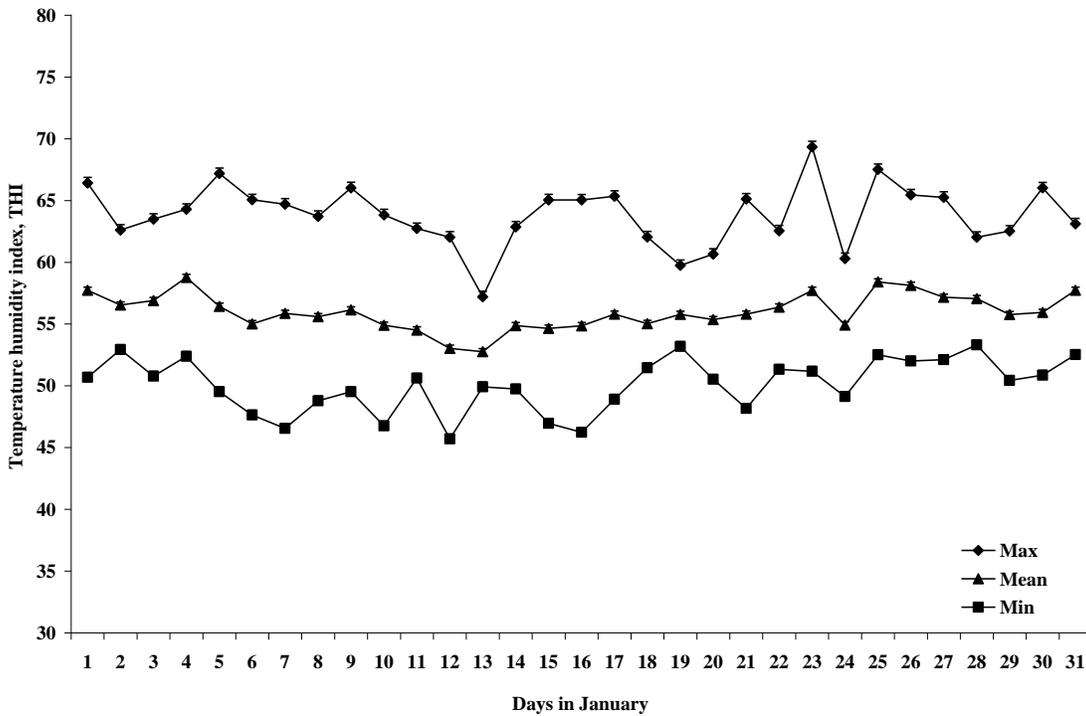


Figure (3). Daily mean, maximum, and minimum temperature humidity index (THI) throughout the experimental time (January, 2012) that animals were exposed to.

3-2- Intake and digestibility:

Although sheep consumed more water (1320 vs. 981 ml/day, SEM = 112.2, $P < 0.05$) and excreted a greater amount of urine (618 vs. 452 ml/day, SEM = 56.6, $P < 0.10$) than goats, water consumption and urine excretion were similar when they expressed as ml/kg BW^{0.75} (Table 2). However, animals fed a control level consumed more water ($P < 0.01$) and excreted much urine ($P < 0.01$) than those fed a restricted feed intake level.

Dry matter intake was higher ($P < 0.05$) for sheep vs. goats and was greater for control vs. restricted intake level (Table 2). On the other hand, a significant interaction was detected between animal species and intake level regarding the DM digestibility. In comparison with sheep, goat digestibility was similar with control group, while it was significantly ($P < 0.05$) lower with restricted group. Similar trend was observed with OM, CP, and NDF intake and digestibility.

At a control intake level, a similar digestibility coefficient for sheep and goats was expected (Wilson, 1977). A similar digestibility for both animal species was reported when they fed *ad lib* alfalfa hay (63.1 and 63.9% EI-Meccawi et al., 2008) and (66.7 and 65.9%, Askar et al., 2015) as a sole diet. However, these later digestibility values were higher than those obtained with the control group (Table 2), although they fed a mixture of alfalfa hay and concentrate supplement and with a limited feed intake, approximately maintenance level. The moderate cold temperature that animals exposed to in the current study might be responsible for this reduction in digestibility. Keyserlingk and Mathison (1993) reported that cold exposure resulted in a reduction in digestibility that is related to the increase in the rate of passage of digesta in the cold-acclimated animals and the increase in the reticulo-rumen motility. Similar findings were reported by Kennedy and Milligan (1978) and Kennedy et al. (1976). On the other hand, at a restricted intake level, a greater digestibility for sheep vs. goats was not expected. Factors responsible for the reduction in goat digestibility are unclear but Askar (2015) reported a significant reduction in digestibility of Balady and Shami goats fed same restricted diet under similar moderate cold condition. He also suggested that goats are much sensitive to the low ambient temperature, particularly when they were given a low feed intake level below maintenance, and that may be due to their coat type. However, this reduction in digestibility might be also due to a lower fermented energy available for rumen microflora and/or to a greater endogenous nitrogen excretion (% of intake) for restricted vs. control feed intake treatment. In addition, it may be due to the significant lower EE for restricted vs. control intake level (Table 3) that increased the load effect of cold on animals

because EE is always used to overcome the cold effect. The contrary was noticed with the full-fleeced sheep. They can handle the cold weather and elements much better than goats. Wool is a very effective insulation against cold and hot, however, many investigators have reported the influence of fleece length and level of feed intake on lowering critical temperature (LCT) in sheep as mentioned by the NRC (1985).

3-3- Energy utilization:

Gross energy intake was higher ($P < 0.05$) for sheep vs. goats and greater ($P < 0.001$) for control vs. restricted intake level (Table 3). Digestible energy (%) was following the same trend of the dry and organic matter digestibility. Furthermore, DE intake (DEI) was higher ($P < 0.01$) for sheep vs. goats and greater for control vs. restricted intake level. Metabolizable energy intake (MEI) was following the same trend of DEI (Table 3).

3-3-1- HR and EE/HR ratio

Although HR (beats/min) was greater for goats vs. sheep, a greater EE/HR ratio (kJ/kg BW^{0.75}:beat) for sheep vs. goats was observed (Table 3). Results are in agreement with those previously reported by Beker et al. (2010) who reported a greater EE/HR ratio for Rambouillet sheep vs. Spanish and Angora goats (6.47 vs. 6.02 and 5.64 kJ/kg BW^{0.75}:beat, respectively). The differences between sheep and goats in EE/HR ratio are not clear but it is probable that the delivery of oxygen by the heart varies among ruminant species (Puchala et al., 2007). On the other hand, a similar EE/HR ratio was observed between both control and restricted intake levels (Table 3), although HR was greater for control vs. restricted intake level. In a similar experimental design, similar EE/HR ratio was noted between control and restricted feed intake levels in Angora, Boer, and Spanish goats (Helal et al., 2011) and in Balady and Shami goats (Askar, 2015). Moreover, Arieli et al. (2002) reported a similar EE/HR ratio in Assaff sheep fed different diets varying in forage/concentrate levels.

3-3-2- Energy expenditure and balance

Energy expenditure (EE) was tended to be higher ($P < 0.10$) for sheep vs. goats (Table 3) in agreement with Asmare et al. (2012) who indicated that with limited planes of nutrition, sheep were less able to reduce EE than goats, which may have involved differences in extra-splanchnic tissue metabolism. However, results revealed a similar EB in both animal species (Table 3) which reflected the difference between the MEI and EE. This indicated a similar rate of using the energy between sheep and goats with moderate or limited nutrition planes. A similar EB was reported for sheep and goats when they fed either at high (El-Meccawi et al., 2008) or at low (El-Meccawi et al., 2009) feed intake level that was

associated with receiving high or low quality diet, respectively. Similar results were reported by Askar et al. (2015) with Barki sheep and Balady goats fed alfalfa hay as high quality forage. Conversely, a better energy use for goats vs. sheep was reported when they were given *Acacia saligna* (-128 vs. -243 kJ EB/kg BW^{0.75}/d, El-Meccawi et al., 2008) or *Atriplex nummularia* (-44 vs. -79 kJ EB/kg BW^{0.75}/d, Askar et al., 2015) as a sole diet. Authors attributed the difference in energy utilization between sheep and goats that goats seem to tolerate anti-nutritional factors and high salt content in diet to a better extent than sheep did in which this is not the case in the current study.

However, total EE was significantly ($P < 0.01$) lower for animals fed restricted vs. control intake level (Table 3), almost 80% less, reflecting the lower feed intake and consequent reduction in heat increment (Asmare et al., 2006; Tovar-Luna et al., 2007b; Askar, 2015; Askar et al., 2015). Hence, the differences in ME intake between control and restricted intake levels were reflected in the EB. At a restricted intake level, it was clear that MEI was below the reported ME_m requirements for both animal species (NRC, 2007), and consequently resulted in a negative EB. However,

the net energy requirements for maintenance (NE_m) estimated from Table 3 (282 and 261 kJ/Kg BW^{0.75} for sheep and goats, respectively), assuming an efficiency of ME utilization for maintenance of k_m 0.62 (ARC, 1980), were about 25 and 11%, respectively, higher than those published for fasting metabolic rate for sheep (220-226 kJ/Kg BW^{0.75}, ARC, 1980) and goats (217-251 kJ/Kg BW^{0.75}, Tovar-Luna et al., 2007a). Askar (2015) estimated a similar NE_m value (253 kJ/Kg BW^{0.75}) for Balady goats fed at same feed intake level and under similar climatic condition. On the other hand, the NE_m estimated for control group were 295 and 274 kJ/Kg BW^{0.75} for sheep and goats, respectively, indicating a similar restricted NE_m/control NE_m ratio for sheep and goats (almost 0.95). This suggests that desert animals, such as Barki sheep and Balady goats were able to reduce their basal metabolic rate to a similar extent as an adaptation mechanism to overcome the low feed intake level. This is in agreement with those previously reported by Asmare et al. (2006), Helal et al. (2011), and Askar (2015), and explained by a reduction in energy used by the splanchnic tissues (Asmare et al., 2012) which account for a considerable portion of the fasting metabolic expenditure (NRC, 2007).

Table (2). Intake and digestion by Barki sheep and Balady goats while feeding control (Cont) or restricted (Rest) feed intake level.

Items	Animal species		SEM	Feeding treatment		SEM	Animal species x Feeding				SEM	Significant		
	Sheep	Goats		Cont	Rest		Sheep		Goats			Animal species	Treat	Interaction
							Cont	Rest	Cont	Rest				
Body weight,														
Kg	32.9	29.1	1.52	33.4	28.5	1.53	35.4	30.4	31.5	26.7	2.11	t	*	ns
Kg^{0.75}	13.7	12.5	0.48	13.5	12.3	0.48	14.5	12.9	13.3	11.8	0.67	*	***	ns
Water consumption,														
ml/day	1320 ^a	981 ^b	112.2	1480 ^a	822 ^b	112.2	1597	1044	1363	599	154.9	*	***	ns
ml/BW^{0.75}/day	94.8	77.8	7.87	106.9 ^a	65.6 ^b	7.87	110.7	78.8	103.2	52.4	10.87	ns	**	ns
Urine excretion,														
ml/day	618 ^a	452 ^b	56.6	689 ^a	372 ^b	56.6	833	404	564	341	78.2	t	***	ns
ml/BW^{0.75}/day	45.2	36.0	4.54	51.2 ^a	30.0 ^b	4.54	60.0	30.3	42.3	29.6	6.27	ns	**	ns
Dry matter,														
Intake, g/day	526 ^a	460 ^b	18.2	673 ^a	313 ^b	18.2	720	332	625	294	25.1	*	***	ns
Intake, g/Kg BW^{0.75}/day	37.9 ^a	36.0 ^b	0.38	48.5	25.3	0.38	49.9	25.8	47.1	25.0	0.52	**	***	t
Digestion, %	58.5 ^a	53.4 ^b	0.92	59.3	52.6	0.92	60.0 ^a	56.9 ^a	58.5 ^a	48.3 ^b	1.27	**	***	*
Organic matter,														
Intake, g/day	479 ^a	419 ^b	16.5	613	285	16.5	656	303	570	268	22.8	*	***	ns
Intake, g/Kg BW^{0.75}/day	34.5 ^a	32.8 ^b	0.34	44.2	23.1	0.34	45.5	23.5	42.9	22.8	0.48	**	***	t
Digestion, %	58.4 ^a	53.5 ^b	1.02	59.3	52.6	1.02	59.9 ^a	56.9 ^a	58.7 ^a	48.3 ^b	1.40	**	***	*
Crude protein,														
Intake, g/day	65.2	57.0	2.25	83.4	38.8	2.25	89.2	41.2	77.5	36.4	3.11	*	***	ns
Intake, g/Kg BW^{0.75}/day	4.69	4.67	0.048	6.01	3.15	0.048	6.18	3.20	5.83	3.10	0.066	**	***	t
Digestion, %	68.1	62.6	0.73	67.7	63.0	0.73	69.3 ^a	67.0 ^{ab}	66.1 ^b	59.0 ^c	1.00	***	***	*
Neutral detergent fiber,														
Intake, g/day	283	247	9.71	361	168	9.71	387	178	336	158	13.40	*	***	ns
Intake, g/Kg BW^{0.75}/day	20.3	19.3	0.21	26.1	13.6	0.21	26.9	13.8	25.3	13.4	0.29	**	***	t
Digestion, %	58.4	51.1	1.28	58.9	50.6	1.28	60.4 ^a	56.4 ^a	57.4 ^a	44.8 ^b	1.77	***	***	*

^{a, b, c} Means without a common superscript letter in the row are differed ($P < 0.05$) between treatments, animal species, or their interactions. ns = non-significant; t < 0.10; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; SEM = Standard error of means.

Table (3). Energy intake, digestion, and metabolism by Barki sheep and Balady goats while feeding control (Cont) or restricted (Rest) feed intake level.

Item	Animal species		SEM	Feeding treatment		SEM	Animal species x Feeding				SEM	Significant			
	Sheep	Goats		Cont	Rest		Sheep		Goats			Animal species	Treat	Interaction	
							Cont	Rest	Cont	Rest					
Gross energy,															
MJ/day	8.9 ^a	7.8 ^b	0.29	11.4	5.3	0.29	12.2	5.7	10.6	5.0	0.40	*	***	ns	
kJ/ BW^{0.75}/day	644 ^a	614 ^b	7.6	825	432	7.6	850	438	801	426	10.5	*	***	ns	
Digestible energy,															
%	62.3	57.0	1.11	63.5	55.8	1.11	63.7 ^a	60.8 ^a	63.2 ^a	50.9 ^b	1.53	**	***	**	
MJ/day	5.62	4.65	0.240	7.27	3.00	0.240	7.81	3.44	6.73	2.57	0.33	**	***	ns	
kJ/ BW^{0.75}/day	404	361	4.0	525	242	4.0	541	266	506	217	10.96	**	***	ns	
Metabolizable energy,															
MJ/day	4.61 ^a	3.81 ^b	0.197	5.96 ^a	2.46 ^b	0.197	6.40	2.82	5.52	2.11	0.271	**	***	ns	
kJ/ BW^{0.75}/day	331 ^a	296 ^b	6.52	429 ^a	198 ^b	6.52	444	218	415	178	8.99	**	***	ns	
Heart rate, HR															
Beat/minute	58.1 ^b	64.0 ^a	1.84	65.8 ^a	56.2 ^b	1.84	61.1	55.0	70.6	57.4	2.54	*	**	ns	
EE:HR,															
kJ/BW^{0.75}/beat	6.83 ^a	5.70 ^b	0.21	6.46	6.08	0.21	7.15	6.51	5.77	5.64	0.283	**	ns	ns	
Energy expenditure, EE															
kJ/kg BW^{0.75}/day	394	364	10.20	420 ^a	338 ^b	10.20	435	352	405	324	14.09	t	***	ns	
Energy balance															
kJ/kg BW^{0.75}/day	-62.4	-68.0	8.27	9.3 ^a	-139.8 ^b	8.27	9.1	-134.0	9.6	-145.6	11.42	ns	***	ns	

^{a, b, c} Means without a common superscript letter in the row are differed ($P < 0.05$) between treatments, animal species, or their interactions. ns = non-significant; t < 0.10; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; SEM = Standard error of means.

There have been several studies showing the effect of feed intake level on energy requirements, particularly those regarding the desert animals, such as black Bedouin/Balady goats (Brosh et al., 1986; Choshniak et al., 1995; Askar, 2015; Askar et al., 2015) and Barki sheep (Farid et al., 1989; Askar et al., 2015). Bedouins goats can reduce their metabolic rate as a mechanism for adaptation when consumed wheat straw as a low quality forage (Brosh et al., 1986). Choshniak et al. (1995) reported that a feeding level of Bedouins goats on a half of a previous *ad lib* level of intake resulted in a reduction in heat production of a magnitude adequate to maintain body weight. Furthermore, a lower EE was observed for desert Barki sheep and Balady goats when they consumed *Atriplex nummularia* vs. alfalfa hay (Askar et al., 2015). Similar results were observed by El-Meccawi et al. (2008) when sheep and goats fed *Acacia saligna* vs. alfalfa hay. However, Asmare et al. (2006) and Helal et al. (2011) concluded that Boer and Spanish goats can markedly reduce EE when MEI is restricted below ME_m . This indicated that the ability of goats to reduce the ME_m with limited nutritional planes may not be a unique to specific genotype. Conversely, results in our laboratory by Askar (2015) reported a similar EE between Balady and Shami goats when they fed approximately at maintenance level (control level), while EE was markedly lower for Balady vs. Shami goats when they fed restricted intake level. Balady goats, but not Shami goats, have the ability to reduce their EE in order to improve their EB as a mechanism of adaptation when their ME intake is restricted below ME_m requirements. Results are supported by Helal et al. (2010) who concluded that EE of Balady goats, but

not Shami goats, is sensitive to climate conditions. We also found a significant correlation between EE and ambient temperature with Balady goats, but not Shami goats, suggested that with hot conditions, dry season/feed shortage, Balady goats have an advantage in a decreased the ME_m requirement which is going with our conclusion that Balady goats have the ability to reduce their EE as an adaptation to overcome the feed restriction.

However, the current ME_m estimated for Barki sheep and Balady goats fed control diets was 431 and 401 kJ/kg $BW^{0.75}$, respectively, based on the EB (Table 3) and the net energy supplied by diet, assuming k_m of 0.68 (ARC, 1980). The estimated value, 431 kJ/kg $BW^{0.75}$, for Barki sheep was practically similar to the value of 450 kJ/kg $BW^{0.75}$ reported by Farid et al. (1983) for local Barki desert sheep. However, it was greater than those estimated by ARC (1980), Kearn (1982) for developing countries, and NRC (2007) for sheep being 389-392 kJ/kg $BW^{0.75}$. In this regard, we have to mention that Barki is the main type of sheep raised in the western desert of Egypt for wool and meat and have a high adaptability to harsh and desert conditions (Payne et al., 1982; Farid et al., 1983 and 1989). On the other hand, the estimated value, 401 kJ/kg $BW^{0.75}$, for Balady goats was typically similar to the 398 kJ/kg $BW^{0.75}$ reported by Askar (2015) with females but lower than the value of 429 kJ/kg $BW^{0.75}$ reported by Helal et al. (2010) with intact male Balady goats. Factors responsible for these differences are unclear but animal sex may have been involved. Sahlu et al. (2004) proposed a 15% higher in ME_m (MJ/day) for intact males vs. females based on body weight.

4- Summary and Conclusions:

With indoor housing and a moderate cold climate condition, similar digestibility was observed for desert Barki sheep and Balady goats fed at approximately ME_m requirements, control level, while it was significantly lower for Balady goats vs. Barki sheep when fed at restricted intake level. Energy expenditure was not significantly varied between Barki sheep and Balady goats when they fed either at control or restricted intake level. The study concluded that local desert Barki sheep and Balady goats are able to reduce their energy expenditure in order to improve their energy balance as a mechanism of adaptation when their ME intake is restricted below ME_m requirements.

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