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Abstract. Twenty-four adult non-productive females, 12 Balady and 12 Shami goats, were employed to evaluate effects of nutrient restriction on energy expenditure (EE) and energy balance (EB). 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 breed for each set. Six animals of each breed were fed a concentrate mixture and alfalfa hay diet (1:1 as DM basis) at a level adequate for the metabolizable energy (ME) of maintenance (ME_m, C). The other six were fed 50% of this amount relative to actual body weight (R). Energy expenditure was estimated by heart rate (HR) monitor after individual calibration by oxygen consumption with a face mask open-circuit respiratory system. Digestible energy was negatively affected (-10 pts) by restricted feeding, without significant differences between goat breeds. Energy expenditure was greater ($P<0.001$) for C *vs* R and higher ($P<0.01$) for Shami *vs* Balady goats. As a result, the EB was similar between both goat breeds fed near maintenance , while it was lesser unbalanced ($P<0.05$) in Balady *vs* Shami goats when underfed. In conclusion, Balady goats, but not Shami goats, had 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 for a long time.

Keywords. Restricted intake – Digestion – Energy expenditure – Energy balance – Goat breed.

Effet d'une restriction alimentaire à long terme sur les dépenses et le bilan énergétiques chez les chèvres de race Balady et Shami

Résumé. *Un essai a été mené sur vingt quatre chèvres adultes, non gravides et taries, 12 de race Balady et 12 de race Shami, pour évaluer l'effet d'une restriction alimentaire sur les dépenses énergétiques (EE) et le bilan énergétique (EB). Les animaux ont été logés individuellement pendant une période de trois mois et ensuite placés dans des cages métaboliques en deux groupes de 12 animaux (3 chèvres par traitement et par race pour chaque groupe). Six animaux de chaque race ont reçu une ration à base de foin de luzerne et de concentré (1:1 en MS) pour satisfaire les besoins d'entretien en énergie métabolisable (*ME_m*, C). Les autres six animaux ont reçu 50 % de cette quantité exprimée par rapport au poids vif (R). Les dépenses énergétiques ont été estimées moyennant la technique de fréquence cardiaque (HR) après un étalonnage individuel de volume d'oxygène consommé en utilisant un masque avec un système de circuit ouvert. La restriction alimentaire a affecté négativement l'énergie digestible, sans différence entre les deux races. Les dépenses énergétiques ont été supérieures (P<0,001) chez les chèvres du traitement C* vs *R, et plus élevées (P<0,01) chez les chèvres de race Shami* vs *Baladi. En conséquence, le EB a été similaire entre les deux races de chèvres pour le traitement C, alors qu'il a été plus élevé (P <0,05) pour les chèvres Balady* vs *Shami pour le traitement R. En conclusion, à long terme, les chèvres de race Balady, contrairement à la race Shami, ont la capacité de réduire leur EE afin d'améliorer leur EB comme un mécanisme d'adaptation lorsque leur ingestion de ME est restreinte et inférieure aux besoins énergétiques d'entretien en ME (*ME_m*).*

Mots-clés. *Restriction alimentaire – Digestion – Dépenses énergétiques – Bilan énergétique – Caprine.*

I – Introduction

Metabolizable energy (ME) requirements for maintenance (ME_m) can be influenced by several factors, including animal breed and feed intake level. Helal *et al*. (2010) concluded that ME_m is significantly differed within goat breeds, Balady and Shami goats. Similar findings were reported by Patra *et al*. (2009) for Boer and Spanish goats. On the other hand, feed intake level is considered one of the most important factors affecting ME_m (NRC, 2007; Helal *et al*., 2011). Ruminants are able to reduce their energy expenditure (EE) to improve their energy balance as a mechanism of adaptation when their ME intake is restricted below ME_m requirements (Asmare *et al*., 2006; Askar, 2015) that 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). In this concern, there have been several previous studies showing the effect of feed intake level on nutrients requirements, particularly those regarding the desert animals, such as black Bedouin/Balady goats (Brosh *et al*., 1986; Askar, 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 EE 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 unique to particular genotypes, such as the desert goat. The objective of the present experiment was to study effects of long-term restricted feed intake on energy utilization and balance of different goat genotypes, local Balady raised for meat and Shami typically reared for milk production.

II – Material and methods

Animals and treatments: Twenty four adult non-productive females, 12 Balady and 12 Shami 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. The average mean, low, and high values through January for ambient temperatures were 13.0 ± 0.19, 8.9 ± 0.324, and 18.9 ± 0.38 °C, indicating that animals were apparently exposed to moderate cold conditions (Askar, 2015). Animals of each breed were allocated to two levels of feed intake. Animals on a control feeding treatment were fed a diet with adequate level to meet the ME_m requirements (C), while those on the other feeding treatment was fed almost 50% of these amount based on body weight basis (R). Alfalfa hay (12.4% CP and 17.1 MJ/kg DM) and concentrate mixture (12.4% CP and 18.0 MJ/kg DM) (1:1) were given based on 429 and 479 kJ/kg $BW^{0.75}$, respectively, for Balady and Shami goats fed a control (Helal *et al*., 2010).

Experimental procedures: Animals stayed in individual pens for 3-month period then moved to elevated cages in two sets of twelve, three animals per treatment and animal breed for each set, for collection of feces and urine. Water was available free choice twice daily, at 08:00 and 14:00 h. It was lasted for 7-day collection period after feed intake establishment.

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 O_2 consumption were made twice daily at the morning and afternoon as described by Askar (2015). 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). Heart rate (HR) was measured on animals fitted with Vermed Performance Plus ECG electrodes according to Askar (2015). 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 was measured individually on elevated cages for at least 48-h periods. The diurnal EE were determined from the EE:HR ratio for each animal. Furthermore, gross energy (GE) of feed, orts and feces was measured by bomb calorimeter (IKA, model C 200, Staufen, Germany), using benzoic acid as standard. The ME was estimated as digestible energy (DE) minus the energy loss in urine (Swift *et al*., 1948) and methane (Blaxter and Clapperton, 1965). Energy balance (EB) was calculated as the difference between ME intake (MEI) and EE.

Statistical analyses: Data were analyzed by the GLM procedure of the SAS statistical package with a model consisting of the effect of feeding treatments and animal species within treatment. The two degrees of freedom of animal species were split into a set of two orthogonal contrasts: C1, Balady *vs* Shami within C treatment and C2, Balady *vs* Shami within R treatment.

III – Results and discussion

Energy intake and digestibility: Although GE intake was greater (P<0.05) for Shami *vs* Balady goats, a similar DE% for both goat breeds at either C or R group was observed (Table 1). However, it is known that lower intake implies a longer digesta residence time and increases the efficiency of feed utilization. Conversely, the reduction in goat's digestibility for R *vs* C intake treatment was not expected (Table 1). The results confirmed the decrease in digestibility at very low intake level as reported by (Doreau *et al*., 2003) and suggested an adaptive process to reduce gut EE. On the other hand, results indicated that goats are much sensitive to low temperature, may be due to their coat type, particularly when they were given a low feed intake level below maintenance for a long period. Part of this reduction might be due to a lower fermented energy available for rumen microflora or to the significant lower EE for R *vs* C (Table 2) that is always necessary to overcome the cold effect. This might increase the load effect of cold on the animals. Kennedy and Milligan (1978) reported that cold exposure resulted in a reduction in digestibility that was due to the increase in the rate of passage of digesta in the cold-acclimated animals and the increase in the reticulo-rumen motility. However, ME intake was trended to be greater (P<0.10) for Shami *vs* Balady goats and greater (P<0.001) for C *vs* R group.

Table 1. Energy intake and digestibility by Balady and Shami goats while feeding at control or restricted feed intake level

Items	Goat breed (treatment)					Significant contrasts		
	Control		Restricted				Balady *vs* Shami	
	Balady	Shami	Balady	Shami	SEM	Treat	Control	Restricted
Digestible energy, %	63.2	60.5	51.2	50.5	1.53	***	ns	ns
Energy utilization, kJ/ $BW^{0.75}$/day								
Gross energy	801[b]	898[a]	426[d]	460[c]	10.61	***	***	*
Digestible energy	506	543	218	232	10.9	***	*	ns
Urine energy	23.8	25.6	17.5	21.3	2.15	*	ns	ns
Methane energy	61.2	67.4	30.2	32.4	0.90	***	***	t
Metabolizable energy	421	450	171	179	10.8	***	T	ns

ns = non-significant; t<0.10; * = P<0.05; *** = P<0.001; SEM = Standard error of means.

Energy expenditure and balance: Heart rate and EE were significantly (P<0.05) lower for Balady *vs* Shami goats with R level, while similar HR and EE were observed between both goat breeds with C level (Table 2). Furthermore, a greater (P<0.001) HR and EE were reported for C *vs* R. Figure (1) showed the effect of goat breed and intake treatment on EE throughout the 24 hours of the day that supported the findings reported in Table 2.

Table 2. Heart rate (HR), energy expenditure (EE) and balance (EB) by Balady and Shami goats while feeding at control or restricted feed intake level

Items	Goat breed (treatment)					Significant contrasts		
	Control		Restricted				Balady *vs* Shami	
	Balady	Shami	Balady	Shami	SEM	Treat	Control	Restricted
HR, beat/minute	68.8	71.3	56.5	66.5	2.45	**	ns	**
EE:HR, kJ/BW$^{0.75}$/beat	5.77	6.22	5.52	6.00	0.272	ns	ns	ns
EE, kJ/kg BW$^{0.75}$/day	395	438	312	399	16.7	**	t	**
EB, kJ/kg BW$^{0.75}$/day	+25.8	+11.6	-141.6	-219.8	16.00	***	ns	**

ns = non-significant; t<0.10; ** = P<0.01; *** = P<0.001; SEM = Standard error of means.

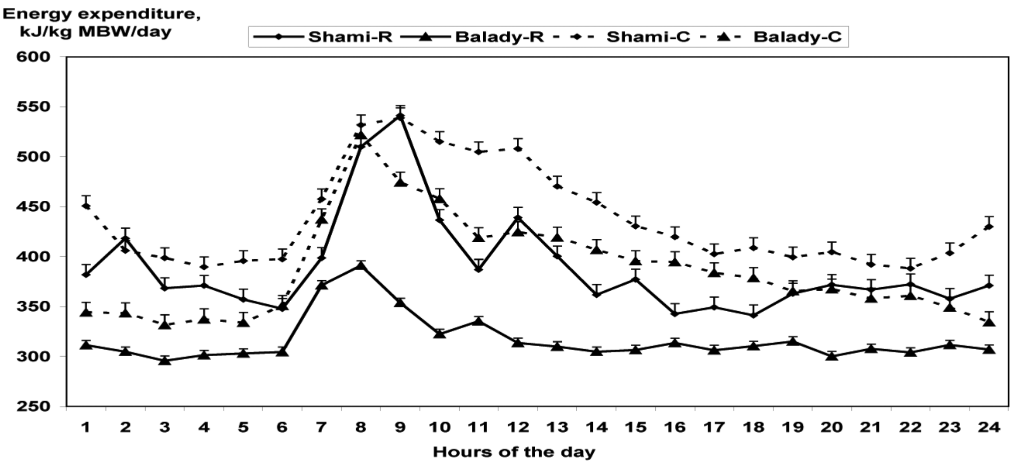

Fig. 1. Hourly energy expenditure (kJ/kg MBW) of Balady and Shami goat fed at control (C) or restricted (R) feed intake level throughout 24-hour period. Arrow indicate once a day meal.

The difference between EE and MEI showed that Balady were in a better state having lower EE than Shami goats when fed R level (Table 2 and Fig. 2), indicating that desert Balady goats, but not Shami goats, have the ability to reduce their EE when they were given a low intake level below ME_m. This reflected upon the EB that was greater (P<0.01) in Balady *vs* Shami goats when fed R level, even though a similar EB was observed in both breeds when fed C level (Table 2). It would appear that dairy goat breeds, such as Shami can not minimize the EE to the extent of other genotypes in response to severe nutrient restriction (Tovar-Luna *et al*., 2007).

In agreement with Asmare *et al*. (2006) and Askar (2015), total EE was significantly greater for C *vs* R intake level. However, in the case of R group, ME intake was clearly below the reported ME_m (NRC, 2007), and consequently animals incurred a negative EB. However, Balady goats had a better state having greater (P<0.01) EB than Shami goats when fed R level (Table 2). This supports the previous conclusion mentioned above and suggests that desert Balady goats, but not Shami goats, were able to reduce their basal metabolic rate as an adaptation mechanism to restricted feeding that is 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). In this concern, there have been a number of previous studies showing the effect of feed intake level on energy requirements and animal's adaptation and survival, particularly those regarding the desert animals, such as desert Bedouin/Balady goats (Brosh *et al*., 1986; Askar, 2015). Choshniak

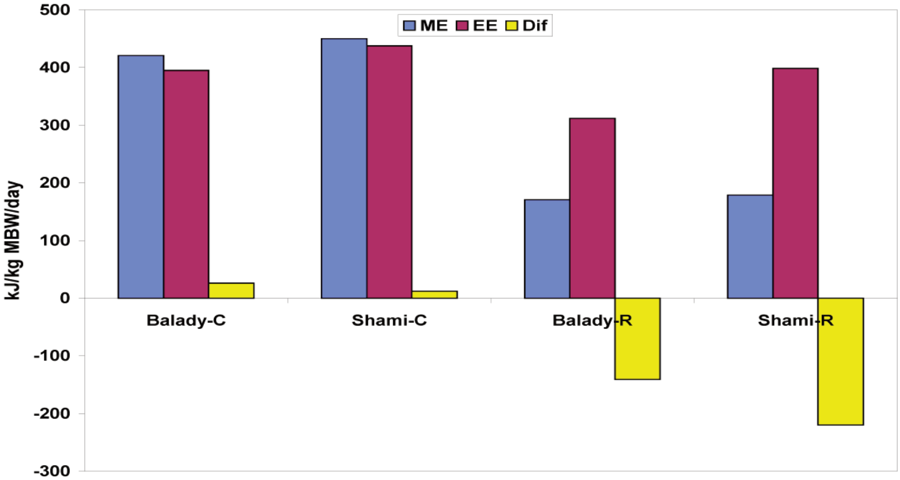

Fig. 2. Metabolisable energy (ME), energy exenditure (EE) and the difference (Dif) between them (kJ/kg MBW) by Balady and Shami goats while feeding at control or restricted feed intake level.

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 EE of a magnitude adequate to stabilize body weight at a lower level sooner than other other goat genotypes. Brosh *et al.* (1986) suggested that Bedouin goats can reduce their metabolic rate while consuming low quality forage as a mechanism for adaptation. These findings agreed with those reported by Asmare *et al.* (2006) and Helal *et al.* (2011) with Boer/Spanish goats and 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 goats.

IV – Conclusions

With indoor housing and a moderate cold climate condition, long-term restricted intake at half of what would be necessary affected negatively the digestible energy in goats (-10 pts). Balady goats, but not Shami goats, have the ability 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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