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in

**Molina Alcaide E. (ed.), Ben Salem H. (ed.), Biala K. (ed.), Morand-Fehr P. (ed.).
Sustainable grazing, nutritional utilization and quality of sheep and goat products**

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 67

2005
pages 255-260

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SUMMARY – The effect of polyethylene glycol (PEG) on energy expenditure (EE), heart rate (HR) oxygen consumption (VO_2), feeding behaviour and performance of Sarda goats browsing on bushland was studied. Eight goats at the end of lactation, supplemented with hay and a commercial concentrate, browsed for 6 h a day on a 2.5 hectare lentisk-based bushland. Two treatments were compared in a switch-over design: Control (C) and PEG (50 g/goat/day). HR (beats/min) was continuously recorded; VO_2 was measured by an open circuit system. EE was estimated from daily HR measurements and oxygen consumption calibrated against oxygen consumption per heart beat (O2 pulse, ml O_2/kgBW$^{0.75}$/beat). Feeding behaviour and intake were quantified by direct observation of biting. *In vivo* DM and CP digestibility were measured by alkane (C_{36}). EE and HR were higher in PEG supplemented goats (516±23 PEG vs 467±18 C kJ/kgBW$^{0.75}$/day, $P<0.05$; 93±2.4 PEG vs 87±2.4 C beats/min, $P<0.01$). The treatment had no effect on O_2 pulse (0.187±0.012 ml O_2/kgBW$^{0.75}$/beat). PEG supplemented goats tended to ingest more at pasture than controls (1103±26 vs 1022±28 g/goat/day, $P<0.09$). DM digestibility was similar in both treatments whereas CP digestibility was higher in PEG supplemented goats (54.7±4% PEG, 36.2±6% C; $P<0.05$). The estimated ME intake was 625±46 and 533±88 kJ/kgBW$^{0.75}$/day ($P<0.2$) respectively in PEG and C groups. Milk yield was similar in both treatments whereas PEG positively affected milk fat and urea.

Key words: Energy expenditure, heart rate, goats, bushland.

RESUME – *"Dépense d'énergie par des chèvres laitières au pâturage dans les zones arbustives méditerranéennes". L'objectif de ce travail est d'étudier l'effet de la supplémentation avec du polyéthylène-glycol (PEG) sur les dépenses énergétiques (EE), la fréquence cardiaque (HR), la consommation d'oxygène (VO_2), le comportement alimentaire et les performances de chèvres Sardes sur parcours. Huit chèvres, en fin de lactation, complémentées avec du foin et du concentré, pâturaient sur une surface (2,5 ha) arbustive et arborée dominée par le lentisque (Pistacia lentiscus). On a comparé 2 traitements : Témoin (C) et PEG (50 g/chèvre/jour) selon une procédure "switch-over". La fréquence cardiaque (HR, bat./min) a été continuellement enregistrée ; VO_2 a été mesurée ponctuellement avec un système de circuit ouvert. On a estimé les EE grâce au produit de HR x O_2 pulse (ml O_2/kgPV$^{0.75}$/bat.). Le comportement alimentaire et l'ingestion ont été estimés par observation directe des coups de dents. La digestibilité* in vivo *de la matière sèche et de la matière azotée totale a été estimée par un marqueur externe (alcane C_{36}). EE et HR ont été plus élevés chez les chèvres PEG (516±23 PEG vs 467±18 C kJ/kgPV^{0,75}/jour, $P<0,05$; 93±2,4 PEG vs 87±2,4 C bat./min, $P<0,01$). Le PEG n'a pas affecté la consommation d'oxygène par battement cardiaque (0,187±0,012 ml O_2/kgPV^{0,75}/bat.). L'ingestion moyenne au pâturage a tendance à augmenter avec le PEG (1103±26 vs 1022±28 g/chèvre/jour, $P<0,09$). La digestibilité de la MS n'a pas été influencée par le PEG tandis que la digestibilité de la MAT a augmenté avec le PEG (54,7±4% PEG, 36,2±6% C ; $P<0,05$). Les ingestions calculées de ME étaient de 625±46 et 533±21 kJ/kgPV^{0,75}/jour ($P<0,2$) respectivement dans les lots PEG et C. La production de lait a été similaire alors que le taux butyreux et la concentration d'urée ont été élevés dans le lot PEG.*

Mots-clés : *Dépenses énergétiques, fréquence cardiaque, chèvres, parcours.*

Introduction

Lentisk-based bushland is featured by a high-condensed tannin (CT) level that limits intake of lentisk as well as CP digestibility of the diet in goats. PEG supplementation can counterbalance CT effect by increasing the intake of high-tannin bushes and substantially enhancing CP digestibility (Decandia *et al.*, 2000a,b). Its effect on energy expenditures (EE) still has to be assessed. Energy expenditure (EE) of ruminants has been mainly estimated under controlled conditions. These estimations are not usable for grazing animals. Many factors, like weather conditions, physiological state, feeding behaviour, tissue and pelage conductance etc. affect the EE in grazing animals. Different methods have been proposed and used to allow EE estimation on free-range conditions (Toerien *et al.*, 1999; Prieto *et al.,* 2001). These methods are expensive and interfere with welfare regulations and the behaviour of animals. Some authors suggested the use of heart rate (HR) as an indicator of EE in ruminants (Webster, 1967; Yamamoto *et al.*, 1979) but the accuracy of HR-based estimations, without individual calibration of oxygen consumption (VO_2) per heartbeat was considered low (Brosh *et al.*,1998a). VO_2 can be estimated by means of open circuit respiration systems (Clar, 1991; Rometsch *et al.*, 1997). The ratio of VO_2 to HR (O_2 pulse, O_2P), measured during a short period, is considered constant. It can be multiplied by the number of heartbeats, recorded in a long period, to estimate the EE in the same period (Brosh *et al.*, 1998a). This estimation is strictly related to the O_2P variability under differing environmental conditions and throughout the hours of the day. Brosh *et al.*, (1998a,b) observed no significant change in O_2P between morning and afternoon measurements or under changing heat loads. The differences in HR, VO_2, and O_2P measurements among similar animals are usually high and should be determined for individual animals to avoid errors (Aharoni *et al.*, 2003) and under similar conditions to those to which the animals are normally exposed. The EE was calculated from HR and O_2 pulse in cattle (Brosh *et al.*, 1999; Aharoni *et al.*, 1999) and in sheep (Barkai *et al.*, 2002) assuming that 20.47 kJ of EE corresponds to the utilisation of 1 l of O_2 (Nicol and Young, 1990). The objective of the study was to evaluate the effect of polyethylene glycol (PEG) on energy expenditure (EE), heart rate (HR) oxygen consumption (VO_2), feeding behaviour and performance of Sarda goats browsing on bushland.

Materials and methods

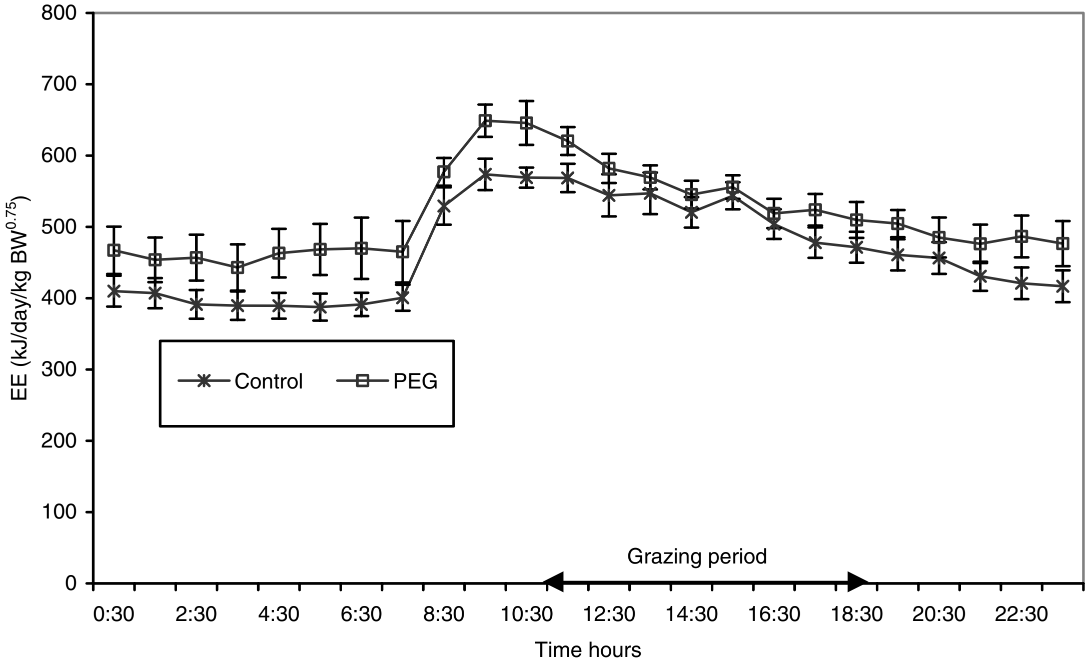
The experiment was run in summer (July 2002) at "Bonassai" farm (NW Sardinia). Eight lactating mature Sarda goats (48.90 ± 5.57 kg, BW) at the end of lactation were used. Goats grazed for 6 hours daily a paddock of 2.5 ha covered mostly by lentisk and received 200 g/goat/day of a commercial concentrate (16% CP, divided into two meals at milking) and 200 g/goat/day of ryegrass hay.

Two treatments have been compared: Control (C) and PEG (50 g/goat/day), dosed by drenching every morning before pasture. After an adaptation period of about 6 weeks each goat was submitted to each treatment in a switch-over design. Each period lasted for 9 days. Four goats were submitted to either C or PEG treatment in both the first and the second experimental period.

HR (beats/min) was continuously recorded every 1 min with data loggers (Polar Electro Oy, Finland; S-610 HR monitors and T 51-H transmitters) fastened to a harness attached to the thorax for the last 3 days of each period. Means of 24 periods of 1 h were then calculated. Oxygen uptake was recorded on each animal on days 7, 8 and 12, 13. A measurement of 10 min each was made using a facemask open-circuit respiratory system (Brosh *et al.*, 1998a). HR was measured simultaneously with O_2 uptake, one recording every 5 seconds, which enables to calculate O_2 pulse (ml O_2/kg/$BW^{0.75}$ per heat beat). The concentration of O_2 was assessed using an oxygen analyser (Servomex 1440, Keison products, Chelmsford, UK). The accuracy was checked gravimetrally by injection nitrogen into the mask. The recovery of nitrogen was 0.99±0.005. The EE was calculated assuming that 20.47 kJ corresponds to 1 l of O_2 (Nicol and Young, 1990). Feeding behaviour was studied on days 7, 13 by the direct observation of biting and the intake was measured by hand plucking of the vegetation (Kababya *et al.*, 1998). The forage samples were analysed for chemical composition (DM, OM, CP, NDF, ADF, ADL) including condensed tannins (CT, Butanol-HCl reagent, Porter *et al.*, 1986). *In vivo* digestibility of dry matter DM and crude protein CP were assessed using C_{36} as external marker corrected by its recovery rate (Dove, 1989). Metabolisable energy intake (MEI, NRC 1981) and retained energy (RE = MEI-EE), were also estimated. Body weight and body score were measured at the beginning and at the end of each experimental period. Milk yield and composition (fat, N*6.38 and urea) were measured individually on days 7,13. Treatment means were compared by paired t-test.

Results and discussion

The diurnal pattern of HR and EE showed higher values in PEG goats than counterparts (Fig. 1). Overall the effect of PEG supply on HR and EE was significant (Table 1). Oxygen consumed per heartbeat (O_2 pulse) was not affected by the treatment. The ME intake showed a tendency to be higher in PEG supplemented goats ($P<0.2$). The retained energy (RE), low in both groups, was not affected by PEG.



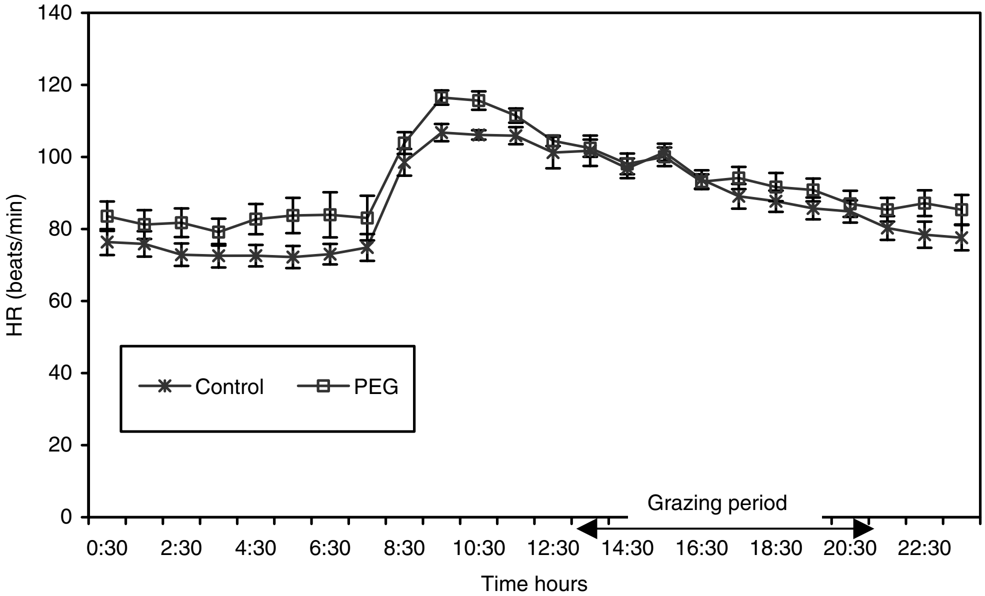


Fig. 1 Diurnal pattern of HR (beats/min) and EE (kJ/day/kg BW$^{0.75}$) in browsing goats with (PEG) or without (C) the supplementation of PEG (means ± SE).

The goats consuming PEG spent more time at grazing (expressed as percentage of total observation time) than C counterparts (55% PEG, 53% C, $P<0.01$). PEG was associated with a tendency for higher intake at pasture (P<0.09) and higher percentage of dietary ADL and CT. C goats selected a diet with higher CP level (Table 2). The higher ingestive activity at pasture in PEG goats, with the same time spent in searching and moving activities than the counterparts, seems to be the main reason of the higher EE.

Table 1. Heart rate (HR), logged during measurement of O_2 pulse and continuously (beats/min), O_2 pulse (ml/kg $BW^{0.75}$/beat), energy expenditure (EE), metabolisable energy intake (MEI) and retained energy (RE; kJ/day/kg $BW^{0.75}$) of goats supplemented (PEG) or not (C) with PEG

	HR at time of O_2 pulse measurement	HR continuously recorded	O_2 pulse	EE	MEI	RE
PEG	85.75	92.76 a	0.189	516.14 a	625.41	109.27
C	88.65	86.92 b	0.182	466.73 b	533.21	66.48
SED†	2.51	1.87	0.006	21.52	103.23	124.53

Means within a column with different letters differ significantly, P<0.05.
†Standard error of the difference.

Table 2. Intake at pasture (g DM), DM and CP digestibility (%), diet chemical composition (%) of Sarda goats supplemented (PEG) or not (C) with PEG

	PEG	C	SED†
Intake at pasture (g DM)	1103	1022	54.09
DM digestibility (%)	51.79	45.60	7.34
CP digestibility (%)	54.73 a	36.20 b	8.18
CP (%)	9.33 b	9.70 a	0.07
NDF (%)	45.06	44.54	1.09
ADF (%)	30.68	29.70	0.57
ADL (%)	12.66 a	10.71 b	0.23
CT (%)	12.85 a	7.96 b	0.85

Means within a row with different letters differ significantly, P<0.05.
†Standard error of the difference.

DM digestibility was similar in both treatments whereas CP digestibility increased with PEG supplementation. No effect of PEG was found in LW and body condition score. Milk yield was similar in both treatments whereas PEG positively affected milk fat and urea (Table 3). Pooling all data, a positive relation was found between EE and milk yield (r = 0.61; P<0.05).

Table 3. Milk yield and milk composition of PEG and control goats

	PEG	C	SED†
Milk (ml)	891	860	85
Fat (%)	4.94 a	4.50 b	0.12
Protein (%)	3.17	3.06	0.06
Urea (%)	26.91 a	15.36 b	2.96

Means within a row with different letters differ significantly P<0.05.
†Standard error of the difference.

Conclusion

It is confirmed the positive effect of PEG on intake and CP digestibility in high-tannin pastures. Energy expenditure of goats increased with PEG. That result should be a consequence of a greater grazing activity and tendency to higher DM intake of PEG supplemented goats due to the tannin neutralization. MEI and, even if at less extent, RE tended also to be higher in PEG supplemented goats. These effects can be stronger in goats with higher energy requirements.

Acknowledgements

The authors wish to thank Mr. G. Scanu and Mrs M.A. Sanna for running the chemical analysis and Mr. S. Picconi for technical support.

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