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Goats locomotion energy expenditure under range grazing conditions: Seasonal variation

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Abstract

The estimation of the energy cost of various activities using calorimetric techniques in conjunction with direct field observations can be used to estimate energy expended in the daily activities of free-ranging animals. The objective of this study was to observe and quantify the grazing activities and to estimate the energy expenditure due to locomotion of goats in open range.

The study was carried out at 'Finca de Bonaya' privately-owned site, which extends over 1,482 ha, located in the Nevada mountain-range, Almería. The local altitude varies from 1,100 to 2,000 m above sea level. The area has a mediterranean mountain climate, with annual precipitation ranging from 400 to 700 mm and average daily temperatures from 4.7°C in winter to 23.0°C in summer. Landscape is characterised by holm-oak wood and pine wood, degradation scrubs and hydrophilic grasses communities.

The experimental flock grazed on 3 routes during the whole year. The goats were released to graze during the day and then returned to an enclosed shed. The type of goat management was considered as semi-extensive. Direct observation was used to simulate the total distance walked, the vertical ascent or descent, and to quantify other grazing activities. Data on activities on range and distance travelled were taken on 3 days in each season. The energy expenditure of locomotion was calculated from the horizontal and vertical components of travel and the corresponding costs, which had been previously obtained by calorimetry.

There was no significant seasonal effect on period devoted to specific activities on range (P>0.05). However, significant changes in the estimated daily energy expenditure and extra energy expenditure due to locomotion of the animals at pasture were found in different seasons (P<0.05). Grazing and walking were the primary activities of goats throughout the study, accounting for 51.7 and 42.0% of the animals' daily period on range, respectively. Daily travelled distances by goats on range fluctuated from 12,777 m in summer to 8,100 m in autumn, with an annual average of 9,954 m, which represents a mean speed of 20.8 m/min calculated over the whole period on range. The mean annual vertical ascent or descent was 500 m. Estimated heat production due to locomotion ranged from 130.9 to 88.5 kJ/kg$^{0.75}$ per day in summer and autumn respectively. These values account for an increased metabolizable energy (ME) requirement at pasture above maintenance of 46.6 and 31.6%, respectively, assuming a ME requirement for maintenance of 401 kJ/kg$^{0.75}$ per day for the restrained goat.

Key Words: goats, locomotion, grazing, heat production.

Resumen

El coste energetiéo de varias actividades, obtenido mediante técnicas calorimétricas, junto a observaciones directas, realizadas en campo, puede utilizarse para estimar la energía transformada en las actividades que realizan los animales en pastoreo. El objetivo de este trabajo fue observar y cuantificar las actividades diarias relacionadas con el pastoreo y estimar el gasto energético debido a la locomoción de cabras en producción extensiva.

El estudio se realizó en la "Finca de Bonaya", de propiedad particular, de 1,482 ha, situada en Sierra Nevada, en la provincia de Almería, con altitud que varía entre 1,100 y 2,000 m sobre el nivel del mar. Su clima es mediterráneo de montaña, con 400 a 700 mm de precipitación anual y temperatura media que oscila entre 4,7°C, en invierno, y 23,0°C, en verano. Contiene áreas de robledal y pinar, monte bajo y comunidades de gramíneas hidrofílicas.

A lo largo del año el rebaño experimental pastaba siguiendo 3 recorridos, accediendo al campo por la mañana y regresando a un redil protegido. El sistema de manejo se considera semi-extensivo. Se empleó la observación directa para calcular la distancia recorrida, las diferencias en altitud, en ascenso y descenso, y para cuantificar las distintas actividades de los animales en pastoreo. Tales datos se tomaron durante 3 días en cada estación del año. El gasto energético de la locomoción se calculó a partir de los componentes vertical y horizontal del desplazamiento efectuado y sus correspondientes costes energéticos, obtenidos previamente por calorimetría.

No se observaron diferencias significativas entre estaciones respecto al periodo relativo que los animales en pastoreo dedicaron a actividades específicas (P>0,05). Sin embargo, se observaron entre estaciones cambios significativos en gasto energético diario y en la cantidad de energía adicional debida a la locomoción (P<0,05). Las actividades relacionadas con la ingestión de pasto y la locomoción fueron las dos actividades más importantes observadas en este estudio, alcanzando el 51,7 y 42,0% del periodo diario de permanencia de las cabras en el campo, respectivamente. Las distancias que las cabras recorrían al día variaron entre 12.777 m en verano y 8.100 m en otoño, con un promedio anual de 9954 m, lo que representa una velocidad media de desplazamiento de 20.8 m/min si el cálculo se realiza sobre el tiempo total de permanencia en pastoreo. La diferencia de altitud media del recorrido fue de 500 m, tanto en ascenso como en descenso. La producción de calor debida a la locomoción se situó entre 130,9 y 88,5 KJ/Kg$^{0.75}$ y día, en verano y otoño, respectivamente. Estas cifras representan un aumento en necesidades de energía metabolizable (EM) para el mantenimiento de 46,6 y 31,6%, respectivamente, asumiendo un valor de 401 KJ EM/Kg$^{0.75}$ y día para las necesidades de mantenimiento del animal en estabulación.

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Goats are well adapted to the hot and dry conditions of the semi-arid areas of southern Spain, where they are widely reputed to give rise to a great productivity (Boza and Sanz Sampelayo 1997). Goats are able to harvest an adequate diet even when forage is scarce and they can graze over rugged and otherwise inaccessible terrain (Lu 1988). In arid lands, goats have to travel long distances for adequate food and water, and thus, their energy expenditure increase outstandingly. The extra energy expenditure related to physical activity of the grazing animal may affect its productive performance and may be influenced by seasonal variation in grazing activities (Lachica et al. 1997a).

The energy requirements for maintenance of grazing ruminants has been reported to be from 0 to 100% greater than those found for animals in confinement, with the cost of travel contributing substantially to this increase (see Lachica et al. 1997a).

The energy cost of various activities estimated using calorimetric techniques can be used in conjunction with direct field observations to estimate daily energy expenditure of free-ranging animals with advantages over other methodologies developed to measure or estimate the energy expenditure of unrestrained animals (Osuji 1974, Prieto et al. 1992), due to uncertainties about the reliability of these available techniques. The usual procedure for measuring the total energy expenditure by grazing animals is a factorial method, whereby the increase in energy expenditure above that measured in confinement is quantitatively estimated from calorimetric determination of the energy cost of various activities. The energy cost of each activity is then multiplied by the total time spent by free-ranging animals performing that activity and total extra energy expended is calculated by summation. Data on energy requirements of confined goats for maintenance and milk production have been obtained from calorimetric measurements in our laboratory (Aguilera et al. 1990, Prieto et al. 1990). Also, the energy cost of locomotion has been determined (Lachica et al. 1997b). This joined information allows to obtain accurate estimations of daily energy expenditure of goats on free range conditions. The described procedure is more advisable than extrapolation of theoretical allowances (i.e. NRC 1981) due to variations in grazing activities induced by environmental effects, as reported earlier (Lachica et al. 1997a).

The present work was designed to obtain additional information on the evaluation of seasonal effects on grazing activities of goats in the Mediterranean ecosystems of southern Spain and on changes they may cause in their daily energy expenditure.

Study Area

The study was conducted on a 1,482-ha privately-owned area called ‘Finca de Bonaya’, located in the Nevada mountain-range, between Laujar de Andarax and Paterna del Río, in the province of Almería, in southern Spain (latitude 37° 02.9' N and longitude 2°54.8' W). The topography is rugged, varying in elevation from 1,100 to 2,000 m above sea level. The climate in this region is typified as mediterranean mountain with rainfall variation of 400 and 700 mm. Summer is characteristically dry. The order of maximum precipitation is winter, autumn, spring, and summer. The average seasonal temperatures range from 4.7°C in winter to 19.4°C in summer.

This area was chosen to carry out the present study because of being rather similar to one used for a previous study (Lachica et al. 1997a) as far as their topographic and climatic characteristics is concerned, but there were important differences in vegetation communities. This later factor was assumed to have an important effect on grazing activities and behaviour of the animals. In this private area a representative flock of goats was available.

The vegetation of the area is dominated by trees formations: holm-oak (*Quercus rotundifolia Lam.*) and pine (*Pinus silvestris L. and P. Nigra Arnold*), degradation scrubs and hydrophilic grasses communities. The most abundant plant species of interest for goat production are listed in Table 1 in decreasing order of palatability. A catalogue of the vegetation of the area has been published by Fernández (1995). This author’s article also reports on the evaluation made of total phytomass (9,931 kg/ha) and forage phytomass (1,718 kg/ha) of the area.

Materials and Methods

The experimental flock was composed of 350 heads (17 males and 333 lactating females). The goats were of the "Malagueña" and "Serrana" breeds and

Table 1. Plant species of interest for goat production in ‘Finca de Bonaya’ (southern Spain).

[1]*Adenocarpus decorticans Boiss*	[2]*Eryngium campestre L.*
[2]*Dactylis glomerata L.*	[2]*Teucrium compactum Clemente ex Lag.*
[2]*Koeleria crassipes Lange*	[1]*Ulex parviflorus Pourret*
[1]*Quercus rotundifolia Lam.*	[1]*Artemisia campestris L.*
[1]*Crataegus monogyna Jacq.*	[1]*Cistus albidus L.*
[1]*Fumana ericoides (Cav.) Gand.*	[2]*Festuca lemanii*
[1]*Helianthemum apenninum (L.) Miller*	[2]*Festuca trichophylla (Ducros ex Gaudin) K. Richter*
[1]*Helianthemum cinereum (Cav.) Pers..*	[1]*Genista scorpius (L.) DC.*
[2]*Argyrolobium zanoni (Turra) P.W. Ball*	[1]*Genista versicolor Boiss.*
[2]*Euphorbia flavicoma DC.*	[1]*Thymus serpylloides Bory*
[2]*Hieracium pilosella L.*	[2]*Festuca elegans Boiss.*
[1]*Rhamnus myrtifolius Willk.*	[1]*Bupleurum spinosum L.*
[1]*Dorycnium pentaphyllum Scop.*	[1]*Erinacea anthyllis Link*
[2]*Ononis repens L.*	[1]*Helichrysum stoechas (L.) Moench*
[1]*Prunus ramburii Boiss.*	[2]*Nardus stricta L.*
[1]*Rosa canina L.*	[1]*Santolina chamaecyparissus L.*
[2]*Anthyllis vulneraria L.*	[1]*Teucrium polium L.*
[2]*Avenula bromoides (Gouan) H. Scholz*	[1]*Thymus zygis L.*
[1]*Genista cinerea DC.*	[2]*Andryala integrifolia L.*
[1]*Cistus clusii L.*	[2]*Arrhenatherum elatius (boiss. & Reuter) Romero Zarco*
[1]*Cytisus oromediterraneus Boiss*	[1]*Berberis hispanica Boiss. & Reuter*
[1]*Genista umbellata Poir.*	[2]*Brachypodium retusum (Pers.) Beauv.*
[1]*Lavandula stoechas DC.*	[2]*Festuca indigesta Boiss.*
[2]*Sanguisorba minor Scop.*	[2]*Festuca scariosa (Lag.) Ascherson & Graebner*
[1]*Staehelina dubia L.*	[1]*Lavandula lanata Boiss.*
[2]*Corynephorus canescens (L.) Beauv.*	[2]*Melica minuta L.*
[2]*Carlina corymbosa L.*	

[1]Woody plants.
[2]Herbaceous plants.

their respective cross-breeds. After morning milking, the goats grazed during the day under the supervision of a shepherd and then returned to an enclosed shed, in which they spent the night. The type of goat management is considered as semi-extensive, for commercial milk production (annual yield 280 liters/animal on average) and meat (carcasses of young kids mainly).

Three routes which were usually followed by the herd, identified as route 1, 2, and 3, were used in this study. They were at 1,600–2,000 m, 1,500–2,000 m and 1,000-1,600 m above sea level, respectively.

A direct observation procedure, described by Somlo et al. (1991a) and Lachica et al. (1997a), was used to quantify time spent on each activity on the range and also to measure total distance walked, vertical ascent or descent. Briefly, the track of a randomly selected lactating female was followed for 10 minutes on foot by 2 observers, one for annotating the animal's grazing activities and another for quantification of the distance travelled. During this 10-minute period this single animal was assumed to be a reliable indicator of the flock activity. At the end of the observation period the nearest goat was followed in a similar way. The procedure was repeated 28 ± 6 times during the day throughout 3 consecutive days (each day, a different route was studied) during each of 4 seasons. The method allows a number of animals to be monitored with minimal labour. In an earlier work (Lachica et al. 1997a) no differences (P > 0.05) were found between data of locomotion activities taken simultaneously by 2 observers from different goats of a single herd. For that reason only 1 observer was employed in this trial. Activities were divided into several major categories: grazing, defined as the time spent searching for and ingesting forage; walking, defined as the movement from one place to another without grazing; standing, defined as no activity; ruminating, defined as the time spent to rumination; and others (socialising, etc.).

For locomotion studies, the observer carried 1 pedometer and 1 altimeter. The pedometer (Podomatic, Eschenbach Optic, Nuremberg, Germany) was attached vertically to the observer's belt. The distance travelled was recorded on a digital indicator and subdivided from 25 m up to 100 km. A stride indicator allows adjustment of the instrument to the step length of the bearer. Several tests of the accuracy of the pedometers were conducted at the beginning of each trial. The corresponding calibration factors of the instruments were obtained by dividing a known distance walked by the pedometer reading. These values were employed to convert pedometer readings into actual distances walked. Somlo et al. (1991b) concluded that pedometers are inaccurate when carried by goats. The average pedometer calibration factors (distance travelled/distance recorded) and their coefficients of variation indicate the reliability of the records made in the present work (mean value 1.087 ± 0.0248; CV = 7.23%; n = 10) The altimeter employed to determine the vertical ascent or descent (Altiplus N1, Pretel, France) is an electronic instrument with several functions (altitude, altitude variation, temperature, barometric pressure). Altitude is calculated from atmospheric pressure with a resolution of 1 meter and ranges from –256 to 9,999 m. Temperature readings are in the range of –25°C to 55°C, with an accuracy of about 1°C.

Daily energy expenditure due to locomotion was calculated from both the horizontal and vertical (ascent and descent) components of goat's travel (obtained by means of pedometer and altimeter readings) and the corresponding energy cost (3.35 and 31.7 $J/kg^{-1} \times m^{-1}$ for horizontal travel and vertical ascent, respectively) and energy recovery (–13.2 $J/kg^{-1} \times m^{-1}$ for vertical descent), which had been obtained by calorimetry trials using a confinement respiration chamber (Lachica et al. 1997b). The results were extrapolated to total time spent by the goats on range during each of 4 seasons and expressed in terms of animals of average liveweight. For example, a 38 kg goat travelling an horizontal distance of H m, ascending A m and descending D m in the course of 24 hours would expend 38 $\times$ (H $\times$ 3.35 + A $\times$ 31.7 – D $\times$ 13.2) J. The energy expenditure obtained by this calculation was then compared with the energy requirements for maintenance of the goat, which had been previously determined by open-circuit calorimetry (401 $kJ/kg^{0.75}$ per day; Aguilera et al. 1990). From these data the increased energy requirements above maintenance due to activity of grazing goats were calculated.

Seasonal effects on locomotion activities were analysed from data taken by the observer throughout the 3 consecutive days within each season by means of a one-way analysis of variance, where season was used as error. Tukey's test was used to determine significant differences (P<0.05) among means.

Results and Discussion

Grazing and walking were the primary activities of goats throughout the period of study (values of activities in summer are missing), accounting for, on average, 51.7 and 42.0% of the animal-day period, respectively (Table 2). Time spent on these activities, as percentage of daily period on range, was not significantly affected by season (P > 0.05).

The distance travelled daily by the goats on range (Table 3) was significantly affected by season (P < 0.05) and fluctuated from 12,777 m in summer to 8,100 m in autumn, with an annual average of 9,954 m. This value was calculated over the whole period on range, not over the time spent walking, and represents a mean annual daily speed of 20.8 m/min. The average speed of travel, estimated overtime on locomotion, was 49.1 m/min, somewhat higher than the animal mean value which can be calcu-

Table 2. Seasonal changes in daily activities (%) of goats on range. (Values are means of 3 days of observation)

	Grazing	Walking	Standing	Ruminating	Others
	(%)				
Autumn	49.9	41.1	6.7	1.5	0.8
Winter	52.3	42.4	2.9	2.0	0.4
Spring	52.9	42.6	3.9	—	0.6
Summer	—	—	—	—	—
$x \pm \sigma/\sqrt{n}$	51.7±0.75	42.0±0.38	4.5±0.93	1.8±0.18	0.6±0.09
Seasonal effect[1]	NS	NS	NS	—	—

[1]NS, not significant (P>0.05).

Table 3. Mean distance travelled daily by goats at pasture. (Values are means of 3 consecutive days)$

	Time spent at pasture	Distance travelled	Vertical ascent or descent	Mean speed	Mean speed
	(h)	(m)	(m)	(m/min)[1]	(m/min)[2]
Autumn	7.2[a]	8100[a]	500	18.7[a]	45.6
Winter	6.4[a]	9003[ab]	500	23.7[a]	55.3
Spring	8.4[b]	9935[ab]	500	19.7[a]	46.3
Summer	10.0[c]	12777[b]	500	21.3[a]	—
Annual mean	8.0	9954	500	20.8	49.1
Pooled std. error	0.12	680.5	28.9	1.51	
Range	(5.7–10.0)	(6090–15192)	(400–600)	(15.2–30.1)	
Seasonal effect[3]	*	*	—	—	—

$Within the same column values bearing different superscripts are significantly different (P<0.05).
[1]Calculated over the whole daily period on range.
[2]Calculated over the time spent walking.
[3]* P<0.05

lated from data previously published (41.5 m/min; Lachica et al. 1997a). The mean annual vertical ascent or descent was 500 m. It is widely accepted that goat's grazing behaviour and diet selection are markedly influenced by seasonal availability of forage. Some information at this respect from dry areas of southern Spain has been obtained in our laboratory (Somlo et al. 1991a, García et al. 1994, Molina Alcaide et al. 1997). The availability of forage may be the main factor affecting physical activity of freely ranging animals and therefore their extra energy expenditure. In our study the estimated heat production due to locomotion increased steadily from autumn to summer (Table 4). Seasonal effect was significant (P<0.05). Extreme values were 88.5 and 130.9 kJ/kg$^{0.75}$ per day with an annual mean value of 105.6 kJ/kg$^{0.75}$ per day. Assuming a metabolisable energy (ME) requirement for maintenance of 401 kJ/kg$^{0.75}$ per day (Aguilera et al. 1990) and a net efficiency of utilization of ME for maintenance (k_m) of 0.70, these increases in heat production account for an extra ME requirement above that of maintenance in the range of 46.6 and 31.6% for summer and autumn periods, respectively (P < 0.05), corresponding to a mean extra energy expenditure of 37.6%. This average value is higher than the mean increase of 11.0, 25.4 and 32.1% estimated for free ranging sheep by Blaxter (1967), Langlands et al. (1963) and Osuji (1974), respectively, but is markedly lower than values reported for free ranging cattle (53.8% (Reid 1958), 74.4% (Wallace 1955), 52.2–106.7% Hutton (1962)) and sheep (49.2% (Lambourne and Reardon 1963), 60.0–70.0% (Young and Corbett 1972), 62.7–91.5% (Coop and Hill 1962)). The National Research Council (NRC 1981) has a tabulated mean value of 424 kJ ME/kg$^{0.75}$ for the maintenance requirements of the goat and makes an extra allowance of energy to be added to account for the increased muscular activity of the animals under grazing conditions: a 25% increment in case of light activity; a 50% increment on semiarid rangelands and on slightly hilly lands; and a 75% increment for long-distance travel on sparsely vegetated grasslands or on mountainous transhumance pastures. The application of these tabulated values to our experimental conditions would overestimate the animals energy expenditure due to locomotion. Moreover, the average value for the increase in energy expenditure over maintenance found in this work is 2.4 times higher than that obtained in a previous study carried out in another semiarid zone of the same geographic area (Lachica et al. 1997a). This fact indicates that it is inappropriate to extrapolate theoretical allowances for activity even to apparently similar conditions. A direct estimation of the time spent on different activities on range, and particularly the distance travelled, will aid for an accurate estimation of the extra expenditure of energy under grazing conditions, as performed in this work.

Table 4. The energy cost of locomotion of goats at pasture during the different seasons of the year. (Values are means of 3 consecutive days)[1]

	Live weight	Heat production (HP)	Estimated increased in ME requirements over maintenance[2]
	(kg)	(kJ/kg$^{0.75}$)	(%)
Autumn	35	88.5[a]	31.5[a]
Winter	35	95.9[ab]	34.2[ab]
Spring	40	107.0[ab]	38.1[ab]
Summer	40	130.9[b]	46.6[b]
Annual mean	37.5	105.6	37.6
Pooled std. error	0.0	4.65	1.66
Seasonal effect[3]		*	*

[1]Within the same column values bearing different superscripts are significantly different (P<0.05).
[2]MEm=401 kJ/kg$^{0.75}$ per day (Aguilera et al., 1990); Km=0.70.
[3]* P<0.05

Conclusions

The method employed appears to be adequate to simulate and quantify grazing activities of goats on open range by means of direct observation. It is simple and easy to apply to field conditions, requiring only 1 observer for locomotion studies. The results also showed that the energy cost of locomotion represented a substantial contribution to the energy expenditure of goats on range. This study will facilitate a more accurate estimation of the energy requirements on range and will contribute to define the stocking rate in the area under study.

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