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Monitoring behavior and its related energy expenditure of a desert goat through inertial and heart rate sensors*

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Monitoring behavior of grazing animals offers great potential to improve livestock management. However, few technologies are capable of collecting data and a limited number of methods may be used to classify these data and determine behavior. We propose an inertial measurement unit (IMU) for classifying the behavior and heart rate (HR) monitoring to estimate energy expenditure (EE) of one (n=1) goat grazing in the Argentinean Monte Desert. Behavior was classified as resting in the pen (RP), resting in the field (RF), walking (W) and grazing (G). The behavior classification was performed using the Random Forests algorithm. Walking was detected with the highest precision (96%), while the precision was lowest for Grazing (80%). Goat activities could be predicted with an average precision above 86% and a recall of 85%, which suggests viability for real-life applications. Total EE of grazing was 535.1 KJ ME kg BW $^{0.75}$ d^{-1}, while EE of W, G, RF and RP were 53.8, 108.5,

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99.0 and 273.9 KJ kg BW $^{0.75}$ d^{-1}, respectively. The goat walked 7,187 km, at an average speed of 4.22 km h^{-1}, with an energy cost of displacement at 7.48 J kg BW $^{0.75}$ m^{-1}. These results expose the viability, relevance and usefulness of applying this methodology to study different factors affecting the behavior and energy expenditure of goats grazing in arid areas.

KEYWORDS: behavior / energy expenditure / grazing goat / Monte desert rangeland

In arid and semiarid regions, goat production is one of the most important economic activities. For example, in the Argentine Monte Desert, goat farming provides economic support for about 50,000 smallholder farmers [Guevara *et al.* 2009]. In these environments, inadequate nutrition and energy availability can be the main factors limiting productivity of these livestock production systems. Both energy availability of pastures and animal energy requirements are influenced by climatic factors such as rainfall and temperature, as well as management factors such as improper use of pastures (overgrazing), lack of water supply points or poor water distribution, lack of paddocks, among others [Silanikove 2000]. Studies on behavior and energy expenditure (EE) of freely moving animals are useful in assessing management practices to minimize grazing energy loss, thereby increasing production levels or elevating efficiencies of feed utilization with constant production [Tovar-Luna *et al*. 2011]. This knowledge is useful for such purposes as determining the most appropriate stocking rate, physiological states and seasons of land use, and need for supplemental feedstuffs, etc. [Lachica and Aguilera 2005]. Currently, several methods are available for determining the EE of animals in confinement conditions. However, most of these methods are difficult or inapplicable in animals in free-living conditions such as grazing [Lachica and Aguilera 2005]. The heart rate has been used as an indirect estimator of EE in grazing animals based on the correlation between heart rate and O2 consumption and, consequently, heat production [Goetsch *et al*. 2010].

The recent outstanding advances in electronic technology, including the development of miniature sensors with low-power consumption and high-memory capacity [Brown *et al.* 2013] facilitate recording of animal movements and predicting their behavior without the need of direct observation. It is now possible to characterize the behavior and estimate the related energy expenditure over 24-hour periods (including nights), while they are grazing freely. However, these methods pose problems related to registering a large volume of complex data, especially from sensors to evaluate behavior. Therefore, computational solutions are required to process all the information recorded by sensors. According to the authors' knowledge, there are no research studies that apply these new technologies to determine the behavior and energy expenditure of grazing goats for an environment such as the Monte desert. Therefore, this work aims to apply and fine-tune a methodology to classify and determine the behavior and energy expenditure of grazing goats in arid areas. It was hypothesized that by using an inertial measurement unit (IMU) in combination with the heart rate method it is possible to identify with very good precision the different activities and their associated energy expenditures in a grazing goat in the Monte desert of Argentina.

Material and methods

Activities in confinement

The experiment comprising the animal's activities in confinement were performed before field grazing measurements at the facilities of the Argentinean Institute for Arid Land Research (IADIZA) located in the Scientific Technological Center CONICET Mendoza, Argentina. An adult dry (non-lactating and non-pregnant) Criollo goat was housed individually in a pen of 0.8x1.5 m (1.2 m^2) for 8 weeks, with a period of 3 weeks of adaptation to housing conditions, followed by a measurement period of 5 weeks.

Data Acquisition System for Behavior Classification

The data acquisition system was based on a Pixhawk autopilot [Meier *et al.* 2012, Pixhawk 2020]. This device was chosen because it contains an inertial measurement unit (IMU), a self-contained system that measures linear and angular motion with a triad of gyroscopes and a triad of accelerometers, while it also provides the proper software to log the raw sensor measurements. Pixhawk's IMU is an MPU-6000 by InvenSense Technology, a very popular sensor in the robotic field because of its reliability when operating on drones. Moreover, the MPU-6000 IMU had been already used in a previous work for animal behavioral analysis [Bhargava 2017]. IMU sensors were set at a sampling rate of 10 Hz and are used to identify specific animal behaviors. Additionally, a GPS receptor working at 5 Hz was included for a later analysis of the animal's trajectory. Both measurements, i.e. IMU and GPS, were logged into an SD card during the animal's activity. A plastic box was designed to hold and protect the Pixhawk, the GPS and a battery. This box was built in a 3D printer. Moreover, a video camera was attached on top of the plastic box to record the activity of the goat. It is worth mentioning that the purpose of using a video camera is to construct a statistical model during the further dataset generation process. Once the model is generated, a video camera will not be necessary and only the input signals from the IMU will be used to classify the goat's behavior. The weight of the plastic box with the complete data acquisition system plus a battery was 639 g, which is equivalent to 1.6% of the body weight of the goat. This percentage is much less than 5%, a value reported by several authors for equipment, using which animal behavior could be affected by the weight of the equipment [Cuthill 1991, Watanabe *et al*. 2005]. The cost of the data acquisition system without the camera was around USD 100. Thus, this system can be considered as low-cost compared to similar commercial solutions for animal behavioral classification. A low-cost data acquisition system was essential, since the equipment could be lost in the field during animal activities.

Determination of the relationship between Heart Rate and Energy Expenditure

To determine the relationship between heart rate (HR) and energy expenditure (EE), metabolizable energy expenditure for maintenance (MEm) of the goat in the pen without activity was determined first, and then the heart rate was determined under the same conditions. The MEm was estimated following the methodology described by Goetsch *et al.* [2017]. This is based on making adjustments in the ration until achieving a dry matter intake (which is the same as energy intake or MEm) that maintains a constant bodyweight of the goat. At the beginning of the measurement phase the goat was weighed and the initial ration (dehydrated alfalfa pellet) was estimated at a level of MEm requirements for indigenous goats [NRC 2007]. After that, the goat was weighed twice a week and adjustments in the offered ration were made according to the changes in body weight in the immediate previous period. That is, if the goat's weight had increased with respect to the previous data, the ration was reduced by 5% compared to the previous offer, and the reverse was done if the goat's weight had decreased. If there were no changes in body weight, the offer remained unchanged from the previous one. Finally, MEm was estimated with the dry matter intake value and the ME concentration of the ration. The ME concentration of the ration was calculated by multiplying digestible energy by 0.82. Energy digestibility was estimated through an *in vivo* digestibility test in the last week of the measurement period following Rooke's methodology [2001]. Heart rate was measured as described by Puchala *et al.* [2009]. Briefly, the goat was equipped with two 10 x 10 cm electrodes prepared from elastic conductive fabric (Less EMF Inc., Albany, NY, USA), glued to Vermed Performance Plus ECG electrodes (Bellows Falls, VT, USA) and attached to the chest just behind and slightly below the left elbow and behind the shoulder blade on the right side. The electrodes were connected by ECG cables (Bioconnect, San Diego, CA, USA) to a T61 coded transmitter (Polar, Lake Success, NY, USA). A human RS400 HR (Polar) monitor with wireless connection to the transmitter was used to collect HR in an interval of 1 minute. In addition, the goat was dressed with a cloth vest to prevent the electrodes or wires from being disconnected. HR data were analyzed with the Polar Precision Performance SW software provided by Polar. With this information and with the previous data on MEm, the ratio between energy expenditure and heart rate (EE: HR) was determined.

Activities on the Monte desert

For the acquisition of data in field conditions the goat was moved back to the original farmer's homestead "La Majada", located in the Monte desert region. In that area the plant communities of major foraging importance with regard to floristic composition, forage species cover and carrying capacity are semi-closed woodlands of *Prosopis flexuosa* with *Atriplex lampa* in interdune valleys and open woodlands of *P. flexuosa* with *A. lampa* and *Tricomaria usillo* on dunes. The trees and shrubs most commonly found include *Prosopis flexuosa, Geoffroea decorticans, Bulnesia retama, Capparis atamisquea, Atriplex lampa, Tricomaria usillo* and *Mimosa ephedroides*, while the primary grass species include *Trichloris crinita, Pappophorum caespitosum* and *Panicum urvilleanum* [Egea *et al.* 2014]. The forage productivity shows temporal changes strongly related to annual rainfall fluctuations, varying from 300 to 650 kg of dry matter ha^{1} year^{1} [Guevara *et al.* 2009].

The behavior data acquisition system was installed on the top of the goat's head, fixed to the horns using plastic straps, while the heart rate monitor was fixed as described before for the confinement conditions. The goat was released to graze freely with the rest of the herd. All the equipment was placed in the morning before grazing started. The behavior recording device was removed at night when the goat returned from the field, which produces about 12 h of inertial sensor activity. The HR monitoring equipment was replaced the next morning to complete 24 h of HR recording. It is worth mentioning that only one animal was used in this work, since the main goal of our research was to validate and test the proposed methodology as a preliminary approach to estimate the animal energy consumption in a difficult environment such as the Monte desert.

An algorithm for behavior classification

Both video and inertial sensor recording had begun at 8:56 a.m. before the goat was released from the pen, and ended at 9:50 p.m., when the animal returned from the field to drink water and rest in the pen until the next day. The total behavior recording time was 12 hours and 54 minutes. The video recording and the inertial sensors' time series were synchronized using the GPS time as the master clock. Four states were distinguished: resting in the pen (RP), resting in the field (RF), walking (W), and grazing (G). The time series corresponding to each inertial sensor was split into fixed 1-minute time windows, a total of 774 time-windows. The labeling of the 1-minute time windows was done by a human operator watching the video recording on the Mplayer video player and adding a label to the time windows of each inertial sensor according to the proposed four types of activities. One hundred twenty-one (121) time-windows were removed, since no video information on the animal's behavior could be identified, thus a total of 653 1-minute time windows were available for behavior classification. It is worth clarifying here that the HR recording time was 24 h, 12 h longer than the inertial sensors dataset, since no behavior classification was needed when the animal was in the pen during the night.

A procedure known as bag-of-features was then applied to extract the predictor variables used by the model. The bag-of-features (BoF) is a technique commonly used in image classification. Its concept was adapted to time series from the information retrieval and the Natural Language Processing BoF method [Baydogan *et al.* 2013]. The hypothesis behind the application of the BoF approach is that samples belonging to different activities will have different histograms. Such differences will help Random Forests (RnF), a tree-based supervised statistical learning algorithm, to create the behavioral classification model [Breiman 2001]. Random Forests, a well-known machine supervised learning algorithm is used to generate the prediction model. Formally, RnF is a bootstrap aggregating (baggin) algorithm that consists of a collection of tree-structured classifiers. Each tree grows with respect to a new bootstrap resample with a selected feature vector Θ_k where, Θ_k $k = 1, \ldots, L$, is independent and identically distributed. Each tree casts a unit vote for the most popular class at input *x* and normally a simple majority is applied for the final decision. RnF has proved to be successful in several classification problems such as banking, stock markets, medicine, e-commerce and transportation, among others. Its default hyper parameters often produce a good prediction result, which makes RnF a good first candidate for the goat behavior classification problem.

The behavior classification performance was evaluated considering the Recall, Precision, and F1 measures. The recall is the ratio of the number of correct detections for a given activity and the number of this particular goat activity. In contrast, Precision is the ratio of the number of correct detections for a given activity and the total number of activities. Finally, the F1 score is the harmonic mean of the Precision and Recall, where an F1 score reaches its best value at 1 (perfect Precision and Recall) and worst at 0. Both micro and macro averages were calculated using the metrics results over classes. Under the Micro-average, smaller classes will account for less on average than larger classes, whereas in the macro-average will compute the metric independently for each class and then take the average. To evaluate RnF for goat behavior classification the dataset was split at a 70/30% ratio. The 70% of the dataset were used to calibrate the RnF hyper-parameters and train the algorithm using repeated cross-validation using 5 folds repeated 3 times. The remaining 30% were used for independent testing of the performance of the RnF classification algorithm on unseen examples.

Results and discussion

Performance of Data Acquisition System for Behavior Classification.

Table 1 shows the expected model prediction performance in terms of the error metrics for the best-resulting model after tuning RnF hyper parameters using a 3x5 repeated cross-validation (CV). Only two RnF parameters were considered during the calibration stage: the number of variables available for splitting at each tree node (mtry) and the maximum number of trees (ntree). The best results were observed for the walking activity (W), while the grazing activity (G) was more difficult to recognize correctly. In the case of the resting activities, resting in the field (RF) results outperformed resting in the pen (RP) in all but the precision metric. However, the high variability observed for RP suggests more samples containing information about the activity are necessary. This is a finding that should be analyzed in future experiments.

Table 1. Average precision, recall and F1-score and the correspondent standard error (SE) for a RnF classifier with mtry = 5 and ntree = 200

Activity	$Precision_{cv}$	SE	$Recall_{cv}$	SE	$F1\text{-}Score_{cv}$	SE
Grazing	0.798	0.0161	0.770	0.0205	0.778	0.0137
Walking	0.871	0.0155	0.933	0.0144	0.898	0.0122
Resting in field	0.823	0.0127	0.851	0.0161	0.833	0.0102
Resting in pen	0.849	0.0194	0.754	0.0236	0.791	0.0165

Table 2 shows the classification results in terms of the standard error metrics on the test set. The number of examples per activity (support) in the test set was also included for completeness. In general, the predictive errors were similar for both the model CV results and independent test samples. When considering the macro average metrics, the RnF algorithm showed a precision value around 86% and a recall value around 85%. Despite presenting the lowest number of episodes (support = 35), the W activity showed the best precision and recall values (96.9 and 91.4%). They were followed by RP with values ranging from 84 to 89% in all the three considered metrics. Although the RF activity was recognized with a higher recall (84%), precision decreased to 79.4%, while the F1-Score was 81.6%. Finally, the grazing activity presented values around 80% for all the considered metrics. When conducting a per-activity analysis, the confusion matrix in Figure 1. shows the high accuracy of the classifier for recognizing the walking activity: only very few samples of the W activity were misclassified as G and RP. In the case of RF, the classification error was distributed between the G and RP activities with only a few misclassifications for the RP activity and a considerably higher error in the case of the G activity. The RP activity was only misclassified as RF.

Table 2. Precision, recall and F1-score for the RnF classifier on an independent test set

Activity	Precision	Recall	F1-Score	Support
Grazing	0.8036	0.8036	0.8036	56
Walking	0.9697	0. 9143	0.9412	35
Resting in field	0.7945	0.8406	0.8169	69
Resting in pen	0.8919	0.8462	0.8684	39
Macro average	0.8649	0.8511	0.8575	199
Micro average	0.8442	0.8442	0.8442	199

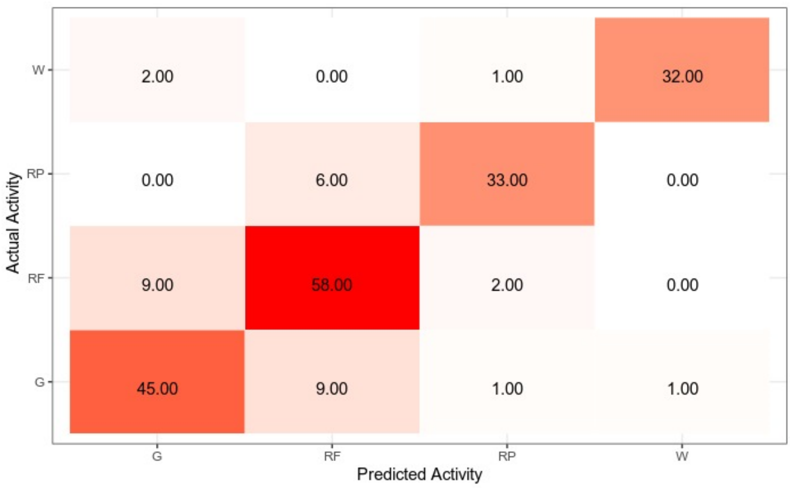

Fig 1. Confusion matrix of the de Random Forest algorithm for goat behavior classification.

Finally, the G activity was incorrectly classified mostly as RF and to a lesser extent as RP and W activities. For a two-class confusion matrix (not shown) considering only the G and RF activities, the recall and precision values were around 83% in both metrics. Such misclassifications could be caused by some unobserved and short RF events during the G activities. For a similar two-class confusion matrix for the other activities the results improved considerably. Since the G and RP activities followed a more natural differentiation, the recall value was around 97%, while precision was close to 100%. Finally, in the case of RF and RP both activities showed a precision value of 90% and a recall of 96%.

Energy expenditure in confinement

The ration composition (as % of DM) was 16.7, 36.8, 31.8, and 9.3 % of CP, NDF, ADF and ash, respectively. The gross, digestible and metabolizable energy concentration was 16.74, 9.48 and 7.78 MJ kg DM^{-1}, respectively. The digestibility of energy was 56.6%. The constant bodyweight of the goat was obtained from the fourth week of the measurement period onwards (Tab. 3). Therefore, the heart rate was determined during the 5th week. The maintenance energy expenditure (EEm) in confinement (476.1 KJ kg $BW^{0.75}d^{-1}$) was similar to that reported in indigenous goats (462 KJ kg $BW^{0.75}$ d^{-1}) [Sahlu *et al.* 2004]. In turn, the EE:HR ratio (7.4 KJ ME kg $BW^{0.75}$ min^{-1}) was higher than that reported in other goat breeds (Alpine, Angora, Boer and Spanish), where the overall average EE:HR ratio for all breeds was 6.01, with values ranging between 4.8 and 7.6 KJ ME kg $BW^{0.75}$ min^{-1} [Puchala *et al.* 2007]. However, it should be noted that this is the data from one animal only and it may differ greatly from the average EE:HR ratio for Criollo goats, since other authors found a very high individual variability for this parameter in goats [Puchala *et al.* 2007, 2009].

Table 3. Body weight, dry matter intake (DMI), energy expenditure (EE), heart rate (HR) and EE: HR ratio of Criollo goat in confinement

Item	Unit	Mean
BW*	Kg	39.7
DMI*	g DM kg $BW^{0.75}$ d^{-1}	61.0
EE**	KJ ME kg $BW^{0.75}$ d^{-1}	476.1
HR	Beats min^{-1}	64.9
EE:HR	KJ ME kg $BW^{0.75}$: beat	7.4

*Body weight and dry matter intake when goat weight remained constant.
**Equal to MEm. Goat without activity in confinement.

Grazing Behavior and Energy Expenditure

The duration of the W, G, RF and RP behaviors was 120, 249, 264 and 807 minutes, representing 8.3, 17.3, 18.3 and 56.0 % of the day, respectively. The goat traveled a total distance of 14.8 km, also including its movement when grazing. The walking time (without grazing) recorded in this experiment was somewhat similar to those reported for Boer wethers [Brassard *et al*. 2016] and for goats and sheep [Beker *et al.* 2010] grazing in pastures with different grasses and forbs (*Cynodondactylon, Festucaarundinacea, Ambrosia spp.*), where animals walked between 1.2 and 2.4 hours per day. Although in the experiment by Beker *et al.* [2010], the greatest distance traveled (5.28 km per day) was much shorter than that of this trial, the discrepancy was probably due to the fact that those grazing paddocks were smaller and enclosed by fences.

It can be seen that when the goat was out of the pen, free in the Monte desert, it spent most of the time resting in the field, and not grazing or eating as one might expect. In fact, grazing time was much shorter than that reported by other authors in different breeds of goats and sheep, where animals grazed between 27.9 and 58% of the day [Animut *et al.* 2005, Beker *et al.* 2009, Brassard *et al.* 2016]. This may have resulted from the fact that on the day of the grazing behavior recording (December 26, 2017), the ambient temperature was very high (29.6, 20.1 and 37.8 °C; average, minimum and maximum, respectively). Information on weather conditions was obtained from the Telteca Reserve weather station, 32° 20' S, 68° 00' W). On the other hand, at this season of the year (summer for the southern hemisphere) there is greater forage availability from the natural grassland, so animals may need less grazing time to harvest forage and cover their nutritional requirements. This situation could change in the winter due to different ambient temperatures and forage availability.

The average heart rate (HR) in the confinement period was 64.9±3.8 beats min-1 (average±SD), while during the field experiment HR was 66.0±3.9, 73.0±2.0, 84.8 ±10.4 and 87.2±6.2 for the activities of resting in the pen (RP), resting in the field (RF), grazing (G) and walking (W), respectively. No marked differences were observed (as low as 1.7%) between HR resting in confinement and resting in the pen in the field experiment. This is logical considering that the conditions were very similar (housing, temperature, etc.). On the other hand, as was also expected, the highest HR was recorded when the goat was walking in the field, being 32.1% higher than the HR recorded when the animal rested in the pen. These values logically correlate with the energy expenditure. The total daily EE of the goat on the grazing day was 535.1 KJ ME kg $BW^{0.75}$. This energy cost is 12.4% higher than that observed when the goat was in a pen without activities in the confinement period (476.1 KJ ME kg $BW^{0.75}$). This small difference could be due to the fact that on the day of the field measurements the goat spent a large percentage of the time (56.0%) spent resting in the pen, which EE (488.6 KJ ME kg $BW^{0.75}$) is only 2.6% greater than the EE in confinement. The total EE of the grazing goat was much lower than that found by several authors [Beker *et al*., 2009, Brassard *et al*. 2016, Tovar-Luna *et al.* 2011]. However, those experiments were conducted with goats grazing in smaller paddocks and with greater forage availability. In these studies the EE of grazing ranged between 35 and 64% of the EE in confinement. The total EE of the grazing Criollo goat was also lower than the estimates proposed by the NRC [2007], which predictions were based on the works of Sahlu *et al*. [2004]. According to the NRC estimates [2007], the EE when grazing would have been 30% of the EE for maintenance for a Criollo goat grazing and walking for 6 hours, with a terrain score of 3, a distance traveled of 14.8 km and digestibility of the organic matter at 45% (the value estimated from a companion paper) [Egea *et al*. 2014].

In the present experiment the goat walked (without grazing) 7.187 km, at an average speed of 4.22 km h^{-1}, with an energy cost of displacement of 7.48 J kg BW $^{0.75}$ m^{-1}. This value is within the range reported by AFRC [1998], which reported an energy cost between 3.5 and 28 J kg BW $^{0.75}$ m^{-1} for horizontal and vertical movements, respectively. The cost of travel found in the Criollo goat was reasonable, given that the grazing area is desert without mountains or large changes in land elevation (varying from 510 to 560 m above sea level). Lachica and Aguilera [2003] affirmed that the requirement of ME for activity can vary tremendously, ranging from 0 to 100% of ME for maintenance for confined goats. In a study conducted with goats in a semi-intensive production system in a rugged Mediterranean mountain environment [Lachica *et al.* 1999], with a distance traveled ranging from 8.1 to 12.8 km, the locomotion energy cost increased the requirements of MEm by 31.5 and 46.6% for autumn and summer, respectively. Similarly, in our experiment the energy cost of walking (645 KJ kg BW $^{0.75}$ d^{-1}) and grazing (627.5 KJ kg BW $^{0.75}$ d^{-1}) represented an increase in the EMm requirements by 35.4 and 31.8%, respectively (Tab. 4).

Table 4. Time spent in different activities and their related energy expenditures for a Criollo goat grazing on the Monte Desert

Item	Unit	Activity			
		W	G	RF	RP
Duration	% of the day	8.3	17.3	18.3	56.0
EE (on a daily basis)*	KJ kg $BW^{0.75}$	645.0	627.5	539.9	488.6
Daily EE**	KJ ME kg $BW^{0.75}$	53.8	108.5	99.0	273.9
EE (% of total daily EE)	%	10.0	20.3	18.5	51.2

W – walking, G – grazing, RF – resting in field, RP – resting in pen.
*EE per unit time (i.e. if the goat spent the entire day in the activity).
**Actual EE for that portion of the day spent in the activity.

The peak energy expenditure values of the grazing Criollo goat were recorded between 4:30 p.m. and 9:30 p.m., at which time the animal was grazing and walking mainly (Fig. 2 and 3). This temporal pattern in EE was similar to that observed in an experiment also carried out in summer [Beker *et al.* 2010], where energy expenditure had its highest values between 6:00 p.m. and 9:00 p.m. However, it was different from what was observed in experiments carried out in cold periods [Patra *et al.* 2008a, 2008b], where the highest energy costs were observed earlier during the day. It is not entirely clear why the total EE of the grazing Criollo goat was lower than that reported by other authors. Additionally, it is not possible to make assertions with the determined EE in a single animal. However, these results demonstrate the relevance and usefulness of applying this technology in a larger sample of animals to evaluate

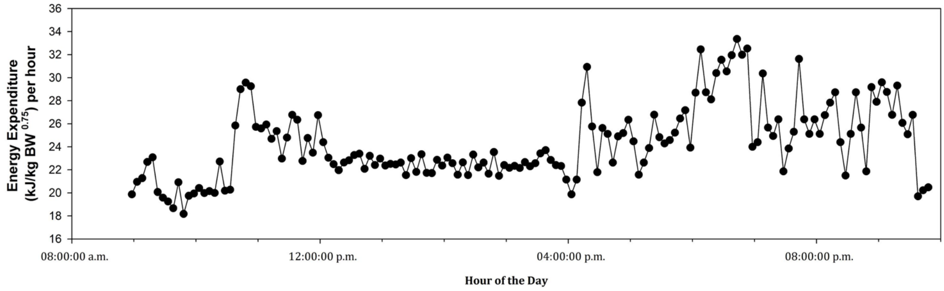

Fig. 2. Energy expenditure according to the hour of the day in a Criollo goat grazing on the Monte Desert.

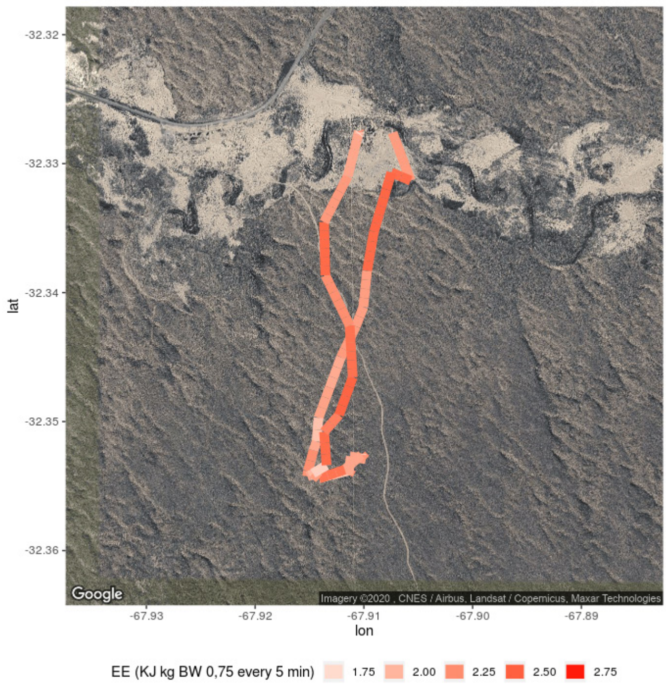

Fig. 3. Energy expenditure according to the geo-location of the Criollo goat in the Monte Desert.

the different factors affecting the behavior and energy expenditure of Criollo goats grazing in arid areas.

In conclusion, the quality of the dataset generated for the behavior study seems to be adequate for building statistical learning classification models. The Walking activity was detected with the highest precision (96%), while the Grazing activity showed an 80%. Most of the misclassification errors were observed between grazing and resting in the field. At some point the former results are expectable if we consider the similarities between both activities. In any case, the macro average for the precision value is around 86%, while in the case of recall the value is around 85%, which suggests the viability for real-life applications. Regarding the measurement of the energy expenditure, it was found that the methodology is viable for the conditions of the Argentinean Monte desert and that the results are somewhat comparable with those obtained by other authors. However, it should be noted that this is an experiment performed on a single animal to adjust the methodology to the conditions of the study site. Therefore, the information obtained must be validated by replicating the test in a larger number of animals and under different environments and goats, in order to obtain data with the required variability to provide results with the required level of statistical significance.

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