Scientific Paper

# Indicators of the gas-energy fasting metabolism in Pelibuey sheep in Cuba

Norge Fonseca Fuentes[1] *https://orcid.org/0000-0001-6635-3165)*, Leticia Tamayo-Ojea[2] *https://orcid.org/0000-0003-4975-0630*, Rafael Orlando Garcés-Sariol[2] *https://orcid.org/0000-0001-7072-0722*, Alejandro Fonseca-Serrano[1] *https://orcid.org/0000-0002-9973-6813*, Jorge Orlay Serrano-Torres[3] *https://orcid.org/0000-0003-1710-6322* and Juraj Grizelj[4] *0000-0001-5963-3409*

*[1]Universidad de Granma, Ministerio de Educación Superior. Carretera de Manzanillo km. 17½, Peralejo, Apartado 21, Bayamo. Cuba. [2]Instituto de Investigaciones Agropecuarias Jorge Dimitrov. km. 12½, vía Manzanillo, Bayamo. Cuba. [3]Universidad de Ciego de Ávila Máximo Gómez Báez, Ministerio de Educación Superior. Carretera Morón esquina Circunvalación. CP. 65 100, Ciego de Ávila. Cuba. [4]Universidad de Zagreb. Trg Republike Hrvatske 14, 10000, Zagreb, Croacia. E-mail:* nfonsecaf@udg.co.cu, jorlay@unica.cu

## Abstract

**Objective**: To determine some indicators of the gas-energy metabolism of fasting Pelibuey sheep, subject to grazing.

**Materials and Methods**: The research was conducted at the Jorge Dimitrov Research Institute, in the Granma province, Cuba. Seventy-five sheep were used, grazing during the growth-fattening stage, at a rate of 25 animals of the Bermejo, Blanco and Patrón invertido genotypes, respectively. The animals were subject to inedia for up to 96 hours, to evaluate the respiratory quotient and heat production every 24 hours. The respiratory rate, heart rate, and rectal temperature were measured.

**Results**: The respiratory rate showed an average of 63 breaths per minute, influenced by climate indicators that affected the welfare zone of grazing sheep. The average heart rate was 75 beats per minute, a value that was considered adequate for sheep under grazing conditions in a tropical climate. Basal metabolism was reached at 96 hours of fasting. Differences were found in the respiratory quotient for Bermejo, Blanco and Patrón invertido (0,67; 0,61; 0,64, respectively). Heat production (KJ/kg $w^{0,75}$/day) also showed differences among genotypes (142,3; 129,4 and 139,4 for Bermejo, Blanco and Patrón invertido, respectively).

**Conclusions**: The Pelibuey sheep, subject to fasting, reached basal metabolism 96 hours after stopping feeding, period in which they reached respiratory quotients typical of fat degradation.

**Keywords**: heart rate, metabolism, grazing

## Introduction

In any region of the planet, in order to obtain adequate agricultural development it is necessary to consider the importance of four factors: man, land, water and climate. Cedeño-Saldarriaga (2017) states that among the factors that modify the meat production of sheep is the stress produced by adverse environmental conditions, and emphasizes the one produced by heat. Climate change increases the environmental temperature and changes the circannual rainfall patterns in the different agroecological regions of the world, which is derived from the emissions of greenhouse gases. This phenomenon is the main one that threatens the production of food of animal origin and, subsequently, food security (Sejian *et al*., 2017).

Precisely, the term climate requires special attention, because it is understood as the environment where the productive potential of the area is manifested. Thus, it is necessary to know in detail the effect of climate on living beings, with the primary objective of properly placing each organism in its environment. In the case of ruminants, which are exploited in tropical climates, they often face environmental factors (high temperatures, intense solar radiation, high relative humidity), which affect the destination of the energy absorbed by the animal, and which can increase the requirements of energy for maintenance.

One of the aspects of interest in animal biometeorology is to evaluate the impacts of the environment on productive and physiological responses. The knowledge of the thermal regime of the environment, together with the thermal and nutritional requirement of the animals, is a useful tool for decision-making (Cruz-Gamboa, 2020).

There are several systems in the world for calculating the nutritional requirements of animals. However, there are still differences in the estimations of the requirements, as well as in the efficiency of using the ME for maintenance among the various energy systems. Modern energy feeding systems

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for ruminants (Valadares-Filho *et al*., 2016) are fundamentally based on two components: the energy requirements of the animal and the degree to which a feedstuff or a combination of several feedstuffs can cover these requirements. Fonseca-Fuentes *et al*. (2008) point out that it is known that all energy systems have the ultimate goal of predicting animal behavior with a high degree of accuracy. However, most are known to have several limitations, when applied.

Regarding the studies of the Pelibuey sheep in Cuba, the works conducted by Fonseca-Fuentes *et al*. (2008) are known, who measured the energy expense associated with the intake and rumination of this breed, in confined growing-fattening animals. However, research on the gas-energy metabolism of the different genotypes of this breed is very limited, which affects its efficiency and productivity in the tropical environment in general.

Based on these considerations, the objective of this work was to develop gas-energy studies in fasting Pelibuey sheep, to contribute to the improvement of its productive efficiency in the region.

## Materials and Methods

*Location*. The research was conducted at the Jorge Dimitrov Research Institute, in the Granma province, Cuba. The climate regionalization of the experimental area is classified as indicated by Hernández-Jiménez (2015), as type II, subtype 6, which is defined as plains and heights with relatively stable seasonal wetting, high evaporation and high temperatures.

*Characteristics of the animals*. Seventy-five grazing male Pelibuey sheep of the Bermejo, Blanco and Patrón invertido genotypes from four months of age were used. The animals were selected using a complete randomized design to measure their fasting metabolism (25 animals per genotype). Coprological analysis was performed on all the animals using the helminth-ovoscopic, flotation and sedimentation technique (Lines *et al*., 1980). Before the beginning of the experiment, antiparasitic treatment with Levamisole was applied, at a dose of 7,5 mg/kg of live weight.

*Management and feeding of the flock*. The flock management and feeding system consisted in continuous grazing, for 8 hours, of an area covered with Jamaican star grass (*Cynodon nlemfuensis* Vanderyst), without fertilization or irrigation, with a stocking rate of 1 LAU/ha, during the hours of 8:00 a.m. to 4:00 p.m. Two hours in the afternoon in a protein bank of *Leucaena leucocephala* Lam de Witt were included. After the grazing hours, the animals remained in the sheds, where they were offered water and mineral salts at will.

The rectal temperature was determined with a maximum clinical thermometer in the morning, at noon and in the afternoon (five animals per genotype). In addition, heart rate and respiratory rate were determined.

For the study of fasting gas-energy metabolism indicators (breed and genotype), the animals were subject to inedia up to 96 hours (five animals per genotype). The methodology described by Kimakovski *et al*. (1979) was applied, where heat production through respiratory exchange was measured in each selected animal, every 15 days, for two consecutive days. Sampling was done three times per day (early morning, noon and afternoon). The expired air sample from each animal was collected and the amount of consumed $O_2$ and produced $CO_2$ was analyzed.

For the statistical analysis of the data simple classification variance analysis was used, and for the difference among means, Duncan's (1955) multiple range was applied, for which the data analysis program Statistics version 8.0, for Windows StatSoft (Weiß, 2007) was utilized.

## Results and Discussion

Table 1 shows the performance of climate, according to information obtained from the meteorological files of three agrometeorological stations that characterize the territory.

Annual average maximum temperatures registered values higher than 30 °C, with variations between 30 and 34 °C. The minimum annual averages recorded values of 19,4 °C, with variations between 16 and 21 °C, which indicates warm days with cool mornings. The average annual temperature in the dry season was 23,3 °C; while in the rainy season it reached 27,3 °C.

The temperature-humidity index (THI) varied between 72 and 80 during the evaluated period. Lopez *et al*. (2015) consider that a sheep can begin to experience heat stress at THI > 72 units. Other authors such as Neves *et al*. (2009) found that hair sheep begin to show signs of heat stress when the THI reaches values between 78 and 79 units. Several studies show that hair sheep tolerate higher temperatures than wool sheep. Therefore, it is to be expected that the THI, in which any sheep breed begins to experience symptoms of heat stress, should

Table 1. Climate performance of the zone.

| Month | Temperature, °C | | | Relative humidity, % | | | THI | D.D.S. hours | Wind speed km/hours | Rainfall, mm |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Mean | Maximum | Minimum | Mean | | | | |
| 1 | 29,6 | 15,9 | 22,9 | 96 | 76 | 86 | 72 | 8,6 | 8,3 | 24,4 |
| 2 | 30,8 | 16,4 | 23,9 | 94 | 74 | 84 | 73 | 8,3 | 10,3 | 42,6 |
| 3 | 31,7 | 17,8 | 24,5 | 95 | 74 | 85 | 74 | 7,8 | 9,4 | 50,5 |
| 4 | 31,6 | 19,0 | 24,8 | 92 | 73 | 83 | 75 | 7,4 | 8,3 | 81,1 |
| 5 | 32,2 | 20,5 | 25,9 | 93 | 78 | 86 | 77 | 7,5 | 6,2 | 134,0 |
| 6 | 33,3 | 21,5 | 27,1 | 95 | 82 | 89 | 78 | 6,9 | 6,8 | 176,0 |
| 7 | 34,0 | 21,3 | 27,6 | 96 | 79 | 88 | 79 | 7,0 | 5,1 | 127,0 |
| 8 | 34,3 | 21,0 | 27,9 | 96 | 78 | 87 | 80 | 7,6 | 4,6 | 97,8 |
| 9 | 33,4 | 21,3 | 27,0 | 97 | 83 | 90 | 80 | 7,5 | 5,3 | 148,0 |
| 10 | 32,2 | 21,2 | 26,0 | 97 | 85 | 91 | 78 | 7,8 | 7,3 | 151,0 |
| 11 | 30,9 | 19,8 | 25,0 | 94 | 81 | 88 | 75 | 8,3 | 7,3 | 37,1 |
| 12 | 30,0 | 17,8 | 23,5 | 97 | 82 | 90 | 73 | 8,8 | 7,2 | 24,4 |
| THI: temperature-humidity index | 32,0 | 19,4 | 25,4 | 95 | 79 | 87 | 76 | 7,8 | 7,2 | 1 088,8 |

be used as a reference for the adaptation process of sheep to the environment.

Physiological variables are considered efficient indicators of animal tolerance to heat stress situations, especially when their basic diet depends on low-quality pastures and forages, an aspect evaluated in studies carried out under other conditions (Serrano-Torres *et al*., 2020). Different studies show that there are relationships between the climate conditions of the environment and heat production (Vicente *et al*., 2020), respiratory rate (Castillo *et al*., 2021) and, to a lesser extent, heart rate (Serrano-Torres *et al*., 2021).

Table 2 shows the results of the average behavior patterns of Pelibuey sheep under grazing conditions with regards to these indicators.

The value related to the respiratory rate showed evidence of stress in the animals, because an average of 63 breaths per minute is above the range considered normal for the species, according to Valdés-Hernández and García-López (2002). These authors, in research conducted at the Institute of Animal Science (ICA, for its initials in Spanish), found a respiratory rate value in sheep of 12-15 breaths per minute, which according to Vicar (2015) is considered normal for the species. Reyes *et al*. (2018) consider that it is important to know that the air temperature limit for fattening lambs is 10-15 ºC and, in this case, the animals were exposed to average temperatures of 25,4 ºC throughout the year.

Vera-Herrera *et al*. (2019) state that when the physical environment exceeds the thermoneutrality zone, as happens in sheep that are managed on the basis of pastures in the tropics, a state of heat stress is generated, which causes an increase in body temperature and respiratory rate, which increases, in turn, the requirements for maintenance, from 7 to 25 %.

Table 2. Clinical triad of Pelibuey male sheep under grazing conditions (mean values).

| Indicator | U/M | Mean | SD ± |
|---|---|---|---|
| Respiratory rate | breaths/min | 63 | 2,8 |
| Heart rate | bpm | 75 | 7,1 |
| Rectal temperature | ºC | 39,3 | 1,1 |

SD: standard deviation

Cristóbal-Trinidad (2018) found that animals decrease intake, especially when they are offered low-quality food, due to the effort they make to reduce heat production and the slower passage of food through the digestive tract.

Other results refer that the rhythmicity of body temperature is an important biological process and a reliable marker of the functioning of the organism (Serrano-Torres *et al*., 2020), as well as an indicator of the general health of an animal and its energy metabolism.

These authors also refer that the daily variation of heart rate is influenced by changes in physical activity and metabolic level, but it is also synchronized with changes in light intensity, ambient temperature and other environmental factors.

The average heart rate of the sheep was 75 beats per minute, value that is considered adequate for the species, under grazing conditions in a tropical climate, subject to intense stressful activity. Serrano-Torres *et al*. (2020) found that this indicator remained between 72,7 and 126,6 beats per minute, in the morning and afternoon, respectively.

The indicators of fasting metabolism, according to the genotype of Pelibuey sheep at 72 hours of fasting (table 3), showed that the animals were not yet in true fasting, expressing a respiratory quotient above 0,78 and heat production higher than 475 kJ/kgW$^{0,75}$/day in the three studied types.

However, in the respiratory quotient, the Blanco genotype (0,78) showed significant differences compared with the Patrón invertido animals (0,81), without differing from Bermejo (0,80). Fonseca-Fuentes *et al*. (2008) indicated respiratory quotient values of 0,81 in the morning hours; 1,04 at noon and 0,97 in the afternoon, when evaluating this indicator in grazing sheep east of the eastern region of Cuba.

Heat production was also lower in the Blanco genotype (475,2 kJ/kgw$^{0,75}$/day), with statistical differences with regards to the Bermejo animals, without differing from Patrón invertido ones. In the other indicators, there were no differences among genotypes.

At 96 hours of inedia (table 4), the obtained values allow us to affirm that the animals, before sampling, were in true fasting, in a status close to basal metabolism, showing a respiratory quotient below 0,70 and a heat production below 247,6 (kJ/kgw$^{0,75}$/day), for all the studied genotypes. Dougherty (1965) suggested that metabolism in ruminants does not reach a low level until two or three days have passed since the last meal, and that respiratory quotients below 0,70 indicate that ruminants are in a status of basal metabolism. This author considers that the reason for this lies on the slowness of the digestion process in the ruminant.

In this case, 80 % of the content of the digestive tract was eliminated between 24 and 96 hours after ingestion, so the respiratory quotient of fasting sheep reached higher values at the end of the second day and, below 0,70 at the end of the third, values that are in correspondence with the data published by Blaxter (1965), when evaluating the state of inedia in ruminants.

The same trend was found as at 72 hours. The Blanco genotype showed lower values ($p < 0,01$) in the respiratory quotient and in heat production, with 0,61 and 129,36 kJ/kgW$^{0,75}$/day for each case. This could be associated with adaptation mechanisms of Pelibuey sheep to the shown environmental and management conditions. Fonseca-Fuentes (2003) indicated a similar performance, when evaluating gas-energy metabolism indicators of Pelibuey sheep at different times of the day.

Table 3. Fasting metabolism at 72 hours of fasting in Pelibuey male sheep, according to the genotype.

| Indicator | Genotype | | | SE ± | Significance |
|---|---|---|---|---|---|
| | Bermejo | Blanco | Patrón invertido | | |
| Metabolic weight, kg | 14,6 | 14,4 | 14,26 | 0,37 | NS |
| Respiratory rate, breaths/min | 28,8 | 26,7 | 28,52 | 2,05 | NS |
| Utilized oxygen, l/h | 8,9 | 9,0 | 8,7 | 0,30 | NS |
| Elimination of $CO_2$, l/h | 7,1 | 7,0 | 7,q | 0,12 | NS |
| Respiratory quotient | 0,80 $^{ab}$ | 0,78 $^{a}$ | 0,81 $^{b}$ | 0,03 | * |
| Heat production, kJ/kgw$^{0,75}$/day | 482,6$^{b}$ | 475,2$^{a}$ | 479,3$^{ab}$ | 0,95 | * |

Different letters in the same row differ at $p < 0,05$

Table 4. Fasting metabolism at 96 hours of inedia in Pelibuey male sheep, according to genotype.

| Indicator | Genotype | | | SE ± | Significance |
|---|---|---|---|---|---|
| | Bermejo | Blanco | Patrón invertido | | |
| Metabolic weight, kg | 14,5 | 14,2 | 14,1 | 0,33 | NS |
| Respiratory frequency, br/min | 19,1 | 18,6 | 17,3 | 1,90 | NS |
| Utilized oxygen, l/h | 4,9 | 4,2 | 4,6 | 0,90 | NS |
| Elimination of $CO_2$, l/h$^-$ | 3,3 | 2,6 | 3,0 | 0,80 | NS |
| Respiratory quotient | 0,7$^c$ | 0,6$^a$ | 0,64$^b$ | 0,02 | ** |
| Heat production, kj/kgw$^{0,75}$/day | 142,3$^c$ | 129,4$^a$ | 139,4$^b$ | 0,43 | ** |

Different letters in the same row differ at $p < 0,05$ *** $p < 0,01$

Heat production is the result of the balance between the produced thermal energy and the dissipated thermal energy. Depending on the air temperature, the animals will be able, to a certain extent, to maintain their body temperature through vasodilation (increased blood flow) and increased surface temperature. At higher temperatures, the animals begin to rely on other mechanisms, such as evaporation, either through sweating or respiration. These results coincide with other studies, where the physiological variables increased with the increase in temperature throughout the day, under conditions of heat stress and thermoneutrality (Seixas *et al*., 2017).

Despite the differences among the genotypes and from the biological point of view, the obtained heat production is normal for sheep and goats. In addition, it is considered that the evaporation mechanism, associated with the performance of the respiratory rate, seems to be the main mechanism of heat dissipation of Pelibuey sheep under the evaluated conditions, which is in agreement with the report by Saldaña-Ríos (2016).

## Conclusions

The Pelibuey sheep subject to fasting did not reach basal metabolism until 96 hours after stopping feeding, period in which respiratory quotients below 0,70 were reached, typical of fat degradation.

Heat production showed significant differences among the studied Pelibuey sheep genotypes, an indicator that affects the efficiency of energy utilization for weight gain, as a response to diet management and environmental factors.

## Conflict of interests

The authors declare that there is no conflict of interests among them.

## Authors' contribution

- Norge Fonseca-Fuentes. Conception and direction of the research, data analysis and interpretation, paper writing.
- Leticia Tamayo-Ojea. Data collection, analysis and paper writing.
- Rafael Garcés-Sariol. Data collection, analysis and discussion of results.
- Alejandro Noel Fonseca-Serrano. Data collection and analysis and discussion of results.
- Jorge Orlay Serrano-Torres. Data analysis and interpretation and paper writing.
- Juraj Grizelj. Data analysis and interpretation and paper writing.

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