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Weather Conditions and Rumen Temperature and pH in Lidia Cattle

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Abstract

The aim of this work was to study the relationship between meteorological parameters (relative humidity, rainfall, temperature and wind speed) and rumen environment (pH and temperature) in extensively reared Lidia cattle. Five four year old Lidia breed bulls have been used. All the animals received 10 kg of a TMR (total mixed rations, ratio forage:concentrate 33:67) per animal and day, supplied by means of unifeed wagon once a day. The bulls had free access to a pasture (dehesa) area of 17 hectares. Rumen pH and temperature ruminal were continuously measured using a wireless internal pH and temperature probe. Meteorological parameters (temperature, humidity, rainfall and wind speed) were registered and provided by the AEMET (State Agency of Meteorology). The correlations were performed using the software SPSS 16.0 for Windows. It has been observed that rainfall, relative humidity and temperature have a relationship with rumen environment. Conversely, wind speed does not seem to influence the rumen conditions (pH and temperature).

Keywords: Bovine; Lidia cattle breed; Meteorology; pH; Temperature

Introduction

The Lidia is a Spanish native breed that is characterized by its rusticity, demanding a breeding in semi-captivity conditions, in the wildness and in a regime of herds in which hierarchies and territoriality are established [1]. Therefore, this breed is reared in an extensive systems in permanent contact with nature and its bioclimatic environment [1]. Throughout its life, Lidia cattle, the greatest exponent of the extensively reared bovine systems, remains in freedom in the dehesa (extensive land generally bounded and dedicated to grazing livestock), without protection or stables, thereby being subjected to an effort of adaptation to the recurring inclement weather, which places animals in a natural state of interaction between the complexity of the biochemical processes of their own organism and the environment that surrounds them [2,3].

Despite being reared extensively, Lidia bulls receive a supplementary ration, whose objective is, on the one hand, provide a sufficient amount of protein and energy (particularly during the last phase of preparation for the bullfight [4,5]. On the other hand, the purpose is to prepare a physiological machine capable of performing a supreme muscular effort during the approximately twenty minutes that will remain in the bullring [6].

Although most breeders appreciate the advantages of supplementing with TMR, especially weight gain, there are certain disadvantages associated to this feeding regime, mainly related to the appearance of ruminal acidosis. Thus, Bartolomé showed the presence of this pathology in fighting cattle with a variable incidence depending on the type of injury observed [7]. Thus, they found that 58.5% of the fought bulls presented ruminal pH values compatible with the suffering of some type of acidosis, most of them chronic; in addition, 27% of these bulls had some liver disease and 71% showed rumen paraqueratosis.

In light of this evidence, farmers try to improve feeding by adjusting rations to try to maintain the ruminal environment within physiological parameters. There is, however, no knowledge about the influence of other factors such as climate and environmental conditions on ruminal physiology.

The influence of climate on cattle has been recognized [8]. Thus, the physiology, behaviour and health of livestock are markedly influenced by the environment in which they live [9,10], whose effects on animals are mediated by metabolic, physiological and ethological responses. These are more or less accentuated depending on breed, age, productive level and individual characteristics [8].

To cope with adverse weather conditions, animals modify their physiological and behavioural mechanisms in order to maintain their body temperature within a normal range. As a consequence, it is possible to observe alterations in food consumption and behaviour. Under extreme conditions of cold or heat [11] animal response can be so marked that it may have a direct influence on the ruminal environment, as indicated by different authors [8,12-16]. Even so, the potential impact of weather variations on Lidia cattle, the paradigm of breeding under conditions of freedom at the mercy of environmental conditions, has barely.

Therefore, the objective of this work is to study the relationship between the meteorological parameters (humidity, rainfall, temperature and wind speed) and the conditions (pH and temperature) of the ruminal environment of Lidia breed cattle reared in freedom.

Materials and Methods

Animals and diets

Five four-year-old Lidia Bulls were used. Animals were handled according to the usual management in their farm, (Tejeda y Segoyuela (Salamanca, Spain; 40° 37′ 56″ N 6° 01′ 21″ O; 927 m above sea level, Köppen- Geiger's climate classification: Csb), and were fed on a total

mixed ration (TMR) whose ingredients and chemical composition are showed in Tables 1 and 2, respectively. All the animals received the same feeding, approximately 10 kg/animal and day of the indicated mixture, supplied by an unifeed wagon once a day in the morning. The management of the animals was carried out in accordance with the Directive 2010/63/EU on the protection of animals used for scientific purposes, and Regulation (EC) 1/2005, concerning the protection of animals during transportation and related operations. The bulls had a fenced space of 17 ha of pasture land, which would allow them to express their grazing behaviour patterns in freedom with full normality. The experimental period lasted from September to November.

Rumen pH and temperature

Rumen pH and temperature were measured using internal wireless smaXtec® boluses (SmaXtec animal care salts GmbH, GRAZ, Austria), developed and evaluated by Gasteiner and Cols [17]. This bolus (132 × 35 mm size) records pH (0-14 ± 0.2 units) and temperature (25-50 ± 0.2°C) every 10 minutes during the entire experimental period of measurement (37 ± 8.2 days).

Each bolus was adjusted using pH 4 and 7 standards before being used. Once calibrated, the bolus was orally introduced with an applicator to be hosted in the reticulum, where it remained until the animal was slaughtered Data were recorded by using a mobile reader and displayed using a particular software (SmaXtec).

Meteorological parameters: The data of temperature, relative humidity, rainfall and wind speed was recorded and provided by the AEMET (State Meteorological Agency).

For the study of the joint effect of the meteorological parameters on the animals, the following indices have been calculated:

Temperature and humidity index (THI) [18]:

$$THI = (1.8\ T + 32) - (0.55 - 0.55\ RH/100)\ (1.8\ T - 26)$$

Thermal sensation or apparent temperature [19]:

$$T\ app.\ (°C) = 33 + (T - 33) \times (0.474 + 0.454\sqrt{(W)} - 0.0454\ W)$$

Cooling index: [19,20]

$$CI = 0.323 \times (18.97 \times \sqrt{(W)} - W + 37.62) \times (33 - T),$$

where T is the ambient temperature (°C), RH the relative humidity (%), T app. the apparent temperature and W the wind speed (km/h).

Analytical determinations: Feed samples were analyzed following the procedures of the AOAC [21] to determine their content of dry matter (934.01), ashes (942.05), crude protein (Nx6.25: 976.06) and crude fiber (962.09). The analytical determinations were carried out in the facilities of MasterLab España Analytical Services (Tres Cantos, Madrid).

Statistical analysis: Data on rumen pH and temperature were first averaged for each day: maximum, minimum and mean, area under the curve, and time spent below pH thresholds of 7.0, 6.6, 6.2, 5.8, 5.4 and 5.0. The area under the curve was calculated by multiplying the absolute value of the deviation in pH by the time (min) the pH was below the threshold, and expressed as pH units × min. The value of the average pH for each hour within each day was also calculated for each animal.

For the temperature analysis, the maximum, minimum and mean data were processed, time below 38.4 and above 39.0, 39.2, 39.4, 39.6 and 39.8°C. The area under the curve was calculated as indicated for pH. The beginning of a drink event was identified when the ruminal temperature suffered a decrease higher than 0.28°C from the previous measurement; and the end of the drinking period was considered when the temperature ceased to increase its values during a period of 10 minutes [22].

Pearson's linear correlation analysis was performed among the different variables using the software SPSS 16.0 for Windows (IBM Corp., New York, USA).

Results and Discussion

The physical-environmental factors affecting livestock were defined by Hahn and Cols [13] and correspond to a complex interaction of air temperature, relative humidity, radiation, wind speed, precipitation, atmospheric pressure, ultraviolet light and dust. This work will focus on those parameters that are more easily measurable and whose influence could be more decisive, such as temperature, relative humidity, wind speed and precipitation, and the relationship that these variables can have with rumen pH and temperature.

Table 3 shows the average values for each of the controlled parameters, whereas Table 4 shows the correlation coefficients between the daily average values of the ruminal parameters (pH and temperature) and the meteorological parameters analyzed (relative humidity, rainfall, temperature and wind speed).

A certain positive correlation (although very weak) was observed between the recorded rainfall and the time the rumen passes at pH<5.0 and the average and minimum rumen temperature. It is estimated that rainfall temporarily decreases feed consumption by 10 to 30%, while the presence of mud (as a consequence of rain) can decrease feed intake up to 30% [23]. Therefore, rainfall can lead to changes in the pattern of feed intake, reducing the number of intakes per day, which could be associated with a reduction in total feed intake. The reduction in the number of meals per day could be offset by an increase in the amount of feed eaten in each of them [24-26], causing a deregulation of the physiological mechanisms to maintain ruminal pH within neutrality [27]. Thus, the correlation between rainfall and the time that rumen pH is low could therefore be explained by a decrease in the number of meals associated with an increase in the amount of feed taken in each of them.

Ingredients (% on fresh matter)	Feed	Ration
Barley	27	
Corn	34.36	
Beet pulp	10	
Salt	0.35	
DDG	7	
Rapeseed 36	10	
Soybean 44	5.05	
Soybean oil	1	
Calcium carbonate	1.4	
Phosphate	0.37	
Fat by pass[1]	1.97	
Vitamin-mineral premix[2]	0.5	
Buffer[3]	1	
Fodder	--	61.91
Cereal Straw	--	33.33
Cane molasses	--	4.76

[1]Hepagras JC Trow Nutition, Madrid, Spain; [2]Ternimax51 TLIDI, Trow Nutrition, Madrid, Spain; [3]Biomax (75% Sodium bicarbonate, 25% Magnesium oxide), Trow Nutition, Madrid, Spain.

Table 1: Ingredients of the rations used.

Chemical composition (% on dry matter)	Feed	Ration
Moisture	10.6	9.6
Crude protein	13.4	10.8
Ashes	5.6	6.5
Crude fiber	9.4	14.7
Starch	33	23.1
Crude fat	4.93	4.1
Non-fibrous carbohydrates		27.7

Table 2: Chemical composition of the ration.

	Average	Typ. deviation	Minimum	Maximum
Rumen parameters				
Temperature	38.88	0.38	38.4	39.3
Mean pH	6.22	0.06	6.16	6.29
Minimal pH	5.52	0.05	5.45	5.58
Maximum pH	6.81	0.1	6.7	6.94
Maximum temperature	40.07	0.3	39.7	40.46
Minimal temperature	31.9	1.09	30.7	33.2
Weather parameters				
Maximum relative humidity	87.55	15.09	35	100
Minimal relative humidity	47.65	21.82	7	100
Rainfall	17	53	0	568
Maximum temperature	16.5	8.24	-0.1	35.8
Minimal temperature	5.8	5.62	-7	19.9
Mean temperature	11.2	6.83	-3.6	27.8
Wind speed	41.66	14.75	15	94

Table 3: Mean values for each of the variables.

Conversely, there is a negative correlation between rainfall and the time the rumen spends at low temperatures (related to the moments when the animal drinks water). This relationship could probably be due to the fact that the animals will tend to consume less amount of water on rainy days. This would be explained by the fact that the higher relative humidity of the air, the lower the water losses (mainly through breathing and skin) [28].

In any case, and despite the fact that both correlations are significant, the correlation coefficient is low. This may be due, in the first place, to the fact that during the development of this experimental protocol rainfall was recorded during 20% of the days. In addition, the different intensity at which the precipitation occurred could have contributed to the unexplained variability (Figure 1).

A positive correlation was observed between relative humidity and the time that the rumen is at low pH values, which, in accordance with the above mentioned rainfall hypothesis, may be associated with a high amount of feed per meal, despite the fact that total feed intake may decrease in environments with mud and humidity [23]. However, the relationship between relative humidity and rumen temperature is inverse: the higher the humidity, the lower the ruminal temperature and the less the time that rumen passes at high temperatures. The reduction of intake in humid environments could cause the ruminal temperature to be slightly lower due to a decrease in ruminal metabolism [29]. In addition, in the present work a negative and significant correlation between mean rumen temperature and the time the rumen passes at low pH was observed. However, in highly productive cattle (intensively producing meat or milk), the relative humidity has hardly an influence, provided that the temperatures are in the zone of thermoneutrality; However, when temperatures are outside the thermoneutral zone, a high relative humidity can have a negative effect on animal welfare [30].

The relative humidity during the development of this study (Table

3) is between 87.5 and 47.6%, with an average value of 67.6%, these values being, therefore, within the optimal range indicated by Aldaz and Cols [31]. There is a range of ambient temperature within which the body temperature remains constant with a minimum effort for the thermoregulatory mechanisms and within which the sensation of heat or cold it is absent (B 'to B), known as thermal comfort or thermoneutrality zone (Figure 2). This zone is between -1°C and 16°C for the bovine breeds in carnivorous habitat typical of the temperate zones. The NRC considers the thermal control zone for Holstein cattle in a range between -5 and 27°C. Johnson situates it between -5°C and 21°C, whereas Aldaz and Cols consider intermediate zone (between -5 and 25°C) [31-33].

The environmental temperature has a clear influence on the ruminal temperature. Thus, there is a positive correlation between both parameters and with the time the rumen passes at high temperatures [34], even though the present experiment has been carried out in thermoneutrality conditions (average environmental temperature of 10°C). Therefore, predictably, it would not be necessary for the animal to set in motion compensation mechanisms. Analogously, a negative and significant correlation between ambient temperature and time spent at low temperatures was also observed.

There also seems to be a certain negative correlation between the ambient temperature and the time the rumen passes at pH<5.4. When the environmental temperature decreases, the animals need to start mechanisms to compensate for the loss of heat through strategies that foresee, in the long term, an increase in isolation with the environment (greater fat cover, longer and thicker fur, etc.), and, in the short term,, behavioral (postural variations to try to reduce the exposure of the body surface and thus the potential heat loss), physiological (peripheral vasoconstriction and generalized pilo-erection) changes or producing more heat through an increase in feed intake, most likely a combination of several mechanisms [33,35-37]. In addition, the activation of thermogenesis processes to cope with cold environments causes a reduction in digestibility of 0.2 units per degree Celsius, thus increasing maintenance needs [37]. As a consequence, in these cases, both feed and water consumption may be affected. Thus, animals increase feed intake when environmental temperatures fall below the thermoneutral zone or, alternatively, change their diets to feed sources that allow them to obtain the extra energy required to increase heat production and satisfy the increase in maintenance needs [37]. In this way, the animal can increase the production of volatile fatty acids in the rumen, which would lead to a decrease in ruminal pH and, consequently, cause the rumen to spend more time at low pH. The alteration in feeding behavior has been observed in bovines, generally,
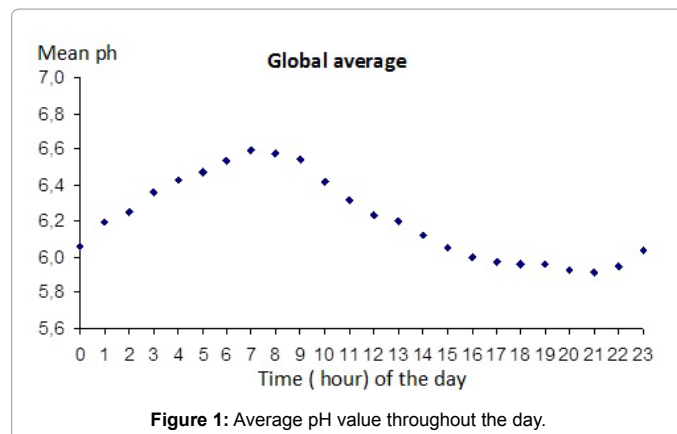
Figure 1: Average pH value throughout the day.

B: Lowest critical temperature; B': Highest critical temperature.
Figure 2: Fuente Resano, 2004.
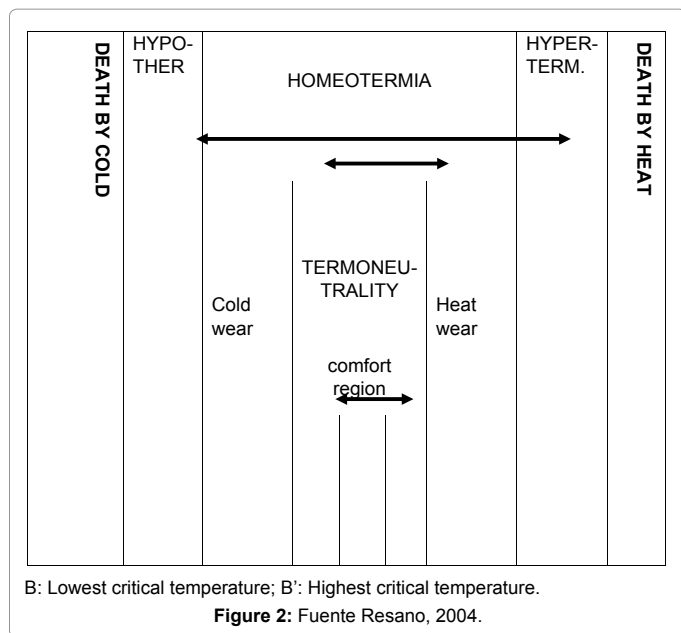
under very low temperatures (-10°C) [38]. Although the temperatures recorded during the experimental period were not so extreme (positive temperature values but close to 0°C), they could have an effect on feed intake. Indeed, it has been observed that the infusion of cold water in the rumen (5°C) produces an increase in feed consumption by 24% [39].

The results obtained in this study agree with those published by Gianesella, who showed the influence that humidity and environmental temperature have on the ruminal environment [15].

An inverse relationship between environmental temperature and voluntary feed intake has been well documented [23,40-42] especially when using high energy density diets [14]. In addition, infusion of hot water (49°C) in the rumen depresses feed intake by 9% [39]. However, this decrease in feed consumption is not always accompanied by an increase in ruminal pH. Thus, in accordance with Church, Kaiser and Weniger reported a decrease in rumen pH associated to an increase in environmental temperature regardless the diet received by the animals (lambs receiving oats straw or concentrate and hay), and due to an increase of the concentration of volatile fatty acids [43,44]. Likewise, Collier also indicated that ruminal pH decreased in conditions of thermal stress due to high temperatures [12]. This phenomenon

Rumen parameters n=189 (all)	Weather parameters						
	Relative humidity		Rainfall	Temperature			Wind speed
	Max	Min		Max.	Min.	Mean.	
pH							
Mean.	0.047	-0.062	-0.036	0.009	0.017	0.013	0.076
Min.	0.113	-0.022	-0.076	-0.047	-0.064	-0.056	0.07
Max.	-0.03	-0.085	0.032	0.054	0.081	0.067	0.09
Time (min/day) at pH<							
7.0	-0.057	0.031	0.001	0.028	0.058	0.042	0.031
6.6	-0.086	-0.005	-0.026	0.059	0.064	0.063	-0.042
6.2	-0.084	0.02	0.017	0.041	0.017	0.032	-0.097
5.8	-0.013	0.089	0.064	-0.032	-0.045	-0.039	-0.074
5.4	0.082	0.217**	0.109	-0.194*	-0.165*	-0.189**	0.021
5.0	0.139	0.255**	0.180*	-0.263**	-0.207**	-0.248**	0.032
Temperature							
Mean.	-0.133	-0.264**	0.203**	0.404**	0.440**	0.431**	-0.052
Max.	-0.05	-0.176*	0.037	0.261**	0.248**	0.265**	-0.135
Min.	-0.094	-0.144*	0.264**	0.335**	0.361**	0.357**	-0.064
Time (min/day) at temperature>							
39.0	-0.250**	-0.384**	0.128	0.530**	0.527**	0.546**	-0.099
39.2	-0.224**	-0.367**	0.141	0.493**	0.492**	0.509**	-0.083
39.4	-0.174*	-0.301**	0.163*	0.401**	0.418**	0.421**	-0.048
39.6	-0.104	-0.221**	0.154*	0.316**	0.357**	0.343**	-0.032
39.8	-0.066	-0.164*	0.125	0.245**	0.299**	0.275**	-0.028
Time (min/day) at temperature <38.4	0.025	0.095	-0.239**	-0.231**	-0.275**	-0.256**	0.011

Significant correlation at $P<0.05$. **Significant correlation at $P<0.01$.
Table 4: Correlation coefficients (Pearson) between the daily mean values of rumen parameters and meteorological parameters.

could be explained by the fact that the particles retention time in the rumen increases due to a diminished rumen motility, thus increasing digestibility [45]. In addition, an increase in the size of meals has been linked to high environmental temperatures, thus increasing the risk of accumulation of large amounts of volatile fatty acids and, therefore, the risk of acidosis [46].

The wind speed does not seem to influence the ruminal environment in the present experiment. However, other authors indicate that in conditions of low environmental temperatures the wind does have a negative effect, since it increases the heat loss [47,48], which could trigger the start of compensation mechanisms, and therefore the increase of dry matter consumption with the possible effect that this can have on the ruminal pH.

The main climatic problem observed is the associated effect of rainfall and wind, because the animals stop eating in the simultaneous presence of both weather events [49]. To assess the joint effect of these meteorological phenomena, there are some indicators, such as the temperature and humidity index (THI) [18], the thermal sensation or apparent temperature [19] and the cooling index [20].

When analyzing all the information, it is observed that there is a significant positive correlation between ruminal temperature and THI and thermal sensation (Table 5). This is in agreement with the general tendency observed, in the present work, between ruminal and environmental temperature. Although there is some divergence with the data shown on the correlation between ruminal temperature and environmental relative humidity, it must be taken into account that the weight of this last parameter within the calculation of THI and thermal sensation is lower than that given to the temperature. Indeed, temperature determines to a greater extent the value of the THI and, consequently, its relation with the rest of the parameters studied. Likewise, the negative correlation between ruminal temperature and cooling index follows the same tendency between environmental and ruminal temperature, since this index is inverse to the temperature.

When only data from temperatures above the thermoneutrality (>16°C) [30] are considered (Table 6), no significant correlation is observed among the variables studied. This could be due, firstly, to the fact that although these values are considered outside the comfort zone, the maximum temperatures reached (average 19°C, maximum 27.8°C) are not extreme enough to activate the mechanisms of compensation that may cause alterations at the ruminal level. And, secondly, the scarce thermal amplitude covered by the data set and the variability of said ruminal temperature values taken from the animals. All this has been able to contribute to that there is no obvious association between the variables studied.

Taking into account the data pairs corresponding to temperatures below (or equal to) 16°C (Table 7), a positive correlation between rumen temperature and THI and thermal sensation is observed, and negative with the cooling index, as indicated previously (Table 5). In this case, the number of data considered is greater, as is the thermal amplitude taken into account. This observation confirms the influence of the environmental temperature on the ruminal temperature in the thermoneutrality zone.

Furthermore, the ruminal pH correlated positively with the THI and the thermal sensation, and negatively with the cooling index. As discussed above in relation to pH and environmental temperature, when the animal loses heat, thermogenesis mechanisms are activated and food consumption increases, which, ultimately, ends up in a decrease in ruminal pH.

(n=188)	Average ruminal parameters	
	Temperature	pH
THI for max. humidity	0.453**	0.034
THI for min. humidity	0.459**	0.069
Thermal sensation	0.423**	-0.009
Cooling index	-0.423**	0.009

**Significant correlation to P<0.01.
Table 5: Correlation coefficients (Pearson) between the daily average values of pH and ruminal temperature and the calculated meteorological parameters.

(n=72)	Average ruminal parameters	
	Temperature	pH
THI for max. humidity	-0.029	-0.093
THI for min. humidity	-0.012	-0.071
Thermal sensation	-0.03	-0.195
Cooling index	0.03	0.195

Table 6: Correlation coefficients (Pearson) between the daily values of pH and ruminal temperature and the meteorological parameters calculated when the ambient temperature was higher than 16°C.

(n=116)	Average ruminal parameters	
	Temperature	pH
THI for max. humidity	0.594**	0.373**
THI for min. humidity	0.574**	0.401**
Thermal sensation	0.542**	0.312**
Cooling index	-0.542**	-0.312**

**Significant correlation to P<0.01.
Table 7: Correlation coefficients (Pearson) between the daily values of pH and ruminal temperature and the meteorological parameters calculated when the ambient temperature was less than or equal to 16°C.

Conclusions

A direct correlation between environmental and ruminal temperature has been observed. Even within the range of thermal comfort, environmental relative humidity and rainfall predispose the rumen of Lidia cattle to remain longer at low pH values. This fact may be associated with an increased risk of ruminal acidosis.

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