Genetics and Reproduction

Original

Agrometeorological Assessment of Companies Holding Beef Cattle

Marco Antonio Suárez Tronco* y **, Manuel Rodríguez Castro**, Yudith Lamothe Crespo**, María del Carmen Guerra Rojas**, María Segunda Martínez Gutiérrez**

*Agrarian University of Havana (UNAH), San José de las Lajas, Mayabeque, Cuba.
** Center for Tropical Livestock Breeding (CIMAGT), Loma de Tierra, Cotorro, La Habana, Cuba.

Correspondence: marcost@cima-minag.cu; marcost@cima-minag.cu

Received: August 2021; Accepted: September 2021; Published: October, 2021.

ABSTRACT

Background: Climatic change is a reality and strategies for animal and crop breeding must include the agrometeorological characteristics of specific areas. **Aim.** To characterize genetic breeding companies in the country with meat producing breeds, depending on the climatic variables. **Methods:** The study determined the monthly information of the climatic variables: minimum (^{0}C) (Tmin), mid (^{0}C) (Tmean), maximum (^{0}C) (Tmax) air temperature; relative humidity (RH) (%). It also estimated the humidity-temperature index (HTI), measured in 3 374 records from companies located in the three main regions of the country, between 1980 and 2018. Variance analysis of the five climatic variables included the company, five-year period, four-month period, and interactions, as sources of variation. **Results:** The general means were, 21.91 ± 1.46 ^{o}C; 27.29 ± 1.52 ^{o}C; 30.57 ± 1.68 ^{o}C; 76.19 ± 4.18%; and 77.78 ± 3.45, for Tmin, Tmax, RH, and HTI, respectively. The company, four-month period, and five-year period in which the performance tests and interactions among them were significant (P≤ 0.001), except for the triple interactions, and four-month period x five-year period. The model's R^2 varied from 51.25% RH, to 76.02% HTI. Turiguano company showed the worst climatic indicators. **Conclusions:** The study concluded that the climatic variables permit the characterization of companies, which facilitates the selection of breeds and/or genotypes that best suit the environmental conditions.

Keywords: bovine, beef breeds, climatic variables (Source*: DeCS*)

INTRODUCTION

The effect of climate on animal production has been studied for a long time, particularly in dairy cattle, with advances in the knowledge of physiological and animal performance aspects under thermoneutral and climatic stress conditions. Climatic change is a reality and strategies for animal and crop breeding must rely on thorough knowledge of the agrometeorological

Citation (APA)
Suárez Tronco, M., Rodríguez Castro, M., Lamothe Crespo, Y., Guerra Rojas, M., & Martínez Gutiérrez, M. (2021). Agrometeorological Assessment of Companies Holding Beef Cattle Companies *Journal of Animal Production*, *33*(3). https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3944

©The author(s), Journal of Animal Production 2020. This article is distributed under the terms of the international license Attribution-NonCommercial 4.0 (https://creativecommons.org/licenses/by-nc/4.0/), assumed by collections of open access scientific journals, recommended by the Declaration of Budapest, which may be consulted at: Budapest Open Access Initiative's definition of Open Access.

characteristics of specific areas, which is a determining factor deriving from the association of production with them (Domínguez-Hurtado, Moya-Álvarez and Estrada-Moreno (2010).

In Cuban livestock breeding, animal welfare has become a determining factor, being the humidity-temperature index (HTI) an indicator of such welfare often used to evaluate the level of animal comfort (Carabaño *et al.*, 2016; Nguyen *et al*., 2016). However, there are few studies including meat producing breeds.

This research aims to characterize genetic breeding companies in the country with beef producing breeds, depending on the climatic variables, and their evolution in time.

MATERIALS AND METHODS

Location, duration, and climatic variables

The monthly minimum (Tmin), mean (Tmean), and maximum (Tmax) temperatures (^{0}C), relative humidity (%) values reported by national genetic companies and farms in the western, central, and eastern regions were used. Table 1 shows the names of the companies and the location of the nearest weather station.

Table 1. Companies and location of weather stations included in the study

Company	Station	Latitude	Longitude	Height (m)
Camilo Cienfuegos	Pinar del Río	22^0 24’16”	83^0 39’14”	56.48
San Juan de los Ramos	Jovellanos	22^0 47’45”	81^0 11’07”	25.33
Rodas	Aguada	22^0 22’22”	80^0 49’35”	28.34
Abra	Cienfuegos	22^0 11’25”	80^0 26’39”	42.40
Rescate de Sanguily	Camagüey	21^0 25’21”	77^0 50’59”	118.00
Manuel Fajardo	Manzanillo	20^0 10’45”	77^0 09’55”	20.17
Turiguanó	Cayo Coco	22º 32’21”	78^0 22’07”	3.40
Vallina	Valle de Caujerí	$20^0$08’51”	74^0 50’29	160.00

The table refers to the 1980-2018 period and the twelve months of the year, with a total of 3 774 records.

The humidity temperature index (HTI) was designed according to Ravagnolo, Mistzal, and Hoogenboom (2000).

HTI = 0.81*Ta + (RH/100) * (Ta – 14.4) + 46.4, where Ta is the mean environmental temperature (^{o}C), and RH is the mean relative humidity (%).

Statistical analysis:

The data were tabulated and analyzed to generate the general statigraphs. Analysis of variance included the climatic variables company, five-year period, and four-month period of the beginning of the performance test (PT), as sources of variation, as well as double and triple interactions between them.

A statistical analysis was conducted through natural four-month periods (January-April, May-August, and September-December); the years were grouped in five-year periods 1980-1984, 1985-1989, 1990-1994,1995-1999, 2000-2004, 2005-2009, 2010-2014, and 2015-2018). That way, the combinations generated in the analysis of interactions were lower, and enabled the authors to conduct a better interpretation of the results.

The maximum and mean temperatures did not have a normal distribution, so the data were transformed using LOG(Y). The rest had a normal distribution. A general linear model was used through the PROC GLM of SAS (2013), with the following mathematical model:

$$\mathbf{Yijkl = \mu + Ei + Aj + Mk + (ExA)ij + (ExM)ik + (AxM)jk + (ExAxM)ijk + eijkl}$$

Where Yijkl is the corresponding climatic variable, μ is the general mean commonly observed; Ei is the company effect (i = 1, 2, ….8); Aj is the effect of the five-year period when the PT began (j = 1, 2, ...8) ; Mk is the four-month period (k = 1, 2, 3) ; (ExA)ij, (ExM)ik, (AxM)jk, and (ExAxM)ijk the interactions between the main effects, and eijkl is the random residual effect $\sim$ N (0, σe^2). Later, the non-significant interactions were removed from the models and new runs were made. The minimum quadratic means were obtained, and the Tukey test was performed for multiple mean comparisons.

PROC CORR from SAS (2013) was used to estimate the Pearson linear correlation; the regression equations were estimated under certain circumstances.

RESULTS AND DISCUSSION

General characterization

Table 2 shows the general statigraphs of the main variables studied. The results present relatively low variation coefficients, with the highest variations for Tmin and Tmean. Suárez Tronco *et al*. (2018), found similar results in a study with fewer companies and records, but the variability of data of the current study was greater, possibly due to the high volume of information. The minimum temperature underwent the highest variability in the two results. Regardless of the analysis of data from different regions of the country, the differences were not so remarkable. The climatic conditions are an important element of the agroecosystem and must be included when choosing the genotypes or breeds to exploit, or both, as well as the system of production. Quite a few times the opposite is done: the genotypes are selected regardless of the climatic conditions, which is not advisable.

Table 2. Means, standard deviation (SD), and variation coefficients (VC) of the climatic data included

Variables	Means	SD	VC (%)
Minimum temperature (^{0}C)	21.91	1.46	6.66
Mean temperature (^{0}C)	27.29	1.52	5.57
Maximum temperature (^{0}C)	30.57	1.68	5.49
Relative humidity (%)	76.19	4.18	5.49
HTI	77.78	3.45	4.43

SD: standard deviation; VC: variation coefficient.

There are different HTI classifications to assess the value of the level of stress in animals (Mader, 2003; de Rensis, García-Ispierto, and López-Gatius, 2015); Enríquez Regalado and Álvarez Adán, 2020), most of which have been used in dairy cattle.

An HTI of 77.78 falls in the classification of mild stress for Mader (2003), severe stress for Rensis, García-Ispierto, and López-Gatius (2015), and surpasses the threshold suggested by Collier *et al*. (2012) for dairy breeds. In the province of Mayabeque, Enríquez Regalado and Álvarez Adán (2020) reported HTI = 78 in the 2005-2016 period, considered as moderate, with a marked contrast in its annual distribution. It is necessary to clarify that these classifications are mainly applied to temperate regions and in dairy breeds. This indicator has been used by some countries to warn farmers about the conditions of heat stress that threaten animal welfare, and evaluate cattle comfort (Vega, Almanza, and Abraham, 2014). As stated previously, most results are associated with the production of milk, such as, Ruíz-García, Carcelén-Caceres, and Sandoval-Monzón (2018) and Ruíz, Carcelén, and Sandoval-Monzón (2019), based on the daily production of milk in Peru; Ruíz-Jaramillo *et al*. (2019) in Costa Rica, and Enríquez Regalado and Álvarez Adán (2020) in the province of Mayabeque, Cuba.

The mean air temperature was 27.29 °C, within the range reported and calculated on a three-hourly data basis, in the municipality of Guaimaro, province of Camagüey, Cuba, in 2000-2005, on dairy farms with temperature values of 22.9 °C-27.7 °C. (Vega, Almanza, and Abraham, 2014), and above the one reported by Suárez Tronco *et al.* (2018).

The relative humidity (76.19%) was lower than the one reported by Vega, Almanza, and Abraham (2014), with a mean value of 82%, ranging between 77% and 86% throughout the year. Besides, it was lower than the one reported by Suárez Tronco *et al.* (2018), and similar to 76% found in the province of Mayabeque (Enríquez Regalado and Álvarez Adán, 2020).

Temperature and relative humidity have also been included in studies measuring their influence on the lactation curve parameters in Brown Swiss cattle under tropical conditions (Lucena, 2014), as well as some physiological responses to heat and humidity of several different genotypes (Espinoza *et al.*, 2011).

Results of analyses of variance

The triple interactions of company x four-month period x five-year period were insignificant in all cases; the double interaction of four-month period x five-year period was insignificant for Tmean, RH, HTI, and Tmax, so they were removed from the final models. The most important interaction related to the purpose of this research (company x five-year period) was insignificant to Tmax.

The results of the analyses of variance of the climatic variables are shown in Table 3. All the sources of variation analyzed in the definitive models were highly significant, except for the company x five-year period interaction for Tmax. The climatic variables changes as expected, according to the company, the five-year period, and the four-month period. The coefficients of determination were relatively high for HTI (76.02%), whereas the RH was low (51.25%). Every coefficient of determination was inferior to the ones reported by Suárez Tronco *et al*. (2018), who considered fewer records and companies, though scattered across the country.

Table 3. Results of analyses of variance of five climatic variables

Sources of variation	LG	Tmin	Tmean	Tmax	RH	HTI
Company	7	***	***	***	***	***
Five-year period	7	***	***	***	***	***
Four-month period	2	***	***	***	***	***
Company x four-month period	14	***	***	***	***	***
Company x five-year period	49	***	***	NS	***	***
R^2 (%)		71.78	74.57	63.63	51.25	76.02

***** P (≤ 0.001) NS not significant**

Figure 1 shows HTI variations, minimum and mean temperatures through the four-month periods, with a marked parallelism between variables, regardless of the scale effect. These variables were selected for their higher determination coefficients, and their positive association with one another (See Table 4). There were significant differences (P<0.05) between the four-month periods in all the cases.

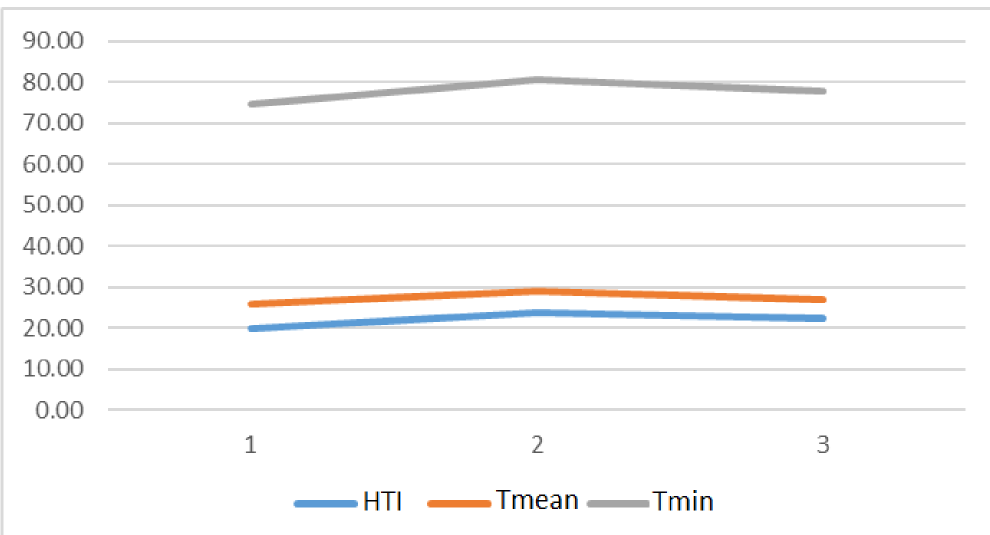

Figure 1. HTI variations, and the minimum and mean temperatures in the four-month periods

The HTI increased in January-August, then it declined, with the greatest values in July (80.42) and August (80.61), which can be regarded as dangerous for the animals. The highest values in these months were found in Guaimaro, by Vega, Almanza, and Abraham (2014), though they were lower (76.9). Enríquez Regalado and Álvarez Adán (2020) in the province of Mayabeque, Cuba, found higher values in the June-September period (83.0), higher than the values found in this work. The previous results corroborate that the best climatic conditions occur in the period comprising the end and beginning of the year.

Because the correlation between Tmin and Tmean was 0.53, the parallelism between them is logical (Figure 1). The temperatures increased between January and August, then they declined. The trends for the three variables were similar to the ones reported by Suárez Tronco *et al*. (2018). Then, the arithmetic means were reported, now it includes the minimum quadratic means adjusted to the effects studied.

Table 4. Pearson correlation coefficients among the climatic variables (n= 3 744).

	Tmin	Tmean	Tmax	RH	HTI
Tmin	-	0.53***	0.45***	0.27***	0.38***
Tmean		-	0.55***	0.002NS	0.68***
Tmax			-	-0.14***	0.31***
RH				-	0.16***

***** P (≤ 0.001) NS: not significant**

More important than the variations between seasons or four-month periods are the variations that occur through time as a clear sign of climate change. Figure 2 shows the variations by five-year period; linear regression analysis evidenced that Tmin increased 0.29 ºC and Tmean increased 0.10 ºC every five year, resulting in determination coefficients (R^2) of 89.09% and 78.47%, respectively. In all the cases, the last five-year period (2015-18) showed the worst indicators.

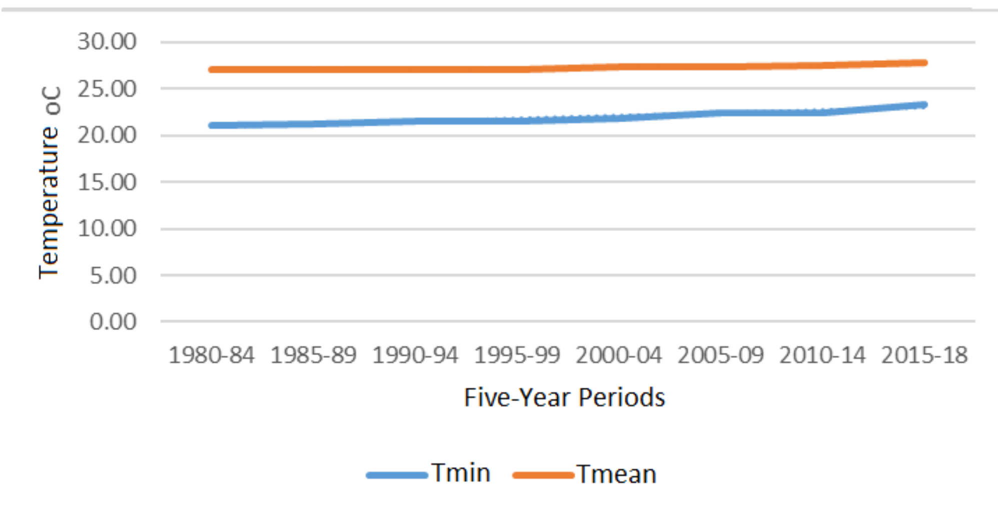

Figure 2. Variations of mean and minimum temperatures in the period studied

Characterization of companies

Table 5 shows the general statigraphs of the companies included in the study. The differences among the companies were remarkable in many cases. HTI, used as an articulator of temperature and humidity, is a very important indicator. In this direction, Turiguano's Manuel Fajardo company had the best conditions, with the highest values observed, differing significantly from the others.

The HTI ranged between 71.06 in Manuel Fajardo and 84.62 in Turiguanó. An ITH < 70 can be regarded as normal values, with no affectations to animals; between 74 and 76, it is considered an alert, with an insignificant state of animal dejection, and found in only three companies (Manuel Fajardo, Abra, and Camilo Cienfuegos). The rest was above those values, representing dangerously significant dejection, based on the previous classification, though possible animal alterations were not demonstrated. Figure 3 shows company behavior of HTI, with clear differences.

Table 5. Differences of some climatic variables of the companies in the study

Company	RH (%)	Tmax (ºC)	Tmean (ºC)	Tmin (ºC)	HTI
Camilo Cienfuegos	76.95 ^{b}	28.07 ^{e}	25.73 ^{e}	23.10 ^{b}	75.67 ^{e}
San Juan	74.57 ^{e}	30.56 ^{c}	27.72 ^{b}	21.04 ^{d}	78.79 ^{c}
Rodas	76.04 ^{c}	30.10 ^{c}	29.50 ^{b}	20.85 ^{e}	81.70 ^{b}
Abra	72.68 ^{f}	31.64 ^{b}	25.64 ^{c}	21.98 ^{c}	75.34 ^{e}
Rescate de Sanguily	75.09 ^{d}	32.10 ^{a}	26.40 ^{d}	22.65 ^{b}	76.80 ^{d}
Manuel Fajardo	78.03 ^{b}	31.58 ^{b}	24.99 ^{f}	19.65 ^{f}	71.06 ^{f}
Turiguanó	75.09 ^{d}	32.10 ^{a}	31.43 ^{a}	22.65 ^{b}	84.62 ^{a}
Vallina	81.09 ^{a}	28.43 ^{d}	26.88 ^{c}	23.34 ^{a}	78.30 ^{c}

Unequal superscripts in the same column means significant differences (P≤ 0.05), according to Tukey.

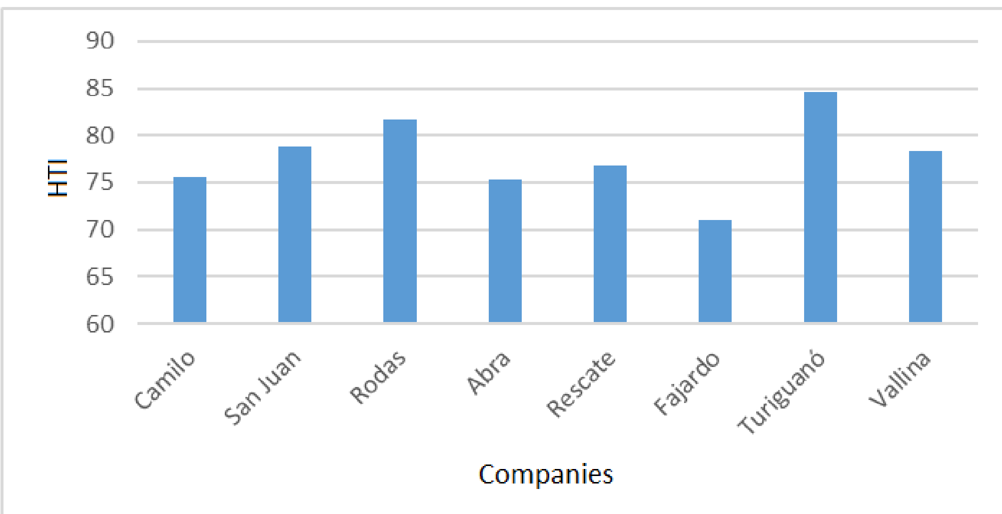

Figure 3. Mean HTI performance by company

The Manuel Fajardo company, contrary to the expectations for a company in the eastern region, had the lowest HTI values (71.06), which differed significantly (P< 0.05) from the rest, which was slightly lower than the one reported by Suárez Tronco *et al*. (2021) for a company having Cuban and Charolais cattle, whereas Turiguano, with Santa Gertrudis cattle, showed the worst values. All the companies, except Manuel Fajardo showed mean values above 74, which can be considered within the alert condition, whereas 4 were above 77, meaning stress conditions.

Figure 4 shows the graphic of company x five-year period interaction for HTI. The dots within the companies represent the quadratic means of HTI in the five-year period. Regardless of the small variations in the merit order of companies by five-year period, there is a quite clear increasing trend every company HTI in time. A similar situation can be observed in relation to the temperatures.

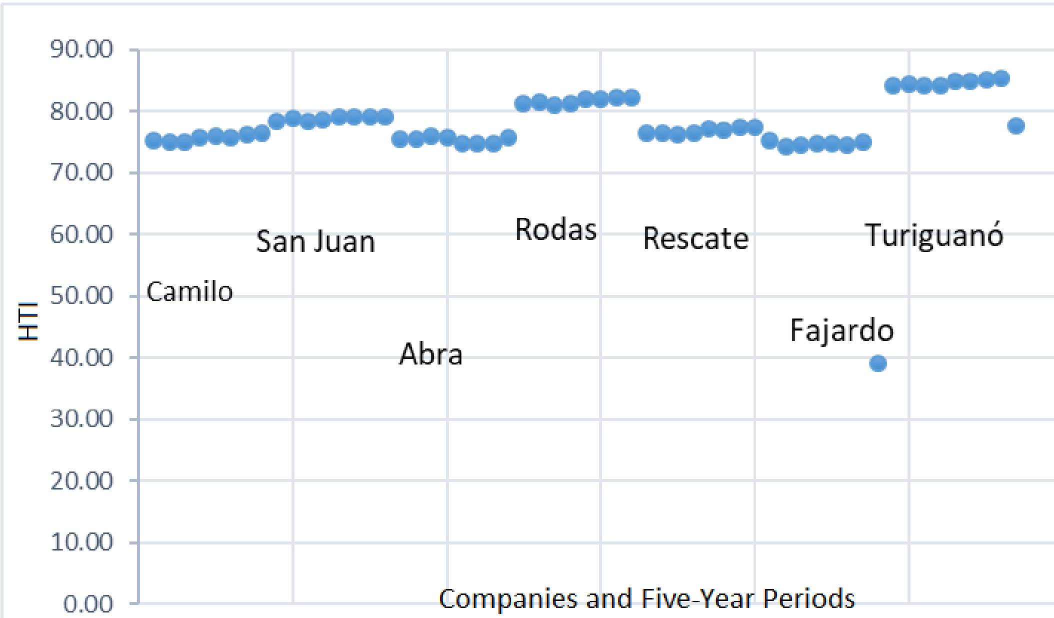

Figure 4. Company-five-year interaction

Agriculture poses the need of efficient management of natural resources, including the climate, to set up strategies that enable the adjustment of the ones having a negative impact on production. Animal welfare has become a determining factor to achieve a better productive expression.

The tropical environments offer advantages and disadvantages to animal production. Among the positive aspects are high precipitation values and long daily, almost constant solar exposure, which favor forage production for most of the year. However, the disadvantages are associated with the proliferation of internal and external parasites; diseases; high contents of cell walls in the forage that favors the generation of internal heat; high temperatures and RH leading to situations of heat stress that affect the expression of the genetic potential when animal welfare is compromised (Tapki and Şahin, 2006). Among the physiological factors triggered by heat stress are increased rectal temperature, respiratory frequency, and panting as a way of keeping body temperature (Pragna *et al.*, 2017). These changes produce a disruption in the feeding patterns and rumen function, with a reduction of dry ingestion, and therefore, productivity.

CONCLUSIONS

These results permit the agrometeorological characterization or classification, or both, of Cuban companies. It contributes to the assessment and selection of breeds or genotypes, or both, suitable for the prevailing environmental conditions, in keeping with the farming of dairy or beef breeds, and their crossbreds. Additionally, the climatic variables were observed to worsen in time, affecting cattle farming.

ACKNOWLEDGMENTS

The results of this study are in compliance with a grant funded by FONCI, by virtue of contract No. 19, 2020.

The authors wish to express their gratitude to Dr. Roberto Vázquez Montes de Oca, Ph.D., for the recommendations to conduct this research.

REFERENCES

Carabaño, M. J., Logar, B., Bormann, J., Minet, J., Vanrobays, M. L., Diaz, C., Tychon, B., Gengler, N., & Hammami, H. (2016). Modeling heat stress under different environmental conditions. *Journal of Dairy Science*, *99*(5), 3798-3814. https://doi.org/10.3168/jds.2015-10212

Collier, R. J., Hall, L. W., Rungruang, S., & Zimbleman, R. B. (2012). Quantifying heat stress and its impact on metabolism and performance. *Department of Animal Sciences University of Arizona, 68.* https://www.researchgate.net/profile/Robert-Collier-6/publication/267844201_Quantifying_Heat_Stress_and_Its_Impact_on_Metabolism_and_Performance/links/547713770cf245eb43729c84/Quantifying-Heat-Stress-and-Its-Impact-on-Metabolism-and-Performance.pdf

De Rensis, F., Garcia-Ispierto, I., & López-Gatius, F. (2015). Seasonal heat stress: Clinical implications and hormone treatments for the fertility of dairy cows. *Theriogenology*, *84*(5), 659-666. https://doi.org/10.1016/j.theriogenology.2015.04.021

Domínguez-Hurtado, I. M., Moya-Álvarez, A. S., & Estrada-Moreno, A. (2010). Vigilancia agrometeorológica de condiciones ambientales para ganado vacuno. *Ingeniería Agrícola y Biosistemas*, *2*(1), 13-19. https://www.researchgate.net/profile/Alejandro-Estrada-Moreno/publication/266009777_vigilancia_agrometeorologica_de_condiciones_ambientales_para_ganado_vacuno/links/5422d2370cf238c6ea6d3375/vigilancia-agrometeorologica-de-condiciones-ambientales-para-ganado-vacuno.pdf

Enríquez Regalado, A. V., & Álvarez Adán, A. (2020). Caracterización del índice de temperatura y humedad y el estrés calórico en el ganado bovino de leche en dos lecherías en la provincia Mayabeque, Cuba. *Cuban Journal of Agricultural Science*, *54*(1), 11-18.

http://scielo.sld.cu/scielo.php?pid=S2079348020200001000011&script=sci_arttext&tlng=en

Espinoza, J., Ortega, R., Palacios, A., & Guillén, A. (2011). Tolerancia al calor y humedad atmosférica de diferentes grupos raciales de ganado bovino. *Revista MVZ Córdoba*, *16*(1), 2302-2309. https://dialnet.unirioja.es/servlet/articulo?codigo=3682264

Lucena, C. (2014). Efecto del estrés calórico sobre parámetros de la curva de lactancia de un rebaño lechero en el trópico. *Gaceta de Ciencias Veterinarias*, *19*(1), 11-16. http://www.ucla.edu.ve/dveterin/departamentos/CienciasBasicas/gcv/2530int2530er2530no/articulos/documasp/~umqk3d3r.pdf

Mader, T. L. (2003). Environmental stress in confined beef cattle. *Journal of animal science*, *81*(14_suppl_2), E110-E119. https://academic.oup.com/jas/article-abstract/81/14_suppl_2/E110/4789865

Nguyen, T. T., Bowman, P. J., Haile-Mariam, M., Pryce, J. E., & Hayes, B. J. (2016). Genomic selection for tolerance to heat stress in Australian dairy cattle. *Journal of Dairy Science*, *99*(4), 2849-2862. https://doi.org/10.3168/jds.2015-9685

Pragna, P., Archana, P. R., Aleena, J., Sejian, V., Krishnan, G., Bagath, M., Manimaran, A., Beena, V., Kurien, E. K., Varma, G., & Bhatta, R. (2017). Heat stress and dairy cow: Impact on both milk yield and composition. *International Journal of Diary Science*, *12*, 1-11. https://krishi.icar.gov.in/jspui/handle/123456789/27614

Ravagnolo, O., Misztal, I., & Hoogenboom, G. (2000). Genetic component of heat stress in dairy cattle, development of heat index function. *Journal of dairy science*, *83*(9), 2120-2125. https://doi.org/10.3168/jds.S0022-0302(00)75094-6

Vega, A. R., Almanza, A. M. A., & Abraham, T. I. P. (2014). Índice de temperatura humedad y el estrés calórico en el ganado bovino de leche en Güáimaro. *Revista Cubana de Meteorología*, *20*(1), 10-15. http://rcm.insmet.cu/index.php/rcm/article/view/159

Ruiz, L. F., Carcelén, F., & Sandoval-Monzón, R. (2019). Evaluación de los indicadores de estrés calórico en las principales localidades de lechería intensiva del departamento de Lima, Perú. *Revista de Investigaciones Veterinarias del Perú*, *30*(1), 88-98. http://dx.doi.org/10.15381/rivep.v30i1.15694

Ruiz-Jaramillo, J. I., Vargas-Leitón, B., Abarca-Monge, S., & Hidalgo, H. G. (2019). Efecto del estrés calórico sobre la producción del ganado lechero en Costa Rica. *Agronomía Mesoamericana*, *30*(3), 733-750. https://hdl.handle.net/10669/78939

Ruiz-García, L. F., Carcelén-Caceres, R., & Sandoval-Monzón, R. S. (2018). El índice temperatura-humedad máximo y la producción de leche de los establos en Lima-Perú. *Archivos de zootecnia*, *67*(257), 99-107. https://doi.org/10.21071/az.v67i257.3497

SAS (2013). User's Manual of Statistical Analysis System (SAS) (Version 9.4). Cary, NC.

Suárez Tronco, M., Rodríguez Castro, M., Cos Domínguez, Y., Lamothe Crespo, Y., Guerra Rojas, M., & Martínez Gutiérrez, M. (2020). Caracterización climática de la EPG “Manuel Fajardo” y su relación con las pruebas de comportamiento en ganado Criollo cubano. *Revista de Producción Animal*, *33*(1). https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3591

Suárez Tronco, Marco A., Rodríguez Castro, Manuel, Martínez Gutiérrez, Ma. Segunda., Guerra Rojas, & Ma. del Carmen. (2018). Valoración agrometeorológica de empresas pecuarias en Cuba. *Ciencia y Tecnología Ganadera*, *12*(2).

Tapkı, İ., & Şahin, A. (2006). Comparison of the thermoregulatory behaviours of low and high producing dairy cows in a hot environment. *Applied Animal Behaviour Science*, *99*(1-2), 1-11. https://doi.org/10.1016/j.applanim.2005.10.003

AUTHOR CONTRIBUTION

Conception and design of research: MAST, MRC, YLC analysis and interpretation of data: MAST, MRC, MCGR, MSMG; redaction of the manuscript: MAST, YLC.

CONFLICT OF INTERESTS

The authors declare the existence of no conflicts of interests.