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Genetics and Reproduction

Original

Climatic Characterization of Los Naranjos Genetic Project and Milk Production

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ABSTRACT

Background: The climatic conditions of tropical countries have a significant effect on milk production. **Aim.** To analyze the climatic conditions at Los Naranjos Genetic Project and their possible relation to milk production in 305 days. **Materials and methods:** The database of milk production consisting of 12 625 records from cows with parturition between 2002 and 2020 (7,711 animals) was studied. The monthly records of minimum temperature (Tmin), mean temperature (Tmean), and maximum temperature (Tmax) in ^{0}C were analyzed, along with the values of relative humidity (RH) measured in %. Then the temperature-humidity index (THI) was established, which was used to calculate the Accumulated Heat Load (AHL) three months before calving. Besides, heredity (h^2) and genetic correlations (gr) were estimated for the different AHLs. **Results:** The general means were PL305: 1 624.45 ± 360.40 (kg/lactation), THI 76.34± 18.70, and AHL 229.21± 128.5. Every source of variation in the study had a significant influence on milk production at 305 days. The h^2 varied between 0.25 and 0.38 and grs were positive and higher for the nearest AHL groups. **Conclusions:** There was an inverse relation between THI and AHL and milk production. The additive genetic variability for the different AHL groups and grs was positive, evidencing certain genetic variability for adaptation to climatic stress.

Keywords: temperature-humidity index, accumulated heat load, genetic parameters (*Source: AGROVOC*)

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INTRODUCTION

The temperature-humidity index (THI) is a useful tool to measure the productive and reproductive responses to climatic differences; it is calculated by using the environmental temperature and relative humidity, and it is used to determine heat stress, particularly in dairy animals (Mylostyvyi *et al*., 2020). HTI was used as a bioclimatic marker for the sum of external factors on animals to change the body temperature of the homeostatic set point. (Dikmen and Hansen, 2009). According to the classification made by Armstrong (1994), there is no heat stress when the temperature-humidity index is < 72, mild stress between 72 and 79, moderate stress between 80 and 89, and extreme stress that might cause death if ≥ 90. These studies indicated that different THI threshold values trigger stress in dairy animals. However, THI values higher than 72 are generally accepted as the beginning of heat stress (Liu *et al.*, 2019; Pinto *et al*., 2020).

In Latin America, the efforts to determine the impact of climatic variables on agriculture have targeted crops (Bouroncle *et al*., 2015), whereas there are fewer studies on livestock (García *et al*., 2015). Tropical areas are characterized by their exposure to greater sun radiation and humidity, so it is important to evaluate and monitor the impact of climatic variables on different dairy breeds, especially during prolonged periods.

The conditions of a changing climate are also influencing, as well as the increasing trends of mean temperature and relative humidity expected for the next 50-100 years, obtained from reference climatic settings in the country (Centella *et al.*, 2013; Bezanilla, 2016), according to the outputs of PRECIS System of Regional Climatic Modeling, forced by the global models of general circulation in the atmosphere (MCG) HadGEM from the Hadley Center (aenwh experiment). They showed the need to take management measures that revert or mitigate the effects of unfavorable heat settings on milk production.

Accordingly, the aim of this paper was to characterize the climate at the Los Naranjos project and set the link between climate changes and milk production (kg) at 305 of lactation.

MATERIALS AND METHODS

Data was collected from 12 625 milk production records from Siboney cattle (Cuba) at Los Naranjos Genetic Project, comprising cows that calved in the 2002-2020 period.

The animals were grazing in an almost clear area, with few trees, while they were confined in houses with limited ventilation at night. The cows mainly fed on grass and fodder.

The monthly air temperature records were used as follows: minimum (Tmin), mean (Tmean), and maximum (Tmax), in ^{0}C, whereas relative humidity was measured in %, using the data from the weather station at the genetic project. This information was used to set the temperature-humidity index (THI), based on the description of Ravagnolo, Mistzal, and Hoogenboom (2000).

ITH = 0.81*Ta + (RH/100) * (Ta – 14.4) + 46.4, where Ta is the mean air temperature measured in ^{0}C, and RH is the mean relative humidity expressed in %.

This indicator was used to estimate the accumulated heat load (AHL) withstood by the animal three months before calving (cm), the formula used was,

$$\mathbf{AHL_X = \sum_{cm=i}^{i=3} (THI)}$$

The climatic data of (THI) and AHL were included in the original database containing the production data.

(THI) and AHL were split into groups according to the following values:

THI	Group
=<70.00	1
70.01-75.00	2
75.01-78.00	3
78.01-80.00	4
>=80.01	5

AHL	Group
=<210.00	1
210.01-220.00	2
220.01-230.00	3
230.01-240.00	4
>=240.01	5

The statistical analysis was performed using PROC GLM (general linear model), SAS 9.4 (SAS 2013). The variation sources were calving month (CM), calving year (CY), temperature-humidity index (THI), accumulated heat load (AGL), and duration of lactation (DL) as linear covariable. Duncan correlation was used for multiple comparisons of means. The PROC CORR SAS (2013) procedure was used to estimate the Pearson linear correlations, while the regression equations were estimated under certain circumstances.

The model used was,

$$\mathbf{Yijklmn = \mu + CMi + CYj + THIk + AHLl + \beta m\,(X_{ijklm} - \underline{X}) + eijklm}$$

Where:

Yijklmn is the milk production comprising 244 and 305 days.

µ, the common general mean.

CMi is the effect of the calving month (i = 1,…..12)

CYj is the calving year since 2002-2020 (j= 1, 2, …,18)

THIk is the THI group number (k=1,2….5)

AHLl is the AHLl group number (l=1,2….5)

βm (Xijklm – X) is the linear regression of the duration of lactation in milk production.

eijklm is the residual or error ~N (0 and σ^2_e).

The genetic analysis included the animal model according to the multicharacter BLUP method, using software MTDFREML (Boldman *et al*., 1995), for milk production, which included the following fixed effects: age group (year-season) which varied according to AHL, lactation number, and the duration of lactation as a linear covariable. the random effects were animal and the residual or error.

The sample included 12 625 pedigrees from 7,711 animals with the following distribution of valid records and age groups according to the AHL group (Table 1).

Table 1. Distribution of genetic analysis information

AHL Groups	No records	Age groups
AHL1	470	8
AHL2	2 895	47
AHL3	2 710	38
AHL4	3 894	55
AHL5	2 656	56

RESULTS AND DISCUSSION

Table 2 shows the general statistics for the ranks studied.

Table 2. Arithmetic means ($\overline{X}$), standard deviation (SD), and variation coefficients (VC).

Characters	$\overline{X}$	SD	VC (%)
MP 305 (kg/lactation)	1624.45	360.40	34.70
THI	76.34	18.70	1.80
AHL	229.21	128.5	1.10

These results are lower than the ones reported by Ríos-Utrera *et al* (2015), with different crossing proportions (Simmental and Brown Swiss, at 1/2; 3/4 y 5/8), with reports of 765,68Kg in every lactation. Cabrera *et al*., (2013), in a study using data from three ranches in the state of Puebla, Mexico, found that 7/8 Brown Swiss x 1/8 Zebu cows produced more milk per lactation (2 441.75 ± 102.39 kg) than 7/8 Simmental x 1/8 Zebu cows (1 669.57 ± 83.29 kg).

THI valued at 76.34 is within the mild stress, according to Mader (2003), severe stress for De Rensis, García-Ispierto, and López-Gatius (2015) for beef animals. Suárez *et al*., (2021) reported THI = 77.78 in the 1980-2018 period, higher than the current study, and was within the mild classification. In some countries, this indicator has been used to alert farmers to the conditions threatening animal welfare and to evaluate cattle comfort (Vega *et al*., 2014).

AHL and THI are in group 3 according to this paper.

Table 3 shows all the significant variation sources. AHL was more significant than THI, whereas R^2 was not high, so other factors not included in the study influenced milk production. Conejo and Wing Ching (2020) found that the age of animals and duration of lactation affected this indicator.

Table 3 Results of the variance analysis for milk production at 305 days.

Variation sources	GL	Mean square	Significance
Calving month	11	4 794 760	***
Calving year	17	18 147 792	***
Duration of lactation	1	1 115 789 166	***
THI	4	592 230	*
AHL	4	744 078	**

R^2 = 36.72%. * (P<0.0001); ** (P<0.05); * (P<0.01).**

Figure 1, shows a 13.54 kg reduction by THI unit, and when THI>78 (group 4), there was a significant reduction in milk production caused by stress, and above 80, it was severe stress. Gómez (2017) found that when THI was higher than 72 (heat stress), there was a reduction in milk production, though there were no significant differences from heat-regulated animals. Similar results were reported by Ruiz *et al.*, (2019), with a similar reduction of production associated with a THI increase.

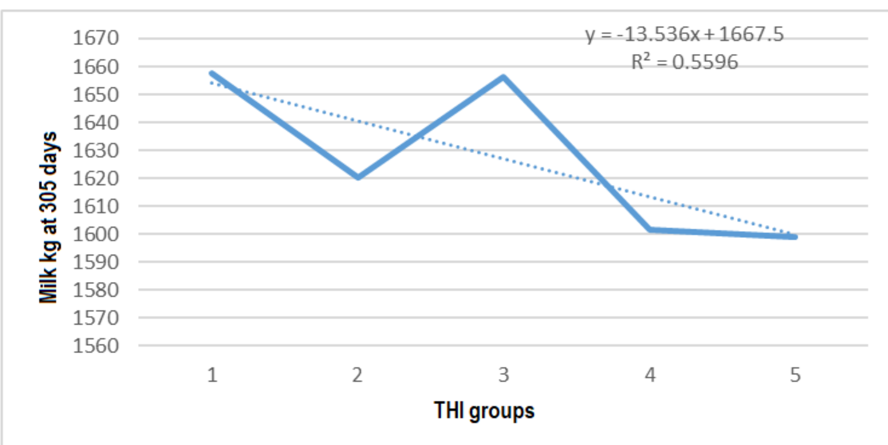

Figure 1. Behavior of milk production according to the (THI) group

Dairy animals suffer from heat stress (HS) when the effective temperature conditions move out of their comfort zone. The temperature and humidity indexes (THI) are commonly used to measure HS in dairy animals.

Figure 2 shows the behavior of milk production and AHL, with a linear link between AHL and MP305, with R^2 = 94.03%, and a 59.59 kg reduction by AHL increase unit, accounting for 3.7% of the mean. The fact that AHL (comprises 3 months) is a more comprehensive measurement method than THI, makes it a more appropriate way of evaluating milk production issues, which is shown in a much higher R^2.

Suárez *et al.*, (2022) found in Cuban cattle that the AHL index >=460 had a depressing effect on the weaning weight at a rate of -0.53 ± 0.12 kg per AHL unit, with a total effect of -18.7 kg on the WW, at the maximum level of heat stress compared to the results found in the tolerance zone.

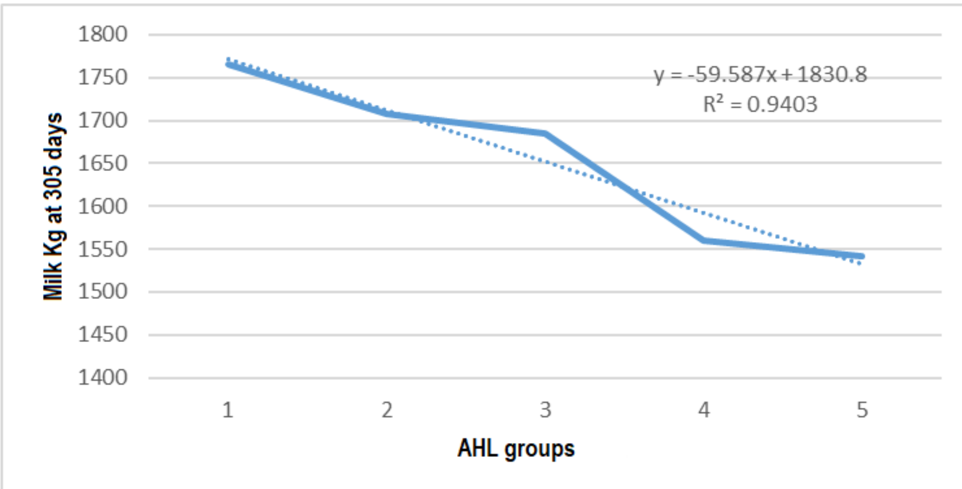

Figure 2. Behavior of milk production according to the AHL group

Figure 3 shows milk production according to AHL be months, and the polynomial regression, which was the one that adjusted best to the data, with R^2 =77.33%.

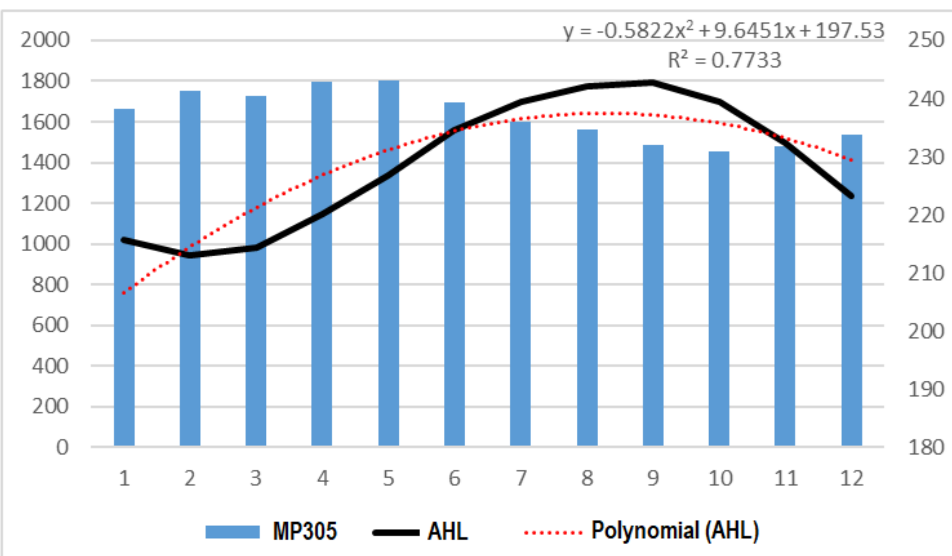

Figure 3. Behavior of milk production according to the AHL group

AGL underestimated MP between March and May, and overestimated it between July and October, coinciding with Cuellar *et al*., (2023), who found that when the animals calve in the warmest months there is a reduction in milk production observed in different breeds.

Table 4 shows the genetic parameters of milk production, according to the accumulated heat load, with heredity in the diagonal line, with the genetic correlations above, which are higher than the phenotypical ones shown in the triangle at the base.

Ansari Mahyari *et al.,* (2022) found that an increase in the temperature-humidity index to 72 units raised genetic variance for the two traits, with a heredity of 0.32 for milk production, and 0.24 concerning the fat percentage in milk.

Table 4 Genetic parameters of milk production according to the accumulated heat load

	AHL1	**AHL2**	**AHL3**	**AHL4**	**AHL5**
AHL1	**0.38±0.03**	0.66	0.75	0.71	0.88
AHL2	0.30	**0.25±0.03**	0.99	0.88	0.76
AHL3	0.40	0.35	**0.32±0.03**	0.91	0.94
AHL4	0.34	0.46	0.34	**0.25±0.03**	0.90
AHL5	0.45	0.46	0.94	0.94	**0.30±0.03**

Note: The standard errors for the genetic and phenotypical correlations varied between 0.03 and 0.05.

These results corroborate the fact of an existing additive variability in milk production, regardless of the climatic conditions. The genetic correlations were positive and varied between 0.66 and 0.99. The phenotypical correlations were also positive, but lower than the genetic ones. The cows with the lowest AHL showed genetic correlations below 0.90, compared to the other AHL groups, which may mean the animals exposed to better climatic conditions do not behave the same under different conditions. It was also noted that the genetic correlations between adjacent classes have a certain trend to show higher values (AHL2-AHL3; 0.99); (AHL3-AHL4, 0.94), and tend to be lower the farther they are, which could indicate the close AHL groups have a similar genetic behavior.

CONCLUSIONS

All the variation sources linked to milk production studied at 305 days were significant, including the climatic indicators THI and AHL, the THI sum for each animal three months before calving.

Milk production is depressed as THI or AHL rise. THI >75, or AHL>220 may produce low stress under the conditions studied.

There is added genetic variability for milk production, regardless of the climatic conditions. The cows exposed to the lowest AHL show production drops when AHL is higher, considering the additive genetic standpoint, which might show some predisposition to robust or plastic animals.

RECOMMENDATIONS

Different practices should be implemented to improve animal comfort seeking higher productivity. Increasing the number of trees to regulate air temperature, livestock agroforestation, and better animal housing, among other measures, are necessary for animal husbandry.

REFERENCES

Armstrong, D.V. (1994) Heat Stress Interaction with Shade and Cooling. *J. Dairy Sci*.,77(7), 2044– 2050. https://doi.org/10.3168/jds.S0022-0302(94)77149-6

Bezanilla, A. (2016). Generación de escenarios climáticos a futuro de alta resolución sobre Cuba, el Caribe y territorios adyacentes. Programa Nacional de Ciencias. Cambio climático en Cuba: Impactos, adaptación y mitigación. Multimedia. https://repositorio.geotech.cu

Ansari Mahyari, S., Hosseini, S.H., Mahin, M., Mahdavi A.H., & Mahnani. A. (2022). Análisis genético de las características de producción y reproducción de Isfahan Holstein vacas lecheras en condiciones de estrés calórico. *Revista iraní de ciencia animal Investigación*, 14(2), 67-281. http://doi: 10.22067/ijasr.2021.38245.0

Boldman, K., Kriese, L., Van Vleck, L., Van Tassel, C., & Kachman, S. (1995). A manual for use of MTDFREML. Lincoln, NE: United State Departament of Agriculture. **https://data.nal.usda.gov/dataset/mtdfreml**

Bouroncle C., Imbach P., Läderach P., Rodríguez B., Medellín C., Fung E., Martínez-Rodríguez MR., & Donatti C.I., (2015). La agricultura de Costa Rica y el cambio climático: ¿Dónde están las prioridades para la adaptación? Copenhague, Dinamarca: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).https://hdl.handle.net/10568/45941

Cabrera, N.A., Lammoglia, V.M.A., Daniel, R.I.C., & Elorza, M.P. (2013). Efecto del genotipo sobre la producción láctea en vacas Europeo Lechero × Cebú de doble propósito. *Rev. Científ. Biol. Agropec. Tuxpan* 1(1),52-58. https://doi.org/10.47808/revistabioagro.v1i1.215

Centella, A., & Bezanilla, A. (2013). Escenarios Climáticos.impactos del cambio climático y medidas de adaptación en Cuba. La Habana: Instituto de Meteorologia, CITMA. pp 99-115 https://ccc.insmet.cu

Conejo-Morales, J. F., & WingChing-Jones, R. (2020). Condiciones climáticas y la producción láctea del ganado jersey en dos pisos altitudinales. *Agronomía Mesoamericana*, 31(1), 157-176. http://www.revistas.ucr.ac.cr/index.php/agromeso

Cuellar Camila, J., Saleem, M., Jensen L.M., & Hansen P. J. (2023) Differences in body temperature regulation during heat stress and seasonal depression in milk yield between

Holstein, Brown Swiss, and crossbred cows. *J. Dairy Sci*.,106(5), 3625-3632 https://doi.org/10.3168/jds.2022-22725

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

Dikmen, S., & Hansen, P.J. (2009) Is the Temperature-Humidity Index the Best Indicator of Heat Stress in Lactating Dairy Cows in a Subtropical Environment? *J. Dairy Sci*., 92, 109– 116. https://doi.org/10.3168/jds.2008-1370

García, A.B., Angeli, N., Machado, de-Cardoso, L. F. & González, F. (2015). Relationships between heat stress and metabolic and milk parameters in dairy cows in southern Brazil. *Trop. Anim. Health Prod*. 47, 889-894. https://doi.org/10.1007/s11250-015-0804-9

Gómez Pataquiva, A. F. (2017). Influencia de los fenómenos climáticos sobre la producción y calidad composicional de la leche en sistemas de producción lechero en Colombia. Retrieved from https://ciencia.lasalle.edu.co/zootecnia/198

Mader, T. L. (2003). Environmental stress in confined beef cattle. *J. Anim. Sci*., 81 (14_suppl_2), E110-E119. https://academic.oup.com/jas/articleabstract/81/14_suppl_2/E110/4789865

Mylostyvyi R., Izhboldina O., Chernenko O., Khramkova O., Kapshuk N., & Hoffman G. (2020) Microclimate modeling in naturally ventilated dairy barns during the hot season: Checking the accuracy of forecasts *J Therm Biol*, 93. https://doi.org/10.1016/j.jtherbio.2020.102720

Liu J., Li L., Chen X., Lu Y., & Wang D. (2019) Effects of heat stress on body temperature, milk production, and reproduction in dairy cows: a novel idea for monitoring and evaluation of heat stress. A review Asia-Australas *J Anim Sci*. 32(9),1332-1339. https://doi: 10.5713/ajas.18.0743

Pinto S., Hoffmann G., Ammon C., & Amon T. (2020) Critical THI thresholds based on the physiological parameters of lactating dairy cows. *J Therm Biol*. 1. https://doi: 10.1016/j.jtherbio.2020.102523

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

Ríos-Utrera, Á., Hernández-Hernández, V.D., Amezcua-Manjarréz, E.V., & Zárate-Martínez, J.P. (2015). Milk yield of Simmental × Zebu and Brown Swiss × Zebu cows in tropical climate. *Agronomía Mesoamericana* 26,17-25. https://doi.org/10.15517/am.v26i1.16891

Ruiz – Jaramillo, J.I., Vargas-Leitón, B., Abarca-Monge, S., & Hidalgo H. (2019) Efecto del estrés calórico sobre la producción del ganado lechero en Costa Rica. *Agronomía Mesoamericana*, 30(3), 733-750 https://doi.org/10.15517/am.v30i3.35984

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

Suárez, M.A., Rodríguez, M., Cos, Y., Lamothe, Y., Guerra, M.C., & Martínez, M.S. (2021). Caracterización climática de la EPG " Manuel Fajardo" y su relación con las pruebas de comportamiento en ganado Criollo cubano. *Revista de Producción Animal* 31 (3), https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3591

Suárez, M.A., Rodríguez M., Coss Y., Mitat A., Ramos, F., & Menéndez-Buxadera, A. (2022). Importance of tolerance to climatic stress on weaning weight in Criollo cattle from Cuba. *Livestock Research for Rural Development* 34(7) https://lrrd.cipav.org.co/lrrd34/7/cont3407.html

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

AUTHOR CONTRIBUTION STATEMENT

Research conception and design: MCGR, MAST; data analysis and interpretation: MCGR, MAST, YLC; redaction of the manuscript: MCGR, MAST.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.