ABANICO VETERINARIO ISSN 2448-6132 abanicoveterinario@gmail.com
abanicoacademico.mx/revistasabanico/index.php/abanico-veterinario

Abanico Veterinario. January-December 2021; 11:1-14. http://dx.doi.org/10.21929/abavet2021.40
Original Article. Received: 05/07/2021. Accepted:08/10/2021. Published: 30/10/2021. Code: e2021-53.

Conformation traits associated with production and milk composition of Holstein cows

Características de conformación asociadas a producción y composición de la leche de vacas Holstein

Cortes-Hernández José*[1] ID, Ruíz-López Felipe[2] ID, García-Ruiz Adriana[2] ID**

[1]Programa de Maestría y Doctorado en Ciencias de la Producción y de la Salud Animal, Universidad Nacional Autónoma de México. Ciudad Universitaria, Delegación Coyoacán, C.P 04510. Ciudad de México, México. [2]Centro Nacional de Investigación Disciplinaria en Fisiología y Mejoramiento Animal, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias. Km. 1, Carretera a Colón, Col. Ajuchitlán Colón, C.P. 76280, Querétaro. México. *Responsible author: Cortes-Hernández José. **Author for correspondence: García-Ruiz Adriana. E-mail: jgch1992@hotmail.com, ruiz.felipe@inifap.gob.mx, garcia.adriana@inifap.gob.mx

ABSTRACT

The association between type conformation systems and milk (PL), fat (PG) and protein (PP) production was evaluated through the correlation between conformation traits (CC) and genetic value predictions for milk (HTPL), fat (HTPGK) and protein (HTPPK) of Holstein cattle, to determine the extent to which CC influence animal production. The study included 31,711 CC, 87,871 MP, 65,593 PG and 43,717 PP records. The CC were grouped into four general systems: structure and capacity (SEC), feet and hooves (SP), udder (SU) and haunch (SA). The effect of end point (FP) classes on MP, PG and PP levels was also evaluated through analysis of variance. HTPL had a correlation of 0.28 with SU, 0.17 with SA, 0.08 with SP and -0.05 with SEC (P<0.001). The correlations of HTPGK and HTPPK with the different systems were low, highlighting those found with SU, 0.15 and 0.21 (P<0.001), respectively. The phenotypic associations and correlations of genetic values reported in this study suggest that selection of cows by CC can modify milk, fat and protein production.

Keywords: phenotypic association, correlation between genetic values, conformation traits, milk, fat, protein.

RESUMEN

Se evaluó la asociación entre los sistemas de conformación de tipo y la producción de leche (PL), grasa (PG) y proteína (PP) a través de la correlación entre las características de conformación (CC) y las predicciones de valores genéticos para leche (HTPL), grasa (HTPGK) y proteína (HTPPK) de ganado Holstein, para determinar en qué medida las CC influyen en la producción de los animales. El estudio incluyó 31,711 registros de CC, 87,871 de PL, 65,593 de PG y 43,717 de PP. Las CC se agruparon en cuatro sistemas generales: estructura y capacidad (SEC), patas y pezuñas (SP), ubre (SU) y anca (SA). También se evaluó el efecto de las clases de puntos finales (PF) en los niveles de PL, PG y PP a través de un análisis de varianza. La HTPL tuvo una correlación de 0.28 con SU, 0.17 con SA, 0.08 con SP y -0.05 con SEC (P<0.001). Las correlaciones de HTPGK y HTPPK con los diferentes sistemas fueron bajas, destacando las encontradas con SU, 0.15 y 0.21 (P<0.001), respectivamente. Las asociaciones fenotípicas y las correlaciones de los valores genéticos reportadas en este estudio sugieren que la selección de vacas por CC puede modificar la producción de leche, grasa y proteína.

Palabras clave: Asociación fenotípica, Correlación entre valores genéticos, características de conformación, leche, grasa, proteína.

INTRODUCTION

The emphasis given until the 1970's to genetic breeding for milk production in Holstein cattle caused a decrease in the genetic progress rates of traits such as milk composition, reproductive, health and conformation aspects, which generated repercussions in the functionality of animals (Corrales *et al.,* 2012; De Vries, 2017; Van Raden *et al.,* 2021).
The advances achieved in statistical methodologies applied to genetic selection and the use of computational tools, have allowed the inclusion of new traits in genetic improvement programs (Misztal & Legarra, 2017). Some countries have developed sophisticated methodologies for the inclusion of traits with high economic value in selection indexes, while others have included a large number of traits in their evaluations, but all seeking a more efficient animal through the inclusion of traits that not only increase milk quantity (Miglior *et al.,* 2017), but also reduce milk production costs (Getu & Misganaw, 2015).

Conformation characteristics (CC) are morphological traits that determine the functional fitness of animals. Several studies have demonstrated their positive relationship with MP (Corrales *et al.,* 2012; Manafiazar *et al.*, 2015), suggesting that CCs can be used as early selection criteria to improve animal performance and increase animal production, longevity and health (Battagin *et al.,* 2013; Madrid & Echeverri, 2014).

Since the 1970s, work has been done in Mexico on the CC qualification of Holstein cattle, based on the system recommended by the World Holstein Friesian Federation (World Holstein Friesian Federation o WHFF; Valencia *et al.,* 2008). From CC evaluation, individual production information, milk composition and pedigree records, genetic values of numerous traits have been predicted that have allowed the identification of the most productive (Getu & Misganaw, 2015), functional animals by their CC and adapted to their needs (Zavadilová & Štípková, 2012). The aim of the present study was to evaluate the association between conformation systems and end point (FP) classes, with milk (MP), fat (PG) and protein (PP) production through Pearson's correlation between direct measurements (phenotypes) and genetic value predictions of Mexican Holstein cattle.

MATERIAL AND METHODS

The study included information from Holstein animals born from 1992 to 2010, which were in the production control system and in the conformation qualification program of the Holstein Association of Mexico (AHM). The information was collected in 94 herds located in Mexican Republic states of: Aguascalientes, Baja California Norte, Chihuahua, Coahuila, Estado de México, Guanajuato, Jalisco, Querétaro, Michoacán, Nayarit, Puebla, San Luis Potosí, Tlaxcala and Zacatecas. Phenotypic records were included for

87,871 lactations for milk production and 65,593 lactations for milk components (fat and protein) corresponding to 43,717 and 31,711 animals, respectively. Cumulative milk and milk component yields were obtained as the sum of yields of the first three lactations adjusted to 305 days and maturity equivalent (Toledo *et al.,* 2014). To avoid biases due to animal age, only animals that had the opportunity to reach the third lactation were included. Also, phenotypic information and predictors of genetic values of the following CC were included: height (STA), height at withers (ACRZ), angularity (AG), size (Siz), body depth (PROFD), loin strength (LOM), chest width (ANPE), haunch tip (PUNA), haunch width (ANCA), bone quality (CALHU), lateral view of hind feet (VLPT), rear view of hind feet (VPPT), hoof angle (ANPEZ), heel depth (PROTL), posterior teat position (POSPP), anterior teat position (POSPA), teat length (LONPE), udder depth (PU), anterior udder insertion (IAU), posterior udder insertion height (AIUP), mid suspensory ligament (LM), udder texture (TEX), posterior udder insertion width (ANIUP) and end points (FP). The description of each of the above characteristics is presented in Table 1, considering that only some of them have an objective qualification, with differences in centimeters and in others the qualification is subjective, so the qualifier must be certified by international breed organizations.

The CC were evaluated on a scale of 1 to 9 with the exception of FP which was evaluated on a scale of 70 to 89 points. The CC were grouped into four conformation systems by weighting the characteristics that were part of each of the systems by weights recommended by the WHFF (Madrid & Echeverri, 2014; De Jong, 2020) and used in the AHM. Finally, the impact of the systems on MP, PG and PP was evaluated. The systems studied were:

Udder system (SU)

$$SU = (PU * 0.16) + (TEX * 0.14) + (LM * 0.14) + (IAU * 0.18) + (POSPA * 0.07) + (LONPE * 0.02) + (AIUP * 0.12) + (AIUP * 0.10) + (POSPP * 0.07)$$

Foot and hoof system (SP)

$$SP = (ANPEZ * 0.18) + (PROTL * 0.22) + (CALHU * 0.12) + (VLPT * 0.17) + (VPPT * 0.31)$$

Structure and capacity system (SEC)

$$SEC = (STA * 0.12) + (ACRZ * 0.03) + (TAM\tilde{N} * 0.17) + (ANPE * 0.23) + (PROFD * 0.17) + (LOM * 0.28)$$

Haunch system (SA)

$$SA = (PUNA * 0.62) + (ANCA * 0.38)$$

Table 1 Conformation features evaluated

	Characteristic	Anatomical points of reference for qualification
1-	Size (SIZ)	It groups characteristics such as height at withers, height at haunch, angularity, body depth, chest width and loin strength
2-	Udder Texture (TEX)	Smooth, pliable, fleshy appearance, with sufficient irrigation and good conformation.
3-	Posterior teat position (POSPP)	Location of the rear teats in relation to the center of the quarter.
4-	Length of teats (LONPE)	Qualification of anterior teats, 1 centimeter equals one point, scale from 1 to 9 cm.
5-	Anterior teat position (POSPA)	Measures the position of the anterior teats with respect to the central axis of the quarter.
6-	Median suspensory ligament (LM)	Depth of the groove at the udder rear base.
7-	Udder depth (PU)	Distance between the lowest part of the udder and the height of the hocks. Every 3 cm of difference represents a point on the characteristic measurement scale, taking as reference the level at the hocks whose qualification is 3.
8-	Posterior udder insertion height (AIUP)	Distance between the vulva and the beginning of the udder. This value is related to the stature of the animal.
9-	Anterior udder insertion (AIU)	Location and strength with which the udder adheres to the abdominal wall.
10-	Angle of hoof (ANPEZ)	Angle formed between the front of the hoof and the floor of the right thoracic limb.
11-	Lateral view of hind feet (VLPT)	Angle formed at the front of the hocks.
12-	Rear view of hind feet (VPPT)	Direction adopted by the hind limbs seen from behind.
13-	Width of the haunch (ANCA)	Distance between the tips of the hind hip bones (ischium) 2 cm per point.
14-	Tip of the haunch (PUNA)	Difference in height measurement between ileum and ischium.
15-	Strength of the loin (LOM)	It should be straight with a slight backward slope and firm in appearance.
16-	Height at withers (ACRZ)	Exact measurement going from the ground on the foreleg to the withers of the animal; 1.35 m to 1.60 m, 3 points per cm.
17-	Body Depth (PROFD)	Distance between the spine and the navel at the level of the last rib, its reference point is optical.
18-	Angularity (AG)	Separation and angle of the ribs. The evaluation is based on three components, rib angle and rib opening (80%), bone quality (20%).
19-	Width of chest (ANPE)	Measurement between the front feet at their highest point. A reference scale of 13 to 29 centimeters is used, 2 cm per point.
20-	Stature (STA)	Exact measurement from the ground to the rump of the animal scale; 1.30 m to 1.54 m, 3 points per cm.
21-	Bone quality (CALHU)	Appearance of flat bones not too thick to give the animal a phenotypical appreciation of femininity.
22-	Hind udder insertion width (ANIUP)	Measure the width of the udder near the height of posterior insertion.
23-	Depth of the heel (PROTL)	Measure the distance from the heel to the ground based on the angle of the hoof, normally 45°.
24-	End points	Overall animal score, weighted according to the scores obtained per system. It has a scale of 79 to 89.

To study CC effect on production traits, four phenotypic classes were generated, taking as reference the FP value obtained in the conformation evaluation performed in the first lactation of each animal, following the recommendations of the WHFF, (2018). The classes were: regular (RE) with 74 points or less, good (G) between 75 and 79 points, better (B) between 80 and 84 points and very good (VG) with 85 points or more. To evaluate the effect of classes by CC on the permanence of animals in the barn, the average number of lactations per animal was analyzed. The effect of conformation evaluated as FP class on MP, PG, PP and number of lactations per animal (NLAC), was evaluated through an analysis of variance by measuring differences between least squares means with the GLM procedure using the SAS 9.3 statistical package (SAS Institute. 2019).

The predicted genetic values used in the study for different traits were obtained and provided by INIFAP and AHM (Ruíz *et al.,* 2020), the institution in charge of carrying out the evaluations of Holstein breed. To determine the phenotypic association of the CC with ML, PG and PP, as well as the association between their predicted genetic values (which in the case of production traits are the predicted transmission abilities for MP, PG and PP; HTPL, HTPGK and HTPPK respectively), Pearson's correlation coefficients were calculated (Wayne, 2017), using the SAS Institute (2019) program.

RESULTS AND DISCUSION

Phenotypic associations

The results obtained showed that more than 60 % of animals included in the study have a score equal to or higher than 80 FP, indicating that more than half of the population is in the top two conformation classes (B and VG). Table 2 shows that there is a statistical difference ($P<0.001$) between the FP classes over MP, PG, PP and NLAC, observing that increasing the FP class increases the production level in three characteristics studied (MP, PG and PP) and the NLAC.

VG animals had 0.26 more lactations than RE animals. This difference represents approximately 79 more days in lactation, which increases the total production of the animals and makes each animal more profitable. These results are reflected in the MP averages of the VG class animals, which had 21% more MP than the RE class. The results in the population under study, coincide with those reported in previous studies conducted in Holstein cattle in Colombia, where they showed that CC are positively correlated with milk production Madrid & Echeverri, 2014. Unlike productive traits, CC can be early selection tools in dairy cattle, since the qualification can be obtained at the beginning of the first lactation; in addition, it has been reported that these traits present positive genetic correlations with traits of economic interest, such as milk production, milk composition and udder health (Duru *et al.*, 2012).

Table 2. Least squares means and standard errors for milk, fat and protein production according to their end point classification

Type of endpoints	Milk records	Lactations	Milk production	Fat and protein records	Fat production	Protein production
RE	1,762	2.02±0.02[a]	21,231±253[a]	1,237	674±10.8[a]	548±10.7[a]
G	14,658	2.19±0.01[b]	23,509±88[b]	10,491	751±3.7[b]	625±3.7[b]
B	23,329	2.22±0.01[c]	24,180±69[c]	17,206	776±2.9[c]	664±2.9[c]
VG	3,968	2.28±0.01[d]	25,804±168[d]	2,777	827±7.2[d]	729±7.1[c]

RE: re, G: good, B: better, VG: very good.
Different superscripts in the same column indicate a significant statistical difference (P<0.001).

As for milk, for components (PG and PP), cows with the highest class (VG) had higher production (827 and 729 kg, respectively) although in the case of PP there was no significant difference (P<0.001) between B and VG cows. Results showed that animals in the lowest class (RE) had 22% lower PG and 33% lower PP compared to animals in the highest class (VG). These results corroborate the positive relationship between milk production and components with CC classification (Madrid & Echeverri, 2014) , and corroborate reports of positive genetic correlations (Zavadilová & Štĺpková, 2012) indicating that cows with better anatomical structure, tend to improve their physiological efficiency.

Correlations between conformation systems were moderate to low, highlighting the one between SU and SEC (0.40), between SU and SP (0.29) and, between SEC and SA (0.27) (Table 3).

The magnitude of these correlations shows the anatomical and functional dependence that exists between the systems and the possibility of being improved by selection on an individual basis; since, for example, VPPT and VLPT are related to haunch inclination and udder development and size are highly influenced by SIZ and STA, characteristics of SEC. Correlations between CC systems and productive traits were generally low, with only SP correlations standing out, which presented a correlation of 0.47 with PP and 0.38 with PG. Similar results have not been reported in other populations.

Table 3. Phenotypic (below the diagonal) and genetic value (above the diagonal) correlations between conformation systems with milk, fat and protein production

	System				Production		
	Udder	Feet and Hooves	Structure and Capacity	Haunch	Milk	Fat	Protein
Udder		0.53*	0.45*	0.13*	0.28*	0.15*	0.21*
Feet and Hooves	0.29*		0.47*	0.08*	0.08*	0.06*	0.08*
Structure and Capacity	0.40*	0.18*		0.30*	-0.05*	-0.01	-0.08
Haunch	0.08*	-0.03	0.27*		0.17*	0.08*	0.09*
Milk	0.07*	0.16*	0.02	0		0.69*	0.76*
Fat	0.11*	0.38*	0.01	-0.05*	0.64*		0.92*
Protein	0.11*	0.47*	0.02	-0.05*	0.63*	0.95*	

*Statistically significant correlations (P<0.001).

Correlations between genetic values

The correlation found between HTPL and HTPPK was high and positive (0.76), similar to that found with HTPGK (0.69), which means that cows with higher predicted genetic value for milk production tend to possess higher genetic value for total solids production (Madrid & Echeverri, 2014). Correlations found between conformation systems with HTPGK and HTPPK were mostly positive. SEC showed the lowest correlations with HTPL (-0.05), and no significance for HTPGK and HTPPK. The correlation between SU and HTPL was low and positive (0.28), being this the system most correlated with HTPL.

From all the SEC CC, the correlation found between STA and HTPL was the one with the highest value (0.21) (Table 4).

Table 4. Estimators of Pearson correlation coefficients between body and haunch conformation characteristics with predictors of genetic values for milk, fat and protein production

	Height	Height at withers	Size	Chest width	Depth	Loin	Point of haunch	Width of haunch
HTPL	0.21*	-0.07*	0.01	-0.06*	-0.12*	0.02	0.08*	0.18*
HTPGK	0.16*	-0.04*	0.08*	0.01	-0.05*	-0.00	0.04*	0.09*
HTPPK	0.17*	-0.07*	0.05*	-0.06*	-0.12*	-0.05*	0.07*	0.08*

HTPL: Prediction of genetic value for milk, HTPGK: Prediction of genetic value for fat, HTPPK: Prediction of genetic value for protein.
*Statistically significant correlations (P<0.001).

Although the estimates in this study were correlations between genetic values, they were similar to the genetic correlations reported in a population of primiparous Holstein cows in Turkey by Tapki & Ziya GÜZEY (2013), which was 0.24 but higher than that reported in

another population of the same breed in third calving cows in the same country which was 0.14 (Duru *et al.,* 2012), indicating that the height of animal influences milk production capacity. In barns, it is recommended to select animals with a score of 7 for STA, since these cows have the same capacity to produce milk as larger cows thus reducing the energetic cost of maintenance in these animals. The correlation found between PUNA and HTPL was low and positive (0.08), partially differing with other authors (Weller & Ezra, 2016) who reported negative and low values (-0.04). The correlation between ANCA and HTPL was higher (0.18) and similar to those reported in Turkish Holstein cattle (Duru *et al.,* 2012) where they reported a correlation of 0.19 between the same traits. ANCA determines the separation between the cow's hind feet that the further apart they are, the wider the hind udder will be, allowing it to store and produce a greater amount of milk (Getu & Misganaw, 2015). The correlations between ANCA with HTPGK and HTPPK were low and significantly different p<0.001 (0.09 and 0.08, respectively).
SU had a positive correlation with HTPL (0.28), a result indicating that cows with strong, large and well implanted udders produce higher milk quantity. From SU traits, PU had a low and negative correlation with HTPL (-0.05), (Table 5).

Table 5. Estimators of Pearson's correlation coefficients between udder conformation traits with predictors of genetic values for milk, fat and protein production

	Udder depth	Texture	Medial ligament	Anterior udder insertion	Anterior teat position	Teat length	Posterior udder insertion		Posterior teat position
							Height	Width	
HTPL	-0.05*	0.33*	0.40*	0.26*	0.35*	0.05*	0.33*	0.37*	0.47*
HTPGK	0.01	0.24*	0.29*	0.21*	0.24*	-0.05*	0.24*	0.24*	0.31*
HTPPK	0.02*	0.27*	0.34*	0.20*	0.29*	-0.07*	0.30*	0.31*	0.35*

HTPL: Prediction of genetic value for milk, HTPGK: Prediction of genetic value for fat, HTPPK: Prediction of genetic value for protein.
*Statistically significant correlations (P<0.001).

For the same traits, in Holstein cattle from Italy (Samoré *et al.,* 2010) reported negative genetic correlations (-0.37), but lower than those reported in Colombia (Corrales *et al.,* 2012) where they found a negative and high correlation (-0.72). The results show that, in these populations, cows with high milk production potential have a shallower udder depth, since animals with shallow udders have little amount of mammary tissue and therefore their production and storage capacity is limited (Piccardi *et al.,* 2012).

Similar to PU, LONPE presented a low genetic value correlation with HTPL (0.05 respectively; p<0.001). The rest of the SU traits showed a positive and moderate correlation with HTPL, highlighting the one between HTPL with POSPP (0.47) and LM (0.40) (Table 5). These results coincide with those reported in Colombia (Corrales *et al.,* 2012), a population in which a positive correlation between HTPL with AIUP and BF was found, because wide udders with high insertion are related to the amount of mammary tissue and greater milk storage capacity. The relationship between HTPL and POSPP may be largely due to the fact that animals with well positioned teats have greater ease of milking, therefore, they tend to produce more milk and at the same time may have a lower incidence of mammary gland diseases. Correlations between SU characteristics and HTPGK and HTPPK presented similar trends to those of HTPL, results that indicate that good udder conformation contributes to increased milk, fat and protein production capacity (Ptak *et al.,* 2011).

Several authors agree that cows with good locomotion tend to be high milk producers and remain in the herd longer than cows with poor scores for the leg system (Wasana *et al*., 2015). In this study, correlations of genetic values between SP and HTPGK, and HTPPK were low (0.06 and 0.08 respectively), similar to genetic correlations reported in a Holstein population from Italy (Battagin *et al.,* 2013), who found a correlation of 0.07 with HTPGK and 0.02 with HTPPK. The correlation of SP with HTPL was also low (0.08), different from that reported in the same population, in which they estimated a correlation of 0.24.
The individual SP traits that presented the highest correlation with HTPL were ANPEZ and CALHU (0.22 and 0.34, respectively), while these same CC presented a medium correlation with HTPGK and HTPPK (Table 6).

In Holstein cattle from Spain, Pérez-Cabal & Alenda (2006) reported a low positive genetic correlation of 0.12 between VPPT and HTPL, results that coincide with those reported in this study, in which a correlation of 0.16 was found. In UK Holstein cattle Ptak *et al.* (2011) suggested that feet and hooves are indirectly related to milk production, as cows with poor scores for ANPEZ, VLPT and VPPT show impaired longevity, production and fertility, as well as being traits related to repeat service at 56 days; suggesting that animals with good scores for feet may be less likely to repeat service, reducing days open (Wall *et al*., 2005). The importance of SP characteristics in production systems lies in the fact that cows have to move daily to be milked and if they do not have good strength and locomotion in the limbs, over time it can cause a deterioration in the productive life (Kern *et al.,* 2015).

Table 6. Estimators of Pearson's correlation coefficients between leg conformation and angularity traits with predictors of genetic values for milk, fat and protein production

	Hoof angle	Heel depth	Bone quality	Lateral view of hind feet	Rear view of hind feet	Angularity
HTPL	0.22*	0.16*	0.34*	0.12*	0.16*	0.34*
HTPGK	0.19*	0.17*	0.24*	0.06*	0.15*	0.27*
HTPPK	0.20*	0.17*	0.28*	0.08*	0.16*	0.30*

(P<0.001). HTPL: Prediction of genetic value for milk, HTPGK: Prediction of genetic value for fat, HTPPK: Prediction of genetic value for protein.
*Statistically significant correlations (P<0.001).

The correlation between AG and HTPL found in this study was positive (0.34) (Table 6), similar to that found in the Brazilian Holstein population (Campos *et al.,* 2015) where they reported a correlation (0.38). Similarly, in Turkish Holstein cows, Duru *et al.* (2012) reported a positive correlation of 0.21 for the same traits, while in Colombia, Corrales *et al.* (2012) reported a lower correlation (0.14). Although the methodology to find the relationship between traits was different, results in Mexico are similar to those presented in Italy in Brown Swiss cattle (Samoré *et al.,* 2010), with a correlation between AG and HTPL of 0.36. With the results found, it can be inferred that more angled cows tend to produce more milk, because animals with greater separation between ribs and greater angle have a better body capacity; in addition, animals tend to have flatter bones, an important aspect in the deposition and extraction of calcium during lactation (Carvajal-Hernández *et al.,* 2002).

CONCLUSIONS AND IMPLICATIONS

The results show that it is possible to use phenotypic data of conformation traits as early predictors of milk production in Holstein cattle, highlighting SU and SP traits; but it is advisable to take into account the other morphological traits. Obtaining genetic values and carrying out improvement programs will allow for more functional and profitable cows. The amount of protein and fat are also positively associated with some conformation traits, especially of the udder system, such as POSPP, LM and ANIUP. To determine the genetic relationship between CC with productive traits, it is necessary to perform bivariate analyses and determine the genetic correlations between the different traits, an aspect that can reinforce the results found in this study.

ACKNOWLEDGMENTS AND FUNDING SOURCE

Thanks to the Holstein Association of Mexico for the information provided.
This project was supporte by the National Center for Disciplinary Research in Animal Physiology and Improvement from the National Institute of Forestry, Agricultural and Livestock Research, under the name "Study of inbreeding and its effect on productive and reproductive traits in Holstein cattle." with SIGI number: 11513634465.

CITED LITERATURE

ASOCIACIÓN HOLSTEIN DE MÉXICO. 2021. Holstein de México, A.C. Sitio web: https://holstein.com.mx/

BATTAGIN M, Sartori C, Biffani S, Penasa M, Cassandro M. 2013. Genetic parameters for body condition score, locomotion, angularity, and production traits in Italian Holstein cattle. *Journal of Dairy Science*. 96(8):5344–5351. ISSN 0022-0302. https://doi.org/10.3168/jds.2012-6352

CAMPOS RV, Cobuci JA, Kern EL, Costa CN, McManus CM. 2015. Genetic parameters for linear type traits and milk, fat, and protein production in holstein cows in Brazil. *Asian-Australas J Anim Sci*. 28(4):476-84. PMID: 25656190; PMCID: PMC4341096. https://doi.org/10.5713/ajas.14.0288

CARVAJAL-HERNÁNDEZ M, Valencia-Heredia RE, Segura-Correa CJ. 2002. Duración de la lactancia y producción de leche de vacas Holstein en el Estado de Yucatán, México. *Revista Biomédica*. 13(1):25–31. https://doi.org/10.32776/revbiomed.v13i1.292

CORRALES J, Cerón-Muñoz M, Cañas J, Herrera C, Calvo S. 2012. Parámetros genéticos de características de tipo y producción en ganado Holstein del departamento de Antioquia. *MVZ Córdoba*. 17(1):2870–2877.
https://www.imbiomed.com.mx/articulo.php?id=83599

DE JONG G. 2020. Progress of type armonisation. v1.
http://www.whff.info/documentation/documents/WHFFprogressoftypeharmonisation2020.pdf

DE VRIES A. 2017. Economic trade-offs between genetic improvement and longevity in dairy cattle. PMID: 28215896. *Journal of Dairy Science.* 100(5):4184–4192. https://doi.org/10.3168/jds.2016-11847

DURU S, Kumlu S, Tuncel E. 2012. Estimation of variance components and genetic parameters for type traits and milk yield in Holstein cattle. *Turkish Journal of Veterinary and Animal Sciences.* 36(6):585–591. https://doi.org/10.3906/vet-1012-660

GETU A. Misganaw G. 2015. The Role of Conformational Traits on Dairy Cattle Production and Their Longevities. *Open Access Library Journal*. 2:1-9. https://doi.org/10.4236/oalib.1101342

KERN EL, Cobuci JA, Costa CN, McManus CM, Campos GS, Almeida TP. 2015. Genetic association between longevity and linear type traits of holstein cows. *Scientia Agricola.* 72(3):203–209. https://doi.org/10.1590/0103-9016-2014-0007

MADRID S, Echeverri J. 2014. Association between conformation traits and productive performance in Holstein cows in the department of Antioquia, Colombia. *Veterinaria y Zootecnia*. 8(1):35–47. ISSN 2011-5415. https://doi.org/10.17151/vetzo.2014.8.1.3

MANAFIAZAR G, Goonewardene L, Miglior F, Crews DH, Basarab JA, Okine E, Wang Z. 2015. Genetic and phenotypic correlations among feed efficiency, production and selected conformation traits in dairy cows. *Animal*. 10(3):381–389. PMID: 26549643. https://doi.org/10.1017/S1751731115002281

MIGLIOR F, Fleming A, Malchiodi F, Brito LF, Martin P, Baes CF. 2017. A 100-Year Review: Identification and genetic selection of economically important traits in dairy cattle. *Journal of Dairy Science*. 100(12):10251–10271. https://doi.org/10.3168/jds.2017-12968

MISZTAL I, Legarra A. 2017. Invited review: Efficient computation strategies in genomic selection. *Animal*. 11(5):731–736. https://doi.org/10.1017/S1751731116002366

JOSÉ MORO MJ, Ruiz LFJ. 1998. Mejoramiento genético de características de conformación en ganado Holstein*.* *Veterinaria México.* 29(4):385-398. https://www.medigraphic.com/cgi-bin/new/resumen.cgi?IDARTICULO=15539

PÉREZ-CABAL MA, García C, González-Recio O, Alenda R. 2006. Genetic and phenotypic relationships among locomotion type traits, profit, production, longevity, and fertility in Spanish dairy cows. *Journal of Dairy Science.* 89(5):1776–1783. PMID: 16606749. https://doi.org/10.3168/jds.S0022-0302(06)72246-9

PICCARDI M, Balzarini M, Bó GA, Funes AC. 2012. Asociación entre las características morfológicas y la producción de leche en vacas Holstein. *Revista Veterinaria.* 23(2):134–137. ISSN: 1668–4834. https://doi.org/10.30972/vet.2321793

PTAK E, Jagusiak W, Zarnecki A, Otwinowska-Mindur A. 2011. Heritabilities and genetic correlations of lactational and daily somatic cell score with conformation traits in Polish Holstein cattle. *Czech Journal of Animal Science.* 56(5):205–212. https://doi.org/10.17221/1432-cjas

Ruiz, L.F.J., García, R.A. Cortes H.J.G, 2020. ¿Qué Toro? Evaluación genética cuatrimestral de toros y vacas Holstein para producción, componentes y células somáticas de leche, longevidad y conformación. Estudio No 61, agosto 2020. INIFAP CENID FyMA. Querétaro, México. https://holstein.com.mx/servicios/evaluaciones-geneticas/#

SAMORÉ AB, Rizzi R, Rossoni A, Bagnato A. 2010. Genetic parameters for functional longevity, type traits, somatic cell scores, milk flow and production in the Italian Brown Swiss. *Italian Journal of Animal Science.* 9(2):145–152. ISSN: 1828-051X. https://doi.org/10.4081/ijas.2010.e28

SAS Institute. 2019. Statistical Analysis Software SAS/STAT®. Version 9.3, Cary, N.C., USA: SAS Institute Inc., ISBN: 978-1-60764-599-3. https://www.sas.com/es_mx/industry/life-sciences/solution/real-world-evidence.html

TAPKI I, Ziya GÜZEY M. 2013. Genetic and Phenotypic Correlations between Linear Type Traits and Milk Production Yields of Turkish Holstein Dairy Cows. *Green Journal of Agricultural Sciences.* 3(11):755–761. ISSN: 2276-7770. https://doi.org/10.15580/GJAS.2013.11.072913763

TOLEDO HO, Ruiz-López FJ, Vásquez CG, Berruecos JM, Elzo MA. 2014. Estimation of genetic parameters for milk production in Holstein cattle in Mexico under two modes of production control. *Revista Mexicana De Ciencias Pecuarias.* 5(4):443–457. ISSN 2448-6698. https://doi.org/10.22319/rmcp.v5i4.4016

VALENCIA M., Montaldo HH, Ruíz-Lopez FJ. 2008. Parámetros genéticos para características de conformación, habilidad de permanencia y producción de leche en ganado Holstein en México. *Técnica Pecuaria en México.* 46(3):235–248. ISSN: 0040-1889. https://doi.org/10.22319/rmcp.v46i3.1807

VAN RADEN PM, Cole J, Parker Gaddis KL. 2021. Net merit as a measure of lifetime profit: 2021 revision. *AIPL Research Reports.* e-353707. https://www.ars.usda.gov/research/publications/publication/?seqNo115=353707

WALL E, White IMS, Coffey MP, Brotherstone S. 2005. The relationship between fertility, rump angle, and selected type information in Holstein-Friesian cows. *Journal of Dairy Science*. 88(4):1521–1528. https://doi.org/10.3168/jds.S0022-0302(05)72821-6

WASANA N, Cho GH, Park SB, Kim SD, Choi JG, Park BH, Do CH. 2015. Genetic relationship of productive life, production and type traits of Korean Holsteins at early lactations. *Asian-Australasian Journal of Animal Sciences.* 28(9):1259–1265. PMID: 26194223. https://doi.org/10.5713/ajas.15.0034

WAYNE WD. 2017. Bioestadística: Base para el análisis de las ciencias de la salud. Limusa. 4th ed. Pp. 432-470. México. ISBN: 978-968-18-6164-3. https://www.academia.edu/17988752

WELLER JI, Ezra E. 2016. Genetic and phenotypic analysis of daily Israeli Holstein milk, fat, and protein production as determined by a real-time milk analyzer. *Journal of Dairy Science.* 99(12):9782–9795. https://doi.org/10.3168/jds.2016-11155

World Holstein Friesian Federation. 2018. World Holstein Friesian Federation. Sitio web. http://www.whff.info/index.php

ZAVADILOVÁ L, Štĺpková M. 2012. Genetic correlations between longevity and conformation traits in the Czech Holstein population. *Czech Journal of Animal Science.* 57(3):125–136. https://doi.org/10.17221/5566-cjas