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Characterization and genetic evaluation of Holstein cattle in Nariño, Colombia¤

Caracterización y evaluación genética del ganado Holstein en Nariño, Colombia

Avaliação e caracterização do gado Holandês, no departamento de Nariño, Colômbia

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Summary

Objective: to characterize and genetically evaluate the Holstein population located in the high tropics of Nariño province, Colombia, in order to propose an improvement program that meets the region's needs and conditions. **Methods:** first, values of heritability (h^2), repeatability (R), and genetic correlations (Γ) between milk production (PL), milk fat percentage (PG), milk protein percentaje (PP), open days (DIAB), number of services per conception (SPC), calving interval (IEP), and several shape or phenotypic variables were estimated. Historical information was collected from 296 farms between 1999 and 2006. Subsequently, the milk production control was conducted until 2010. An Animal Model was used to estimate the genetic parameters and genetic value. **Results:** a group of 22 males and 350 females was identified for the highest genetic values for productive and reproductive traits as well as anatomical conformation. **Conclusion:** intensive dissemination of this animal group to initiate the Holstein breeding improvement process in the dairy areas of Nariño was recommended.

Key words: *animal model, BLUP, genetic improvement, milk production.*

Resumen

Objetivo: caracterizar y evaluar genéticamente la población Holstein en el Trópico Alto de Nariño, para proponer un programa de mejoramiento acorde con las necesidades y condiciones de esta región. **Métodos:** primero se estimaron los valores de heredabilidad (h^2), repetibilidad (R), y correlaciones genéticas (Γ) entre las variables producción de leche (PL), porcentaje de grasa en leche (PG), porcentaje de proteína en leche (PP), días abiertos (DIAB), numero de servicios por concepción (SPC), intervalo entre partos (IEP), y algunas

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variables de conformación o tipo. La información histórica se recolectó en 296 fincas entre los años 1999 y 2006. Posteriormente se efectuó el control de producción hasta el año 2010. Para la estimación de los parámetros y del valor genético se utilizó un Modelo Animal. **Resultados:** se identificó un grupo de 22 machos y 350 hembras con los valores genéticos más altos para los rasgos productivos, reproductivos, y de conformación anatómica. **Conclusión:** se recomendó la difusión intensiva de este grupo de animales con el fin de iniciar el proceso de mejoramiento genético del ganado Holstein en la cuenca lechera de Nariño.

Palabras clave: *BLUP, mejoramiento genético, modelo animal, producción de leche*.

Resumo

Objetivo: caracterizar e avaliar geneticamente o gado Holandês no Trópico Alto de Nariño (Colômbia), com o intuito de propor um programa de melhoramento que esteja de acordo com as necessidades e condições da região. **Métodos:** estimaram-se os valores de herdabilidade (h^2), repetibilidade (R) e correlações genéticas (Γ) entre as variáveis: produção de leite (PL), percentagem de gordura (PG), percentagem de proteína (PP), dias abertos (DIAB), serviços por concepção (SPC), intervalo entre partos (IEP) e algumas características de avaliação lineal ou tipo. As informações históricas foram coletadas em 296 fazendas entre 1999 e 2006; após o controle de produção realizado até 2010. Para estimar os parâmetros e os valores genéticos, foi utilizado um modelo animal. **Resultados:** foi identificado um grupo composto por 22 machos e 350 fêmeas com maiores valores genéticos para as características de produção, reprodução e conformação anatômica. **Conclusão:** recomendou-se a divulgação intensiva desse grupo de animais com o objetivo de fazer um programa de melhoramento genético do gado Holandês na região leiteira de Nariño.

Palavras chave: *BLUP, melhoramento genético, modelo animal, produção de leite.*

Introduction

Milk production in the Nariño province is one of the most important regional economic activities, representing 23% of its GDP (Viloria, 2007). According to the classification established by the Cooperativa de Productos Lácteos de Nariño (Colácteos), the herds are concentrated in the Andean region where there are many non-mechanized farms, fairly technologically advanced farms, and a minority with high technological development. Holstein is the predominant cattle breed in this area.

Holstein was introduced to Nariño during the early twentieth century with the primary objective of increasing milk production, a trend that continues today. Throughout the decades, farmers have preferred to use semen imported mainly from the U.S., Canada, and Holland. However, due to the new demands of national and international markets, in recent years farmers have shown interest in modifying the genetic management of the herd to improve milk fat and protein content, as well as several anatomical features related to health and productivity. An evaluation process was conducted for this purpose.

The evaluation started with a general characterization of milk production systems, an estimation of genetic parameters for productive, reproductive, and anatomical variables, as well as identification of the animals with the highest genetic merit for traits of interest. Once this information was gathered, an intensive dissemination of high merit animals was proposed by using reproductive biotechnologies. To accomplish this, a selection process including clearly defined targets and objectives was initiated for the first time in the region. The process considers that animals should be selected in the same environment where they will develop their production process in order to minimize the effects of genotype-environment interactions.

Materials and methods

Location

The information was collected in 296 herds located in three dairy districts: Pasto, Pupiales, and Guachucal municipalities, from which 50, 133, and 113 farms, were studied, respectively (Figure 1). The life-zone of the studied region corresponds to a lower montane rain forest (bh - M) and sub-Andean drylands (p - SA) characterized by the presence of natural pastures and secondary forest (Evaluation of World-Wide Forestry Resources, 2000).

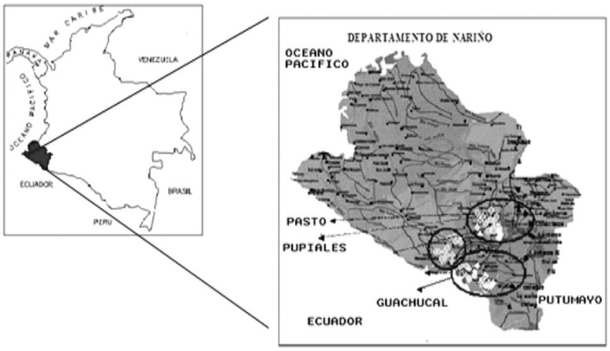

Figure 1. Map of the upper tropical dairy districts in the Nariño province.

Characterization of Production Systems

Variables considered for each farm were altitude above sea level (ASNM), total farm area (ATF), area devoted to livestock (ATG), rainfall (PV), temperature (T), solar brightness (BS), general characteristics of soils and grassland (CSYP), calves and heifers raising system (SCTYN), management of mature cows (MVA), milking system and its routine (SYRO), common diseases (EMF), and main culling reasons (PCD). The variables evaluated for the production process were milk production (PL, liters), milk fat percentage (PG), milk protein percentage (PP), calving interval (IEP), days open (DIAB), and number of services per conception (SPC). Due to their importance in the overall health of the animal and udder, linear classification traits included chest width (AP), udder depth (PDU), and suspensory ligament (LIS).

Sampling and Data Adjustments

Milk production data were adjusted to 305 days and to adult equivalent using the factors obtained by Ceron *et al.* (2003) and extending only lactations above 150 days. A total of 2,372 complete lactations were assessed, averaging 1.98 lactations per cow. A total of 7,846 animals were included in the pedigree file for all traits. The records were adjusted to adulthood in the model, obtaining results at the lowest estimation error.

The fat and protein production records were adjusted to 305 days and adult equivalent using the factors given by Schutz (2004). Milk samples were collected monthly from a single lactation using the procedures by ICAR (2009). Each sample of whole milk was evaluated in an industrial-type analyzer (EKOMILK). The values were compared in each district laboratory using the Gerber butyrometric method (BSI, 1955) for fat, and the Kjeldahl method (BSI, 1966) for protein.

Type Traits

The score for anatomical characteristics was assigned by expert Holstein judges. In total, 812 cows were classified and used for determining fat and protein content, assuming that suitable females would be selected from this group.

Linear Models of Genetic Evaluation

Case 1. Multi-trait analysis without permanent environmental effect, including three variables for each analysis.

The model was as follows

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} X_1 & 0 & 0 \\ 0 & X_2 & 0 \\ 0 & 0 & X_3 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 & 0 \\ 0 & Z_2 & 0 \\ 0 & 0 & Z_3 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix}$$

Where:

$\boldsymbol{y}_i$ = vector of observations for the *ith* trait, $\boldsymbol{\beta}_i$ = vector of fixed effects for the *ith* trait, $\boldsymbol{a}_i$ = vector of random effects of animal for the *ith* trait, $\boldsymbol{e}_i$ = vector of random residual effects for the *ith* trait, $\boldsymbol{X}_i$ and $\boldsymbol{Z}_i$ are incidence matrices relating the records of the *ith* trait with fixed and random effects, respectively.

The fixed effect for PL, PG, and PP was herd-year-season (HAE) and included only first lactation data previously adjusted to 305 days and adult equivalent. Adjusted records corresponded only to animals that did not fully lactate in the corresponding farm for reasons other than voluntary culling, or animals that did not finish lactation when the sum was done. Fixed effects for conformation traits were herd-year-classifier (HAC), and age at classification as a covariate. Fixed effects for reproductive traits were herd-year-season (HAE), and animal age as a covariate. Data solely corresponded to reproductive events occurring between the first and second parity.

It is assumed that

$$var\begin{bmatrix}a_1\\a_2\\a_3\end{bmatrix} = G = \begin{bmatrix}g_{11}A & g_{12}A & g_{13}A\\g_{21}A & g_{21}A & g_{23}A\\g_{31}A & g_{32}A & g_{33}A\end{bmatrix} = G_0 \otimes \mathrm{A}$$

Where:

g_{ij} = ij-th element of the G_0 matrix containing the variances and covariances for random effects of animal for each of the traits included in the analyses.

A = additive relationship matrix.

$\otimes$ = Kronecker product operator.

Also,

$$var\begin{bmatrix}e_1\\e_2\\e_3\end{bmatrix} = R = \begin{bmatrix}r_{11}I & r_{12}I & r_{13}I\\r_{21}I & r_{21}I & r_{23}I\\r_{31}I & r_{32}I & r_{33}I\end{bmatrix} = R_0 \otimes \mathrm{I}$$

Where:

r_{ij} = ij-th element of the R_0 variance and covariance matrix of residual effects for each of the traits included in the analyses.

I = identity matrix

Case 2. Multi-trait model with permanent environmental effect.

The model was as follows

$$\begin{bmatrix}y_1\\y_2\\y_3\end{bmatrix} = \begin{bmatrix}X_1 & 0 & 0\\0 & X_2 & 0\\0 & 0 & X_3\end{bmatrix}\begin{bmatrix}\beta_1\\\beta_2\\\beta_3\end{bmatrix} + \begin{bmatrix}Z_1 & 0 & 0\\0 & Z_2 & 0\\0 & 0 & Z_3\end{bmatrix}\begin{bmatrix}a_1\\a_2\\a_3\end{bmatrix} + \begin{bmatrix}W_1 & 0 & 0\\0 & W_2 & 0\\0 & 0 & W_3\end{bmatrix}\begin{bmatrix}p_1\\p_2\\p_3\end{bmatrix} + \begin{bmatrix}e_1\\e_2\\e_3\end{bmatrix}$$

Where:

$\boldsymbol{y}_i$ = vector of observations for the *ith* trait, $\boldsymbol{\beta}_i$ = vector of fixed effects for the *ith* feature, $\boldsymbol{a}_i$ = vector of animal random effects for the *ith* feature, $\boldsymbol{p}_i$ = vector of random permanent environmental and non-additive genetic effects, $\boldsymbol{e}_i$ = vector of random residual effects for the *ith* feature, $\boldsymbol{X}_i$, $\boldsymbol{Z}_i$ y $\boldsymbol{W}_i$ are incidence matrices relating the records of the *ith* trait with fixed, random, and permanent environment effects, respectively.

Fixed effects for PL were herd-year-season (HAE) and lactation. Adjustment of the records was done in the same manner described for case 1. For IEP, DIAB, and SPC, the effects were those specified for PL.

It is assumed that

$$var\begin{bmatrix}a_1\\a_2\\a_3\end{bmatrix} = G = \begin{bmatrix}g_{11}A & g_{12}A & g_{13}A\\g_{21}A & g_{21}A & g_{23}A\\g_{31}A & g_{32}A & g_{33}A\end{bmatrix} = G_0 \otimes \mathrm{A}$$

Where:

g_{ij} = ij-th element of the G_0 matrix containing variances and covariances for random effects of animal for each trait included in the analyses.

A = additive relationship matrix.

$\otimes$ = Kronecker product operator.

Also,

$$var\begin{bmatrix}p_1\\p_2\\p_3\end{bmatrix} = P = \begin{bmatrix}p_{11}I & p_{12}I & p_{13}I\\p_{21}I & p_{21}I & p_{23}I\\p_{31}I & p_{32}I & p_{33}I\end{bmatrix} = P_0 \otimes \mathrm{I}$$

$$var\begin{bmatrix}e_1\\e_2\\e_3\end{bmatrix} = R = \begin{bmatrix}r_{11}I & r_{12}I & r_{13}I\\r_{21}I & r_{21}I & r_{23}I\\r_{31}I & r_{32}I & r_{33}I\end{bmatrix} = R_0 \otimes \mathrm{I}$$

Where:

p_{ij} = ij-th element of the P_0 variances and covariances matrix for the random effects of permanent environmental and non-additive genetic included in the analyses.

P = permanent environmental matrix

r_{ij} = ij-th element of the R_0 variances and covariances matrix of residual effects for each of the traits included in the analyses.

I = identity matrix.

The (co) variance components in each model were obtained with the ASREML (VSN International, 2009) and MTDFREML (Boldman *et al.,* 1993) software. The significance of fixed effects was previously established with the GLM procedure of SAS (SAS, 2009).

Estimation of Breeding Value

Assessment models for this purpose were exactly the same used in the calculation of the (co) variance components, obtaining the breeding value of each individual, with the corresponding reliability and standard error.

Results

Characterization of the Milk Production Systems

As shown in table 1, the average ASNM is above 3,000 m with frequent occurrence of frost, which creates complexity for this region's dairy herds. Ideally, the land at this altitude should be devoted exclusively to the preservation of ecosystems rather than agriculture or livestock.

Table 1. General characteristics of milk production systems in the Nariño high tropics.

Variable	Mean	St. Dev.	Percentile 5	Percentile 25	Percentile 50	Percentile 75	Percentile 95
ASNM	3,079.99	159.31	2,800	3,040.0	3,100	3,156	3,300
ATF (ha)	25.75	27.91	3.00	6.00	16.00	34.00	79.00
ATG (ha)	22.19	24.03	3.00	6.00	14.00	30.00	62.00

ASNM: height above sea level; ATF: total farm area; ATG: area devoted to livestock.

These results confirm the smallholder nature of the region, where many farmers earn their income from very small areas exclusively devoted to cattle and few producers use more than 14 ha devoted to this activity. Therefore, the need to transfer appropriate technologies for these production systems seeking to improve the income of smallholder farmers is urgent, thereby contributing to the region's social stability.

Soil and grassland. Soils in the area are acidic, deep, moderately coarse textured, imperfectly drained, with low moisture retention, high organic matter content, and low to moderate fertility (IGAC, 1999). Most of the region is dominated by moderately broken and undulating terrain surfaces, although farms in the Guachucal district have mostly flat surfaces. In general, forages are deficient in protein, energy, calcium, and zinc, and possess excess potassium (Colácteos, 2009).

Productive and reproductive variables. Table 2 shows the principle PL statistics.

Table 2. Milk production (L) of Holstein cattle in the Nariño high tropics, adjusted to 305 days and adult equivalent.

Lactation (Lac)	N	Mean	St. Dev.	Percentile 5	Percentile 25	Percentile 50	Percentile 75	Percentile 95
1	736	4,220.95	495.58	3,449.00	3,813.00	4,251.00	4,669.00	4,943.00
2	652	4,133.61	535.62	3,233.00	3,682.00	4,200.00	4,561.00	4,927.00
3	442	4,058.72	582.62	3,127.00	3,526.00	4,079.00	4,522.00	4,934.00
≥ 4	542	4,116.92	551.07	3,274.00	3,648.00	4,134.00	4,578.00	4,937.00
TOTAL	4,132.55							

The average PL was 13 l / cow / day, which is lower than the national average reported for this breed and other Colombian provinces such as Antioquia, Valle, and Cundinamarca (Restrepo *et al.,* 2008; Ceron *et al*., 2001). Similarly, this breed has higher production levels in Venezuela, Mexico, and the United States than those calculated in this study (Valle, 1995; Palacios *et al*., 2001; Heins *et al*., 2006). Therefore, it is necessary to improve this trait in the selection process proposed for the area.

Protein and fat percentages (Table 3) are below the Argentine and Venezuelan national averages (Quijano, 2007; Vera *et al.,* 2008; Valle, 1996) and are similar to those of the U.S. (Powell, 2003). These results may be partially explained by the preferential use of U.S. sperm in most technologically advanced areas of the region. This reaffirms the need to reorient the selection process in order to improve both traits, which are closely linked with compositional quality, industrial performance, and increased income from milk sales.

Table 3. Milk fat and protein of Holstein cattle in the Nariño high tropics.

N	Variable	Mean	St. Dev.	Percentile 5	Percentile 25	Percentile 50	Percentile 75	Percentile 95
695	PP	3.02	0.10	2.90	3.00	3.00	3.04	3.28
	PG	3.61	0.42	2.90	3.29	3.55	3.94	3.94

PP: percent protein; PG: percent fat.

Calving interval (IEP), open days (DIAB), and services per conception (SPC) are the most important variables related to fertility and reproduction, as reported in table 4.

Table 4. Descriptive statistics for reproductive traits in Holstein breed in the Nariño high tropics.

N	Variable	Mean	St. Dev.	Percentile 5	Percentile 25	Percentile 50	Percentile 75	Percentile 95
7172	IEP	444.5	96.2	335.0	368.0	418.0	499.0	649.0
	DIAB	166.3	94.5	60.0	90.0	139.0	220.0	367.0
	SPC	2.7	2.0	1.0	1.0	2.0	4.0	7.0

IEP: calving interval; DIAB: days open; SPC: services per conception

These results are higher than the ideal for an optimum process, reflecting the prevalence of reproductive problems. The IEP is greater than that indicated by Fedegan (2007) for Colombian regions with similar production conditions, and is also higher than countries such as Costa Rica and Canada (Cedeño and Vargas, 2004; Raheja *et al.,* 1987). The DIAB average is higher than that in Colombia, Costa Rica, and the U.S. (Quijano and Montoya, 2000; Godinez and Soto, 1995; Heins *et al*., 2006). The SPC results are consistent with reports by Morante and Trejo (2003) in Honduras and by Alvarez *et al*. (1982) in Mexico.

Genetic Parameters

Heritability (h^2) and repeatability (R) of productive and reproductive variables. Table 5 presents heritability and repeatability results for productive and reproductive variables with the corresponding standard error for each.

Table 5. Heritability (h^2) and repeatability (R) for productive and reproductive variables in Holstein cattle in the Nariño high tropics.

Characterístic	Heritability (h^2)	Repeatability (R)
PG	0.16±0.0031	-
PP	0.15±0.0003	-
PL	0.24±0.0033	0.31±0.0029
DIAB	0.02±0.0041	0.05±0.0039
SPC	0.02±0.0043	0.08±0.006
IEP	0.04±0.005	0.06±0.007
LIS	0.39±0.004	-
PDU	0.15±0.0039	-
AP	0.33±0.0041	-

PG: fat percentage; PP: protein percentage; PL: milk production; DIAB: days open; SPC: services per conception; IEP: calving interval; LIS: suspensory ligament; PDU: udder depth; AP: chest width.

The PL heritability calculated in this study is similar to that reported by Kaya *et al*. (2003) in western Turkey farms, higher than that observed by Bilal *et al*. (2008) in Pakistan, and lower than those reported in Colombia by Ceron *et al*. (2001) in their study on four specialized dairy regions: Cundinamarca, Valle del Cauca, Antioquia, and Nariño. This variation can be attributed to the influence of several factors, including sample size and environmental variations between study locations, implying that it is advisable to estimate genetic parameters in each environment and conduct recalculations as the selection process develops.

In general, heritability for PP and PG is lower than that calculated in other Colombian regions and abroad, a fact explained by the sample size and the difficulties of building the pedigree due to lack of information on the parents in many farms of this region. It is also important to simultaneously consider both environmental and genetic aspects because phenotype is the result of the joint action of genes and the environment, where environment is understood as all nonhereditary factors.

The heritability values for reproductive variables confirm the weak influence of the additive effect of genes on these traits, coinciding with the results obtained by different researchers such as Price *et al.* (2001), Veerkamp *et al.* (2001), and Restrepo *et al*. (2008), so it is not appropriate to attempt to improve these traits by selection.

Genetic correlations between productive, reproductive, and conformation or type variables. Table 6 shows the genetic correlations values estimated in this study for productive and reproductive variables. Only genetic correlations are included due to their great significance for breeding programs.

Standard error of genetic correlations between production traits ranged between 0.0032 and 0.0038. These errors ranged between 0.0037 and 0.005 for production and conformation characteristics. The highest values were observed between productive and reproductive traits, fluctuating from 0.004 to 0.005. These results indicate a negative correlation between milk production and fat and protein percentages, which concurs with the majority of literature reports (Ochoa, 1991; Welper and Freeman, 1992; Spelman and Garrick, 1997). Regarding the association of reproductive traits and milk production, a negative correlation between them was observed. These results are similar to those calculated by Restrepo *et al*. (2008) and Philipsson *et al*. (1994). Additionally, reports by Caraviello *et al*. (2004) and Sewalem *et al*. (2004) proved low genetic influence of reproduction on production traits. Therefore, their improvement should be carried out through nutritional and management strategies, as well as by identifying gene actions other than the additive ones. On the other hand, the high standard errors found in these correlations do not ensure that a genetic association between milk production and reproductive variables exists.

Discussion

According to these results, specialized milk production systems in the Nariño high tropics develop mainly on small farms (22.19 has average), confirming the smallholder nature of a region with unique environmental conditions in the Colombian territory. This reality requires the generation of technological developments in accordance with the aforementioned characteristics.

Table 6. Genetic correlations in Holstein cattle in the Nariño high tropics.

Característica	PL	PG	PP	PDU	LIS	AP	IEP	DIAB	SPC
PL	1.0	-0.273	-0.34	0.02	0.10	0.13	-0.056	-0.06	-0.04
PG	simétrica	1.0	0.56	0.08	0.13	0.14	-0.0034	-0.0026	-0.0005
PP			1.0	0.046	0.04	0.10	-0.0082	-0.0064	-0.0005
PDU				1.0	0.18	0.22	-0.01	-0.007	-0.012
LIS					1.0	0.27	-0.033	-0.006	-0.0076
AP						1.0	-0.09	-0.0056	-0.0043
IEP							1.0		
DIAB								1.0	
SPC									1.0

PL: milk production; PG: fat percentage; PP: protein percentage; PDU: udder depth; LIS: suspensory ligament; AP: chest width; IEP: calving interval; DIAB: days open; SPC: number of services per conception.

Average productions, as well as fat and milk protein percentages, are below national and international data. There is also low reproductive efficiency, with long calving intervals and a high number of services per conception. This scenario reveals the need to comprehensively review the production processes, emphasizing the selection of animals best suited to the region's conditions. It should be considered that the Holstein breed was introduced to the area a century ago, but had not been evaluated or selected, thus losing the adaptive advantages of many animals that were discarded for breeding. Parallel to the selection program for breeding purposes, it is urgent to design and implement plans for a more efficient reproductive management. These plans should include heat detection, effective artificial insemination practice, and veterinary follow-ups for the early detection and monitoring of reproductive diseases, nutritional management, and implementation of corrective measures. These practices would help to improve productivity and profitability of the herds.

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