Effect of breed, parity number, and location on productive and reproductive parameters of dairy cattle

Efecto de la raza, el número de parto y la localización sobre los parámetros productivos y reproductivos del ganado lechero

Efeito da raça, número de paridade e localização nos parâmetros produtivos e reprodutivos em bovinos leiteiros

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Abstract

Background: Productive and reproductive parameters of dairy cattle in the high tropics are affected by various factors related to management, but also by specific factors such as breed, calving, and herd location. **Objective:** To analyze the effects of breed, calving, and location on herd efficiency by assessing productive and reproductive information from dairy herds in Antioquia province (Colombia). **Methods:** Productive and reproductive information from 5,440 records of cows between 1 and 11 calvings and various breeds and crosses was obtained. The animals belonged to 57 herds from 16 municipalities in three dairy regions of Antioquia province: North-N, East-E, and Valle de Aburrá-V. The variables analyzed were milk production adjusted to 305 days (PLa), kilograms of protein per lactation (KgPRO), kilograms of fat per lactation (KgF), somatic cell score (SCS), number of services per conception (S/C), days open (DO), and calving interval (CI). The independent variables were associated with the parameters through a generalized linear model (GLM). **Results:** The total PLa average was 5,492.6 (±1,027.2) kg/lactation. The values were 177.1 (±29.5) and 215.1 (±37.1) kg/lactation for KgPROa and KgFa, respectively. For SCS, an average value of 3.62 (±1.6) was found. Reproductive parameters were 2.02 (±1.4), 385.7 (±52.8) days, and 110.9 (±55.4) days for S/C, CI, and DO, respectively. Ayrshire × Holstein cows from region V, presented low PLa (58%). Holstein cows in their third parturition presented low PLa (31%), somewhat similar to the decrease in PLa of Ayrshire in second calving (56%). Furthermore, decreased milk production was observed in Angus × Holstein cows (46% less PLa) and in Brown Swiss in region V, with 41% less milk per lactation. The KgFa data decreased when compared to the general average, with values of

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172.9±24.7 kg for Holstein, 132.5±46.2 kg for Ayrshire × Holstein in E region, and 102.2±26.5 kg in Ayrshire × Jersey cows. The longest CI was significantly ($p<0.05$) associated with the third parity and with the Holstein breed (37% increase) and with BON × Holstein crosses (57% increase). **Conclusions:** Productive and reproductive parameters are variable, and multiple interacting independent variables –such as breed, parity and location- lead to decrease or increase in the studied parameters.

Keywords: *calving order; cattle; cows; dairy; herd; milk production; milk yield; parity; records; yield.*

Resumen

Antecedentes: Tanto los parámetros productivos como reproductivos del ganado lechero en el trópico alto pueden verse afectados por diversos factores relacionados con el manejo, pero también por factores específicos como raza, número de parto y ubicación del hato. **Objetivo:** Evaluar la información productiva y reproductiva de hatos lecheros en el departamento de Antioquia (Colombia) para analizar los efectos de raza, parto y ubicación sobre la eficiencia del hato. **Métodos:** Se obtuvo información productiva y reproductiva de 5.440 registros de vacas de varias razas y cruces entre 1 y 11 partos. Los animales pertenecían a 57 hatos de 16 municipios del Departamento de Antioquia en tres regiones lecheras: Norte-N, Oriente-O, y Valle de Aburrá-V. Las variables analizadas fueron: producción de leche ajustada a 305 días (PLa), kilogramos de proteína por lactancia (KgPRO), kilogramos de grasa por lactancia (KgF), conteo de células somáticas (SCS), número de servicios por concepción (S/C), días abiertos (DO), e intervalo entre partos (CI). Las variables independientes se asociaron a los parámetros arriba mencionados mediante un modelo lineal generalizado (GLM). **Resultados:** El PLa promedio fue de 5.492,6 (±1.027,2) kg/lactancia. Para KgPROa y KgFa se encontraron valores de 177,1 (±29,5) y 215,1 (±37,1) kg/lactación, respectivamente. Para SCS se encontró un valor de 3,62 (±1,6). Los resultados de los parámetros reproductivos fueron: S/C de 2,02 (±1,4), CI de 385,7 (±52,8) días, y para DO fue 110,9 (±55,4) días. Los cruces Ayrshire x Holstein -ubicados en la región V- presentaron menor PLa (58%). Las vacas Holstein presentaron menor PLa (31%) en su tercera lactancia, y las Ayrshire disminución de PLa en su segunda lactancia (56%). Similarmente, se observó disminución en vacas Angus × Holstein (46% menos de PLa) y en las Pardo Suizo en la región V, que producen 41% menos de leche por lactancia. Los KgFa disminuyeron al comparar con el promedio general, con valores de 172,9±24,7 kg para las Holstein, 132,5±46,2 kg en vacas cruzadas de Ayrshire × Holstein en la región O, y 102,2±26,5 kg en cruces Ayrshire × Jersey. El CI más extenso se asoció significativamente ($p<0,05$) con el tercer parto de la raza Holstein (37% de incremento) y con el cruce BON × Holstein (57% de incremento). **Conclusiones:** Los parámetros productivos y reproductivos son variables y existen múltiples variables independientes –tales como raza, número de parto y localización geográfica, que al interactuar conducen a una disminución o aumento de los parámetros de interés.

Palabras clave: *ganado; hato; lácteos; producción de leche; orden de parto; parto; rendimiento; vacas.*

Resumo

Antecedentes: Os parâmetros produtivos e reprodutivos do gado leiteiro nos trópicos podem ser afetados por vários fatores relacionados ao manejo, mas também por fatores específicos, como raça, parto e localização do rebanho. **Objetivo:** Amostra dados produtivos e reprodutivos de rebanhos leiteiros especializados em Departamento de Antioquia (Colômbia), a fim de analisar os efeitos da raça, parto e localização na eficiência de rebanhos leiteiros. **Métodos:** Informações produtivas e reprodutivas foram obtidas de 5.440 registros de vacas de várias raças e cruzamentos que tiveram entre 1 e 11 partos. Os animais pertenciam a 57 rebanhos de 16 municípios do Departamento de Antioquia em três regiões (Norte-N, Leste-L e Valle de Aburrá-V) dedicados à produção de leite. As variáveis analisadas foram produção de leite ajustada para 305 dias (PLa), quilos de proteína por lactação (KgPRO), quilos de gordura por lactação (KgF); escore de células somáticas (SCS), número de serviços por concepção (S/C), média de dias abertos (DO) e intervalo entre partos em dias (CI). As variáveis independentes coletadas em campo foram associadas aos parâmetros supracitados por meio de um modelo linear generalizado (GLM). **Resultados:** O Pla médio foi de 5.492,6 (±1.027,2) kg/lactação, para KgPROa e KgFa foram encontrados valores de 177,1 (±29,5) e 215,1 (±37,1) kg/lactação, respectivamente; para SCS foi encontrado um valor médio de 3,62 (±1,6). Os resultados dos parâmetros reprodutivos foram: S/C de 2,02 (±1,4), CI de 385,7 (±52,8) dias e para DO foi de 110,9 (±55,4) dias. Os cruzamentos Ayrshire × Holstein, que se localizam na região V, apresentaram menor PLa (58%); as vacas holandesas na terceira lactação apresentaram menor PLa (31%), algo semelhante à queda da PLa Ayrshire no segundo parto (56%), semelhante ao observado nas vacas cruzadas com Angus × Holandesa (46% menos PLa) e na raça Pardo Suica na região V, pois produz 41% menos leite por lactação. Os dados de KgFa diminuíram quando comparados com a média geral com valores de 172,9±24,7 kg para a raça Holandesa, 132,5±46,2 kg nos mestiços Ayrshire × Holandês na região L e 102,2±26,5 kg nos cruzamentos Ayrshire × Jersey. O CI mais longo foi significativamente ($p<0,05$) associado ao terceiro parto e à raça Holandesa (aumento de 37%) e ao cruzamento BON × Holandês (aumento de 57%). **Conclusões:** Os resultados obtidos nas vacas leiteiras especializadas das três regiões em estudo permitem observar claramente que os parâmetros produtivos e reprodutivos são variáveis e existem múltiplas variáveis independentes –como raça, número de parto e localização, que ao interagir levam a uma diminuição ou aumento nos parâmetros de interesse.

Palavras-chave: *colheita; gado; laticínios; leite; ordem de parto; parto; produção de leite; rebanho; vacas.*

Introduction

Antioquia province has the highest bovine inventory in Colombia (South America), with 11.3% of the total (ICA, 2021), which shows the importance of this activity for the economy of the region, where dairy farms represent 22.3% of all cattle farms. This province has become one of the main milk-producing regions in the country, with 19% of the national production, generating 3,551,183 liters per day in 1,356 dairy farms registered (Secretaría de Agricultura y Desarrollo Rural, 2019). Around 50% of this production is obtained in dairy farms mostly located in the East, North, and Valle de Aburrá, where milk price paid to farmers depends on milk composition, including protein and fat content and somatic cells score (Ministerio de Agricultura y Desarrollo Rural, 2020).

It is known that profitability of dairy herds is greatly affected by productive and reproductive performance of cows. The economic losses due to reproductive issues are mainly attributed to prolonged calving interval (CI), greater number of services per conception (S/C), which increase insemination costs, decrease the number of calves per cow per year, and leads to high discard of animals, high replacement costs, and short productive life of cows (Camargo 2012; Chegini *et al.*, 2019). Thus, characterizing basic productive and reproductive parameters in the main dairy regions of Antioquia would set a basis for further studies on farm productivity. Accordingly, the objective of the present study was to evaluate several productive and reproductive traits using 5,440 records of cows of different breeds from 57 dairy herds located in the Valle de Aburrá, North, and East of Antioquia province.

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Materials and Methods

Ethical considerations

This study was approved by the Institutional Committee for the Use and Care of Animals of Universidad Nacional de Colombia, Medellin, on August 28th, 2020 (Agreement: CICUA-D20-2020). Therefore, it was conducted in accordance with the ethical standards established in the 1964 Declaration of Helsinki and its subsequent amendments.

Population and study area

A total of 5,440 dairy cow records were analyzed. The breeds studied were Ayrshire, Holstein, Jersey, Norman, Brown Swiss, Viking Red, and their crosses. The records covered 16 municipalities of the province: three within the Valle de Aburrá region (V; Bello, Girardota, and Medellín), seven in the Northern region (N; Belmira, Don Matías, Entrerríos, San José de la

Montaña, San Pedro, Santa Rosa, and Yarumal), and six in the Eastern region (E; Abejorral, Carmen del Viboral, La Ceja, Marinilla, Rionegro, and El Santuario). The N region involved 37 herds, with 3,806 animals. The E region included 10 herds and 687 animals. Valle de Aburrá included 10 herds with 947 animals. These regions are in very humid lower montane forest zones (bmh-mb), with temperatures ranging between 12 and 18 °C and annual rainfall between 2,000 to 4,000 mm. Altitude ranges between 1,800 to 2,800 m.a.s.l. Animal management, feeding, and health conditions were variable among herds, as well as topography and geographic location. The number of animals in each breed were as follows: Jersey (JER; n=369), Holstein (HO; n=1,611), Swedish Red (SR; n=103), Swiss Brown × Holstein (SBHO; n=48), Jersey × Holstein (JH; n=1,066), Swedish Red × Holstein (SRH; n=33), Ayrshire (AYR; n=65), Ayrshire × Holstein (AYRHO; n=47), Swiss Brown (SB; n=14), unidentified breed (NN; n=2,012), and others ((i.e., Black-and-white (BON) × Holstein; Norman (NORM); Angus (ANG) × Holstein; SR × JER; BON × HO; NORM × HO; ANG × HO; Gyrolando (GYR; n=72)), and unidentified breed (NN; n=27)). Therefore, the sample was representative of the population in the dairy herds, Similarly, the number of births per breed was as follows: Holstein (HO; n=4,980), Jersey (JER; n=845), Swedish Red (SR; n=167), Ayrshire (AYR; n=132), Swiss Brown (SB; n=64), Jersey × Holstein (JH; n=1,923), Ayrshire × Holstein (AYRHO; n=129), Swiss Brown × Holstein (SBHO; n=92), Swedish Red × Holstein (SRH; n=78), and unidentified breed (NN; n=25).

Data analysis

Dairy control. Representative samples from a morning or afternoon milking were taken every 30±8 days for milk composition analysis using proportional milk meters (in herds with mechanical milking) or directly in the bucket (for farms with manual milking). A minimum of three milk samples were taken per animal during the study. Additionally, historical information taken during the milk control program in herds associated to Cooperativa Lechera COLANTA were used.

After filtration, milk samples were placed in 50-mL plastic bottles and preserved with bronopol (Advanced Instruments Companies, Norwood, MA, USA). For mechanical milking, the amount of milk (kg) produced per milking was taken with a milk meter. For manual milking this data was obtained from the milking bucket. The amount of milk per each third of lactation was obtained from the record of milk per cow (kg), which also allowed to calculate the total amount of milk produced in 305 days. Biochemical analysis of milk was conducted at Laboratorio de Calidad de Leche, COLANTA (COLANTA Milk Quality Laboratory) for the percentage of total solids, non-fat solids, lactose, protein, fat, and urea nitrogen (MUN; mg/dL) using a MilkoScan equipment (Advanced Instruments Companies, Norwood, MA, USA). Total cell count was calculated with a Fossomatic equipment (Advanced Instruments Companies, Norwood, MA, USA) and transformed to Somatic Cell Score (SCS) using its logarithmic form according to Rodríguez-Zas *et al.* (2000) to obtain more balanced data ($SCS=LOG_2(RCS/100000)+3$). Lactations sixth to eleventh were grouped as sixth lactations+sd (LA6+). Reproductive information was updated during each visit.

Productive and reproductive parameters. A unified database including 177 productive and reproductive variables recorded between birth and eleventh parturition was built. Reproductive and health information (parturition, drying-off, insemination, pregnancy detection, among others) was obtained from the records and management software at the herds. This monitoring was carried out by the producers and collected by the COLANTA dairy control program, as mentioned before.

The reproductive traits evaluated were as follows: calving interval (CI; measured as the number of days elapsing between two consecutive calvings), number of services per conception (S/C; number of inseminations conducted until detecting pregnancy), and days open (DO; days from parturition to conception). The productive traits evaluated were as follows: days in lactation (DL), milk production per lactation (PL; measured in kg/lactation), protein per lactation (PP; %), fat

per lactation (PF; %), and somatic cell count per lactation (SCC; cells/mL). With those variables, adjusted values were obtained, as follows: adjusted milk production (Pla; measured in kg/ lactation adjusted to 305 days), percentage of adjusted protein per lactation (PPa), kg of protein per lactation (KgPRO), kg of adjusted protein per lactation (KgPROa), kg of fat per lactation (KgF), fat percentage adjusted (PFa), kg of adjusted fat per lactation (KgFa), as well as duration of lactation for each animal, and somatic cell score (SCS).

Extreme data was eliminated -it was considered physiologically abnormal or erroneously recorded and non-valid. The following ranges were considered: For DL, values ranging from 200 to 400 days; for Pla, from 3,000 to 7,500 kg milk; for PP, values from 2 to 5%; and for PG, values from 2.5 to 6%. Additionally, CI from 300 to 540 days; and DO ranging from 30 to 260.

Statistical analysis

For this longitudinal study, a unified database was built in Excel with information on 177 productive and reproductive variables recorded between birth and eleventh calving (the record of the last birth corresponds to the date when it was discarded from the farm). Reproductive and health information (calving dates, drying-off dates, insemination dates, pregnancy detection, among others) was obtained from historical records in notebooks and the livestock management software used in the herds. This follow-up was carried out by the participating producers and was collected by the COLANTA dairy control program, as mentioned above. The average of each population variable was determined from complete lactations, establishing the average for each parameter. Significant effects of independent variables on productive and/or reproductive parameters were determined simultaneously by interaction of two or more variables with a significant effect.

Statistical analysis was conducted with the R i386 4.2.0–RStudio package (R Core Development Team, 2023) (Kohl 2015).

Results

As it is well known, PL per animal depends on a series of factors both environmental or external and internal (physiological) to the animal. The average PL (kg) adjusted to 305 days was 5,492.6±1,027.2 kg/lactation. The evolution of average milk production adjusted to 305 days in the different parturitions shows an increasing trend until the fourth lactation, stabilizing at the fifth lactation, and then beginning to decrease (Figure 1). The average production was 18 kg of milk/cow/day.

The PL of cows in the V region was 6,146.39 kg/lactation, significantly higher than production in the N and E regions (5,527.53 and 5,225.47 kg/ lactation, respectively).

In the V region, Ayrshire × Holstein cows showed low PLa (58%); Holstein cows in their third calving presented low PLa (31%); and Ayrshire cows showed decreased Pla in the second calving (56%). Decreased milk production was observed in the Angus × Holstein cows (46% less PLa) and Brown Swiss in the V region, with 41% less milk per lactation (Figure 2).

The SCS gradually increased from first lactation until L6 or higher, averaging 3.62 (Table 1), The KgPROa and KgFa were 117.1±29.5 and 215.1±37.1, respectively; both parameters increased as lactation number increased up to L5 and then decreased at L6+ (Table 1). Compositional quality of milk was 3.24%±0.27 for protein and 3.95%±0.6 for fat.

We found that Holstein breed has lower milk fat production (172.9±24.7 kg) compared with the average for Antioquia. Additionally, Ayrshire × Holstein cows in the E region produced less fat (132.5±46.2 kg) than the general mean; and Ayrshire × Jersey cows produced also less fat (102.2±26.5 kg) in the three regions compared to Antioquia's average (Figure 3).

Regarding reproductive parameters, the average CI in Antioquia was 385.7±52.8 days (Figure 4). When analyzed by region, CI from Valle de Aburrá was 389 days, higher than the East and North (386.5 and 384.4 days, respectively).

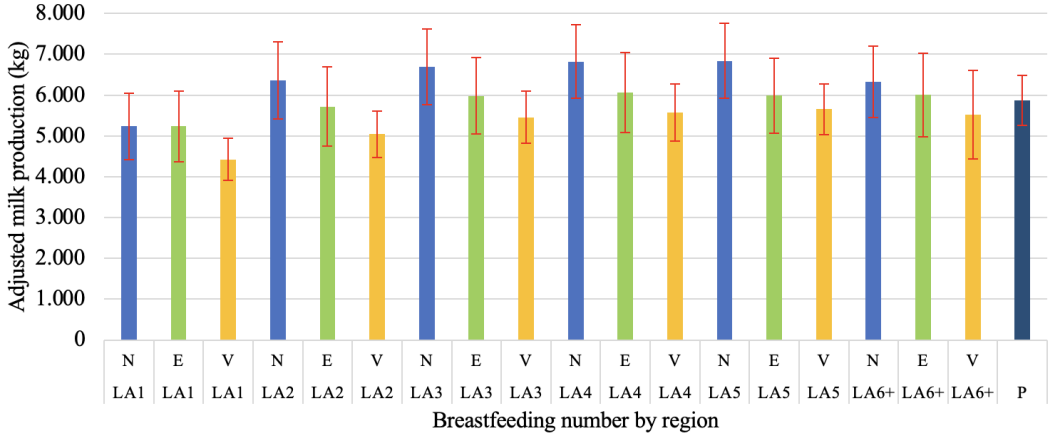

Figure 1. Milk production adjusted-PLa (kg) per lactation by region: North [N] in blue, East [E] in green, Valle de Aburrá [V] in yellow, and general average Pla for Antioquia [P] in dark blue. LA=adjusted milk production; LA6+=grouping of adjusted lactation 6 or higher than 6. Red lines show standard deviation (SD).

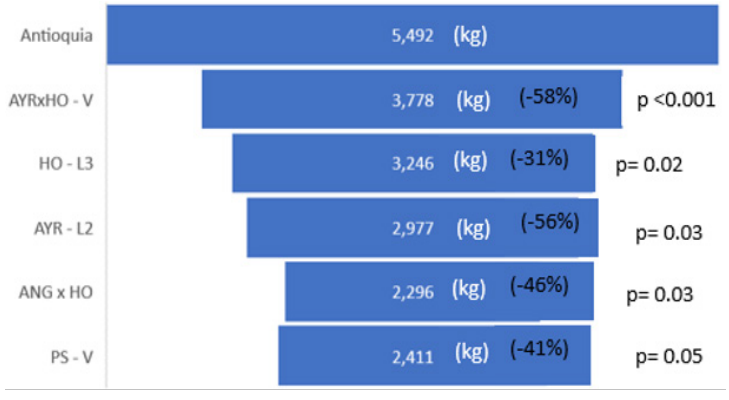

Figure 2. Interaction effects of breed, region, and parturition on milk production (Pla, in kg). HO=Holstein; AYR=Ayrshire; ANG=Angus; PS=Brown Swiss; ANG × HO=Angus × Holstein; AYR × HO=Ayrshire × Holstein; V=Valle de Aburrá; L2=adjusted production in lactation two; L3=adjusted production in lactation three.

Table 1. Compositional parameters and sanitary quality of milk in dairy herds at the high tropics of Antioquia (Colombia), according to lactation order.

Parameter/ variable	KgPROa			KgFa			SCS		
	variable	SD	N	A	SD	N	A	SD	N
L1	163	28.9	1,471	192	32.7	1,472	3.2	1.4	664
L2	178	30.2	949	215	36.9	938	3.4	1.5	646
L3	187	28.9	718	230	38.0	711	3.6	1.5	585
L4	190	28.6	561	236	40.5	546	3.9	1.7	469
L5	190	29.8	394	234	40.6	389	4.1	1.7	369
L6+	184	31.5	463	230	43.4	428	4.2	1.8	548
General	**177.1**	**29.5**	**4,556**	**215.1**	**37.1**	**4,484**	**3.62**	**1.6**	**3,281**

KgPROa= Kilograms of adjusted protein per lactation; KgFa=Kilograms of adjusted fat per lactation; SCS=Somatic cell score; L=Lactation; L6+= Grouping lactation from parturition 6 or greater; N=Amount of data in the analysis; A=Average; SD=Standard deviation.

The CI between lactations was 385.2, 386.4, 387.3, 388.4, 388, and 390.7 days for CI1, CI2, CI3, CI4, CIP5, and CIP6+, respectively. Although gradually increasing, cows with six or more parturitions had 5.5 days more than CI1 (between first and second calvings).

Regarding average interval between calvings (Figure 4), lactation 3 is where the longest intervals occurred, and it was associated ($p<0.05$) with Holstein cows (37% increase) or BON × Holstein (57% increase) in the three regions.

The DO average was 110.9 days in the three regions, which is directly related to 1.15 services (S/C), with expected higher DO when S/C increases. The S/C of Holstein cows (HO) and Holstein × Jersey (HO × JE) significantly increased ($p<0.05$: 7 and 68%, respectively) compared to the general mean in N, E, and V regions (Figure 6).

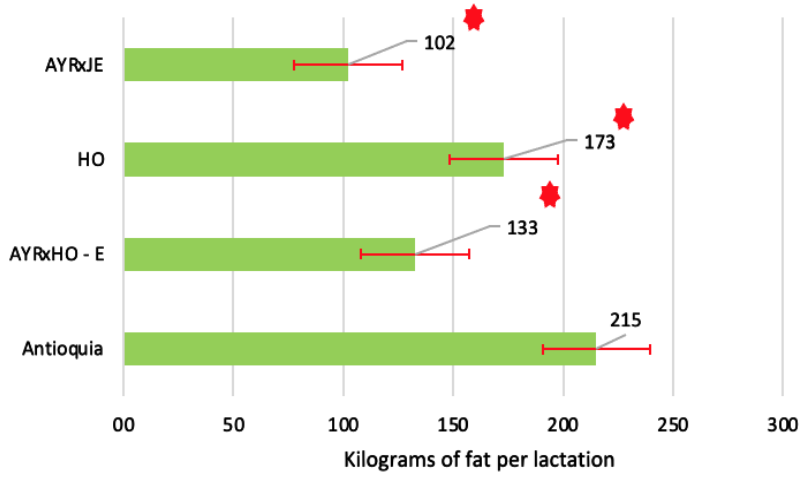

Figure 3. Effect of breed and location on milk fat production_(KgFa). HO=Holstein; AYR=Ayrshire; JE=Jersey; AYR × HO=Ayrshire × Holstein; AYR × JE=Ayrshire × Jersey; E=East. Red lines correspond to standard deviation (SD), and red stars show statistical significance when compared to Antioquia´s values.

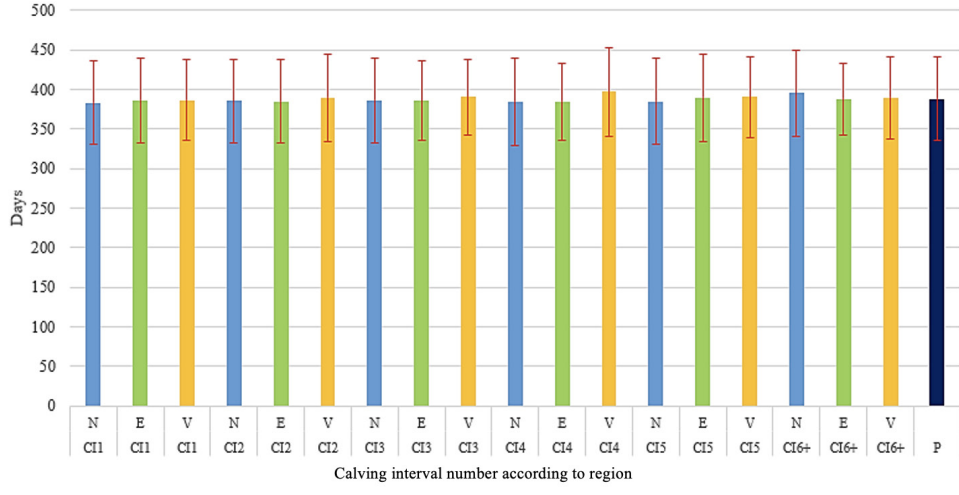

Figure 4. Calving interval (CI; days) per region (1 to 6). North [N] in blue, East [E] in green, Valle de Aburrá [V] in yellow, and general average [P] in dark blue. CI1=interval between calving 1 and 2; CI2=interval between calving 2 and 3; CI3=interval between calving 3 and 4; CI4=interval between calving 4 and 5, CI5=interval between calving 5 and 6; CI6+=mean interval between parturition 6 and higher. Red lines correspond to standard deviation (SD).

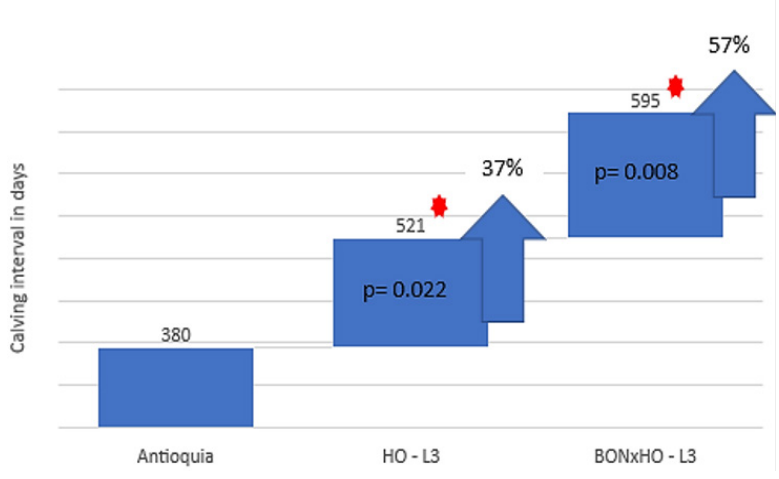

Figure 5. Increase in interval between calvings (CI) associated with the interaction of breed, region, and parturition to lactation period. HO=Holstein; BON=black-eared white cows; BON × HO=BON × Holstein; L3=adjusted production of lactation three. Red stars show statistical significance compared to Antioquia´s value.

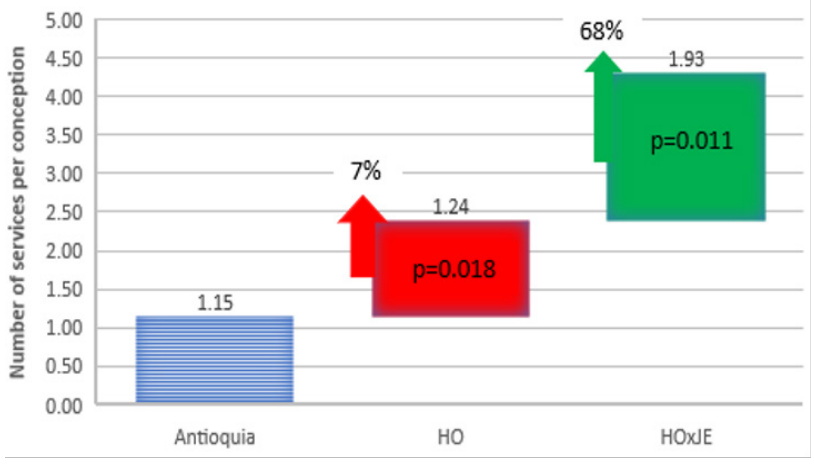

Figure 6. Increase in services per conception (S/C) associated with breed compared to the average of three regions in Antioquia Province. HO=Holstein; JE=Jersey; HO × JE=Holstein × Jersey.

Discussion

The PL value (5,492.6±1,027.2 kg/lactation) was lower than that reported by Secretaría de Agricultura y Desarrollo Rural de Antioquia-Colombia (2019) for dairy herds in Antioquia Province (6,886.3 kg/lactation). This decrease in milk production is possibly due to the high rainfall that occurred in the region since early 2021 (FEDEGAN, 2022), causing oversaturation of soils in addition to lower light intensity received by forages. Additionally, increased costs of chemical fertilizers and concentrates reduced the capacity of owners to supplement the cows.

Average milk production of 18 kg/cow/day is lower than earlier reports (18.9 kg; Unidad de Planificación Rural Agropecuaria-UPRA, 2020). On the other hand, Builes *et al.* (2021) found 17.6 kg milk/cow/day in a farm located in Don Matías, lower than results in the present study. The PL of cows in the V region was 6,146.39 kg/lactation, significantly higher than N and E regions (5,527.53 and 5,225.47 kg/lactation, respectively). This could be explained by the fact that herds with higher genetic values are in the Valle de Aburrá region, with higher selection pressure and better management. Besides, its ecosystems are more advantageous for dairy production compared with

N and E regions where genetic value of animals is lower (Munera *et al.*, 2018).

The SCS gradually increased from lactation first to L6 or higher (Table 1). The general value was 3.62 points, which is lower than 4.4 points reported by Cerón-Muñoz *et al.* (2015) for this same study area. The SCS reported by those researchers was 263,856 cells/ml, similar to 250,000 cells/ml reported by Barrios and Olivera (2013), which corresponds to a SCS value of 4.3 points. Both SCC values are higher than those found in the present study. At the region level, significant differences were found in SCS, being higher in the N region (3.77 points) compared to 3.46 and 3.62 points in E and V regions, respectively, which are low, as ideally expected.

A SCC greater than 400,000 cells/ml may be associated with subclinical mastitis, while SCC below 200,000 cells/ml are typical of herds with good management practices, as is the case of Antioquia's dairy farms. High SCC scores are associated to poor hygiene protocols and long periods between milkings, which put animals at risk. Milk from the Antioquia's dairy region can be classified as regular based on its SCS according to the quality classification proposed by Cuartas *et al.* (2017).

Values for KgPROa and KgFa were 117.1±29.5 and 215.1±37.1, respectively. Both parameters increased as lactation number increased up to L5 and then decreased at L6+ (Table 1). Compositional quality of milk in the present study was 3.24%±0.27 for protein and 3.95% ±0.6 for fat. These values are higher than those reported by Ruiz *et al.* (2019), who found protein and fat contents of 3.16±0.13 and of 3.74%, respectively, for dairy farms in the same region, and higher than 2.85 and 3.05% protein and fat contents, respectively, previously reported in San Pedro de los Milagros (N region) (Montoya *et al.*, 2017). The protein and fat content of milk found in the present study is excellent, showing great progress in genetic programs, implementation of milking protocols, and feeding plans, according to the milk quality classification proposed by Cuartas *et al.* (2017). However, we found that Holstein breed in average, Ayrshire × Holstein cows in the E region, and Ayrshire × Jersey produced less KgFa than the mean in the three regions, which confirms that breed is a key factor for milk quality.

As previously mentioned, the general average CI was 385.7±52.8 days (Figure 4). By region, significant variations were found in this parameter, with 389 days for CI of cows in Valle de Aburrá; higher to values in East and North regions (386.5 and 384.4 days, respectively). Variations were also found when evaluating CI between lactations; with 385.2, 386.4, 387.3, 388.4, 388, and 390.7 days for CI1, CI2, CI3, CI4, CIP5, and CIP6, respectively. These results indicate that cows in the three regions are adequately fed according to their reproductive performance, presenting a good condition. These results range between values recommended by Chegini *et al.* (2019), who pointed out that CI should be 365 days, with a maximum of 380 to 395 days, while values greater than 456 days are considered deleterious. Ruiz *et al.* (2002) reported a CI of 401±38 days in a study conducted in several farms in Antioquia, which is similar (402.5±4.8 days) to the study in the same province reported by Barrios *et al.* (2015). In both reports values were higher compared to the present study. Our results show that lactation 3 is where the longest CI interval occur in the three regions, and it is significantly associated with Holstein cows or with crosses between BON and Holstein.

The average DO was 110.9 days in the present study, which is related to 2.02 S/C, with the expected increase in number of S/C at higher DO (Figure 6). This value is lower than the 2.3 S/C reported by Barrios *et al.* (2015), indicating good reproductive performance. Similarly, Quiroz *et al.* (2011) found 2.4±0.5 S/C studying several dairy breeds in Eastern Antioquia. Our average S/C also differs from the report by Quijano (2002), who recorded 2.21 S/C in a study with Holstein cows. As already mentioned, our study analyzed data from several pure breeds and various crosses, which could explain the difference with the results by Quijano (2002). It is known that response depends on each animal, and it can vary between them. Nevertheless, there are also tendencies between animals of the same breed, and differences

between breeds. This is associated with a series of traits and physiological parameters, which, although specific for each animal, are preserved among animals of the same breed (Chegini *et al.*, 2019). This parameter is of great importance in dairy farms because it directly affects the cost of insemination services and the number of lactations. In fact, it is one of the most important reproductive parameters in dairy farms. According to Chegini *et al.* (2019), the ideal DO should be 60 days (a value much lower than the 110.9 days found in the present study) for high efficiency of milk production. The DO is strongly affected by CI and both factors are influenced by feeding and health of the animals. They can also be associated with heat detection failures (Barrios *et al.*, 2015).

In conclusion, cows in Valle de Aburrá present positive productive indicators but lower reproductive values compared to the North and East regions. This can be associated with greater productive capacity (in quality and quantity) that can affect reproductive rates. Our results encourage continuing evaluating the zootechnical parameters of cows in the three regions.

Declarations

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Conflicts of interest

The authors declare they have no conflicts of interest regarding the work presented in this report.

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Author contributions

All authors contributed to the design of the study. Material preparation, data collection and analysis were performed by Cristian Camilo Rúa Giraldo, Zulma Tatiana Ruiz Cortés, and Albeiro López Herrera. The first draft of the manuscript was written by Cristian Camilo Rúa Giraldo and all authors contributed to later versions of the manuscript. All authors read and approved the final manuscript.

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

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