

Milk Production in Dual-Purpose Cattle Systems under a Humid Subtropical Climate Af(c)

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ABSTRACT

Objective: To evaluate the effects of environmental factors year, season, and parity on milk production and lactation duration in Holstein×Zebu and Brown Swiss×Zebu cows in a humid subtropical region.

Design/methodology/approach: Data from 2010 to 2021 were analyzed from the dual-purpose production unit El Paraíso de Ayototxco, located at 240 meters above sea level in the municipality of Ayototxco de Guerrero, Puebla, under a humid subtropical climate Af(c). The studied traits included total milk yield (TMY), daily milk yield (DMY), milk yield per day of calving interval (MYDCI), and lactation duration (LD). Data were analyzed using the GLM procedure in SAS. The final model included year, season, and parity as fixed effects.

Results: A total of 934 lactations were evaluated, with an average LD of 339.65±94.75 days and a TMY of 3,392.6±1,185.9 kg. The average DMY and MYDCI were 9.94±1.99 kg and 7.43±2.36 kg, respectively. Year and parity significantly affected all traits (P<0.05), whereas the calving season was significant only for MYDCI. The parity effect showed that first-lactation cows had lower TMY, DMY, and MYDCI, while cows with more than three calvings exhibited the highest performance in these traits. The average values for TMY, DMY, MYDCI, and LD in the validation module were 3,392.6 kg, 9.94 kg, 7.43 kg, and 339.65 days, respectively. A productive improvement was observed over the years, attributed to the adoption of new technologies.

Findings/conclusions: Year and parity significantly influenced all analyzed variables, while calving season affected only MYDCI.

Keywords: Validation, adoption, lactation, Holstein×Zebu.

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INTRODUCTION

In Mexico, the bovine population is approximately 35,998,885 head, of which, according to data from the past decade, dual-purpose cattle aged two years or older account for 28.4% of this category, equivalent to 2,466,477 head. Additionally, Mexican



livestock farming utilizes approximately 110 million hectares, 28.3% of which corresponds to tropical areas, which are predominantly covered with forage used for meat and milk production in dual-purpose systems. These systems are primarily developed in tropical regions and have historically been characterized by low milk production (Calderón *et al.*, 2016).

Cattle farming in Mexico faces an increasingly critical situation. There has been a milk production deficit since the 1970s, resulting in the importation of approximately 20% of the annual national consumption. This crisis is further exacerbated by the rising costs of inputs compared to the low prices of livestock products (meat and milk), a trend particularly evident in the tropical and subtropical regions of the country. These regions contribute approximately 20% of the national milk production (González, 1993; SADER, 2023), mainly through traditional systems with low technological adoption. These systems often involve indefinite crossbreeding between *Bos taurus* and *Bos indicus* cattle (Koppel *et al.*, 2002).

In tropical regions, milk and meat production depend on the season of the year, with the highest production occurring during the rainy season. Although productivity indicators remain low, studies on dual-purpose livestock in the tropics have shown the feasibility of improving prospects for increasing milk and meat production in Mexico (CIPEP-INIFAP-SARH, 1989a, 1989b).

In response to these challenges, the National Institute of Forestry, Agricultural, and Livestock Research (INIFAP) has conducted applied research by establishing projects in the tropics to develop and evaluate technologies. This has led to the creation of technological packages to enhance the efficiency and competitiveness of dual-purpose production systems (CIPEP-INIFAP-SARH, 1989a).

The dual-purpose production unit 'La Doña' operates with Holstein×Zebu, American Brown Swiss×Zebu, and Simmental×Zebu cattle under grazing conditions at the Las Margaritas experimental site. This unit has achieved an average milk production per lactation of 3,190 kg over 322 days, a calving interval of 446 days, an average calf weight of 293 kg at one year of age, and heifers reached first calving at an average age of 29.7 months and a weight of 443 kg (SAGARPA-INIFAP-CIPEP A.C., 2004).

In summary, the adoption of various technologies has contributed to increased milk production. The Las Margaritas experimental site in Puebla, established in 1981, has been dedicated to generating and validating technologies to improve dual-purpose production systems. These efforts aim to address the technological demands of producers and enhance their productivity (SAGARPA-INIFAP-CIPEP A.C., 2004). Validated technologies have been transferred to producers, and a demonstration module was established with a collaborating farmer in 2008. This initiative sought to implement a dual-purpose production unit as a validation and demonstration model based on technologies developed at La Doña. Initially, over 50% of the recommended technologies were adopted, with gradual increases over time. By 2017, a newly implemented technology, fertilizing pastures with a recommended formula (138:69:00), led to increased milk production and an increase of 2.4 times in yield per unit of land. Another significant technological advancement has been achieving the recommended proportion of European genetic influence in the herd, ranging

between 3/4 and 5/8, as suggested in the technology package. Currently, it is estimated that over 80% of the recommended technologies have been adopted in this production unit.

Therefore, the objective of this study was to evaluate the effects of selected environmental factors such as year, season, and parity on milk production traits (total milk yield per lactation (TMY), daily milk yield (DMY), milk yield per day of calving interval (MYDCI), and lactation duration (LD)) in Holstein×Zebu and Brown Swiss×Zebu cows at the El Paraíso de Ayotoxco production unit in Puebla's humid subtropical region.

MATERIALS AND METHODS

Study Area

Data from 2010 to 2021 were collected from the dual-purpose technology validation module El Paraíso de Ayotoxco, located at coordinates 19° 59' 54" to 20° 08' 48" N and 97° 21' 18" to 97° 27' 42" W, at an altitude of 240 meters above sea level in the municipality of Ayotoxco de Guerrero, within the Sierra Oriente region of Puebla, Mexico. The climate of the study area is classified as humid subtropical Af(c), with an average annual temperature of 23 °C and mean annual rainfall ranging between 2,200 and 2,500 mm. Three distinct seasons can be identified: 1) Rainy season, which occurs from June to October and is characterized by heavy rainfall; 2) Windy season, which runs from November to March and is characterized by drizzle and a drop in temperature; and 3) Dry season, in April and May, which experiences isolated showers and an increase in temperature.

Animals and Management

The females included in this study are *Bos taurus taurus* crossed with *Bos taurus indicus* (ranging from 3/4 to 5/8 European) and belong to a validation module covering a total area of 158 hectares (ha). Of this area, 100.5 ha are planted with grasses of the *Brachiaria* genus, predominantly *Brachiaria brizantha* (Insurgente). Within this pasture, 49 ha are allocated to milking cows, 23 ha to dry cows, 16 ha to heifers under reproductive management, 8.5 ha to developing heifers, and 4 ha to nursing calves. Additionally, 54.5 ha are covered with native grasses (*Axonopus* and *Paspalum* spp.), where 50 ha are used for heifers under reproductive management, 3 ha for developing heifers, and 1.5 ha for weaned calves. Lastly, 3 ha are cultivated with Japanese sugarcane (*Saccharum sinense*), which is used as supplemental forage. During the critical season, each female received a daily ration of 15 to 20 kg of freshly chopped Japanese sugarcane (*Saccharum sinense*). Furthermore, milking cows were provided with 2 kg of concentrate (16% CP and 70% TDN) during each milking session. All females had *ad libitum* access to a mineral supplement and water.

Milking cows, dry cows, and developing heifers undergo rotational grazing, with rest periods of 30 and 45 days during spring-summer and autumn-winter, respectively. Since October 2017, pasture fertilization has been carried out using the formula 138-69-00 kg/ha of N and P in the paddocks designated for lactating cows and nursing calves. The diet of dry cows consists of pasture consumed directly from the field, along with *ad libitum* access to mineral salts and water. Additionally, from November to May, they receive 15 to 20 kg/animal/day of freshly chopped Japanese sugarcane. Calf nutrition includes pasture grazing, supplemented with milk obtained from one-quarter of the udder plus residual milk, until

they reach a body weight of 100 kg. After this point, they consume only supplemental and residual milk, along with 850 g/day of concentrate (18% CP) throughout the rearing period. Weaned heifers are managed under a rotational grazing system and receive 1.5 kg/animal/day of concentrate (18% CP), along with *ad libitum* mineral salts and water. Developing heifers, until they reach the reproductive management stage (RMS), are also managed under rotational grazing, with their diet consisting of pasture, mineral salts, and water available *ad libitum*. Reproductive management in cows follows a continuous mating system with natural mating. Estrus detection is conducted in the morning and afternoon during milking, and rectal palpation is performed every three months.

Heifers begin reproductive management at approximately 330 kg and remain in continuous mating system with natural mating. Similarly, rectal palpation is performed every three months.

Cows began milking four days after calving, once it was confirmed that they no longer produced colostrum. Milking was performed mechanically with the “assistance” of the calf. The calf was used to stimulate milk letdown until it reached approximately 11.5 months of age, at which point it was weaned. Milking was conducted twice daily using a mechanical system equipped with a two-stall setup powered by an electric and/or gasoline engine. The reproductive management of cows followed a continuous mating system with natural mating.

Design and Experimental Unit

The studied traits were: total milk yield per lactation (TMY), daily milk yield (DMY), milk yield per day of calving interval (MYDCI), and lactation duration (LD).

Statistical Analysis

The traits were analyzed using the GLM procedure in the SAS software. The fixed effects included in the final model were year, season, and parity number. Sequential analyses were performed for each trait to determine the final models, removing non-significant interactions from the preliminary model at $P < 0.05$.

Evaluated Variables

Lactation milk yield was measured using daily production records for each cow, obtained with Waikato-type commercial milk meters installed in each stall of the milking parlor. These records were collected from the beginning to the end of lactation. The start and end dates of lactation were recorded to determine lactation duration in days. Daily milk yield (milk yield per day in lactation) was calculated by dividing the total milk production per lactation by the lactation duration. Finally, milk yield per day of calving interval was determined using calving date records for each cow. The total milk production per lactation was divided by the number of days in the inter-calving period to obtain this value.

RESULTS AND DISCUSSION

The descriptive statistics for the different traits are presented in Table 1. A total of 934 lactations were evaluated, with an average LD of 339.65 ± 94.75 days and TMY of

Table 1. Descriptive statistics for milk production traits.

Variable	N	Mean	SD	Min	Max	CV
LD ^A	934	339.65	94.75	120.00	727.00	27.90
TMY ^B	933	3392.56	1185.94	787.50	7926.00	34.96
DMY ^C	933	9.94	1.99	4.37	17.24	19.98
MYDCI ^D	814	7.43	2.36	1.26	14.92	31.73

^ALD=Lactation duration, ^BTMY=Total milk yield per lactation, ^CDMY=Daily milk yield, ^DMYDCI=Milk yield per day of calving interval.

3,392.56±1,185.94 kg. DMY and MYDCI averaged 9.94±1.99 kg and 7.43±2.36 kg, respectively. According to a previous study (Calderón *et al.*, 2016), LD was the same; however, the other traits showed lower values (TMY=2,905 kg, DMY=8.5 kg, and MYDCI=6.6 kg). This improvement can be attributed to the increasing adoption of technology developed by INIFAP within the demonstration module, which has consequently enhanced productive indicators.

Considering the overall means from the present study and the previous one (Calderón *et al.*, 2016), LD was higher (340 days) than the values reported in other studies conducted in southeastern Mexico, which range from 214 to 255 days (Hernández *et al.*, 2001; Parra *et al.*, 2005; Magaña *et al.*, 2006; Magaña *et al.*, 2016). Similarly, TMY reported by these authors ranged from 1,322 to 1,862 kg, which is lower than the values obtained in both the present study and the previous one (Calderón *et al.*, 2016). Consequently, DMY in this study (9.94 kg), despite the longer lactation period (340 days), also exceeded the 5.81 kg reported by Parra *et al.* (2005) and the 6.71 kg documented by Magaña *et al.* (2016). Notably, MYDCI also surpassed the values reported by these authors.

The effects of year and parity number were significant in all models, whereas calving season was significant only for MYDCI. This finding aligns with previous reports (Vite *et al.*, 2007; Simón *et al.*, 2010), which found significant differences ($P<0.05$) between lactations. Except for MYDCI, no other significant associations were found between calving season and the evaluated production traits. Least squares means and their standard errors for milk production traits are presented in Table 2, Figure 1, and Table 3.

Table 2. Least squares means and standard errors for productive traits by parity number.

Parity Number	Trait			
	LD ^A	TMY ^B	DMY ^C	MYDCI ^D
1	342.14±6.43 ^{ab}	2908.04±76.54 ^b	8.40±0.11 ^c	5.91±0.14 ^c
2	347.59±6.56 ^{ab}	3415.24±78.09 ^a	9.75±0.11 ^b	7.15±0.15 ^b
3	355.40±7.37 ^a	3673.37±87.74 ^a	10.31±0.12 ^a	7.79±0.17 ^a
4	341.39±8.77 ^{ab}	3454.35±104.44 ^a	10.05±0.15 ^{ab}	7.68±0.20 ^{ab}
>5	326.76±7.20 ^b	3382.21±85.83 ^a	10.31±0.12 ^a	7.95±0.17 ^a

^{a,b,c} Means within the same column with different superscripts differ significantly ($P<0.05$). ^ALD=Lactation duration, ^BTMY=Total milk yield per lactation, ^CDMY=Daily milk yield, ^DMYDCI=Milk yield per day of calving interval.

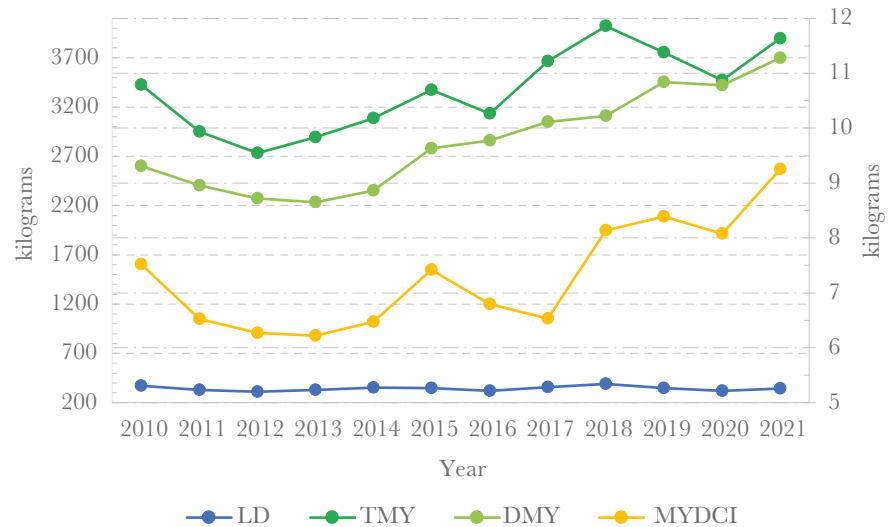


Figure 1. Productive traits (LD=Lactation duration, TMY=Total milk yield per lactation, DMY=Daily milk yield, MYDCI=Milk yield per day of calving interval) by calving year.

As shown in Table 2, total milk yield (TMY), daily milk yield (DMY), and milk yield per day of calving interval (MYDCI) were lowest during the first lactation and increased progressively with each subsequent lactation. Cows with more than three lactations showed the highest milk yield. In contrast, lactation duration (LD) decreased as the number of lactations increased, with the shortest duration observed in cows with more than five lactations. Calderón *et al.* (2016) reported no significant differences in LD and TMY but found results consistent with the present study for DMY and MYDCI. Except for LD, all other traits reported lower values compared to the present study, with peak production observed during the third lactation (TMY=3,006 kg, DMY=9.13 kg, and MYDCI=6.8 kg). Similar trends have been observed in previous studies, such as López *et al.* (2009), who also reported lower milk yield in the first lactation compared to subsequent ones. Furthermore, milk production reported in both South American studies (Santana *et al.*, 2022) and research from southeastern Mexico (Magaña *et al.*, 2016) was lower than in the present study.

The effect of calving year (Figure 1) was significant ($P<0.05$) for all evaluated traits. A steady increase in total milk yield (TMY), daily milk yield (DMY), and milk yield per day of calving interval (MYDCI) was observed over the years. This trend became more evident after 2017, coinciding with the implementation of fertilization technology. In contrast, lactation duration (LD) fluctuated from year to year (ranging from 310 to 390 days), however, these variations did not negatively affect DMY or MYDCI.

Table 3 shows that cows calving during the rainy season had a significantly higher ($P<0.05$) MYDCI (7.64 kg) compared to those calving during the windy season (7.34 kg) and the dry season (6.92 kg). Similar to this study, lactation duration (LD) was not significant in a previous study (Calderón *et al.*, 2016). However, that study did report differences in total milk yield (TMY), with lower values during the rainy season, a pattern not observed in the present study, although the numerical trend remained similar.

Table 3. Least squares means and standard errors for productive traits by season of measurement.

Season	Trait			
	LD ^A	TMY ^B	DMY ^C	MYDCI ^D
Rainy	337.17±4.75	3355.13±56.59	9.87±0.08	7.64±0.11 ^a
Windy	344.03±4.99	3365.10±59.46	9.78±0.08	7.34±0.12 ^{ab}
Dry	346.77±7.95	3379.69±94.70	9.63±0.13	6.92±0.18 ^b

^{a,b} Means within the same column with different superscripts differ significantly ($P < 0.05$). ^ALD=Lactation duration, ^BTMY=Total milk yield per lactation, ^CDMY=Daily milk yield, ^DMYDCI=Milk yield per day of calving interval.

CONCLUSIONS

Calving year and parity significantly affected all evaluated variables, while calving season influenced only MYDCI. The effect of lactation number indicated that first-lactation cows had lower TMY, DMY, and MYDCI, whereas cows with more than three calvings exhibited the highest performance in these traits. The mean values for TMY, DMY, MYDCI, and LD in the evaluated validation module were 3,392.56 kg, 9.94 kg, 7.43 kg, and 339.65 days, respectively. A productive improvement was observed compared to earlier years, primarily attributed to the adoption of new technologies, particularly pasture fertilization, and an increased proportion of European genetics, ranging between 3/4 and 5/8 European.

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