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Research Article

Effects of Breed, Calving Season and Parity on Milk Yield, Body Weight and Efficiency of Dairy Cows under Subtropical Conditions

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Abstract: Records of 354 Holstein Friesian (HF) and Brown Swiss (BS) cows born from 1986 to 2006 at Las Margaritas research station, under subtropical conditions of Mexico, were analyzed to estimate milk yield per lactation (MYL, n = 1229), milk yield per day (MYD, n = 1227), milk yield per calving interval (MYCI, n = 929), lactation length (LL, n = 1229), calving weight (CW, n = 1164) and efficiency of milk production (EMP, n = 890). The cows were daughters of 144 sires and 232 dams. Models included breed of cow (2 classes: HF and BS), calving year (22 classes: 1989-2010), calving season (3 classes: cold, from November to February; dry, from March to June; and rainy, from July to October), lactation number (4 classes: 1, 2, 3 and ≥4), linear (except for CW) and quadratic (except for MYD and CW) effect of lactation length and linear effect of calving weight (except for LL). The random effect, other than the error term, was sire of the cow nested within breed of cow. Holstein Friesian cows yielded 261, 0.8 and 0.7 kg more milk per lactation, per day and per calving interval, respectively, than BS cows. In addition, HF cows were more efficient ($p<0.05$) to yield milk and had heavier CW (21 kg difference; $p<0.05$) than BS cows. Non-significant difference was found between HF and BS cows in LL (358±5.8 and 348±6.0 day, respectively). Milk yield per lactation, MYD, MYCI, EMP and CW increased significantly from first to second and from second to third lactation. However, first-, second-, third- and fourth-parity dams did not differ in LL ($p>0.05$). Cows that calved in the cold season had greater ($p<0.05$) MYD, MYCI and EMP than cows that calved in the dry and rainy seasons. Lactation length was similar among cold, dry and rainy seasons.

Keywords: Brown swiss, cow efficiency, cow weight, Holstein, milk yield, subtropics

INTRODUCTION

There are constraints on livestock production that can be addressed by improving the genetic potential of the animal; examples include: feed conversion efficiency, female productivity and fertility, influencing sex ratios, resistance to parasites and pathogens and quality attributes such as nutritional content and meat texture (Crute and Muir, 2011). One of the most common ways of increasing dairy production in the tropics and subtropics is through importation of breeds with superior genetic potential from other countries either for use in purebred breeding or in crossbreeding with local breeds (McDowell, 1985). The choice of superior breeds have to be considered not only by genetic aspects but also other related factors especially farmers' experiences in livestock, socio-economic and market conditions and profitable and practical levels of feeding, management and health cares (Chantalakhana, 1998). Recognition of high production of the Holstein Friesian breed has stimulated interest in setting up dairy industries in tropical and subtropical countries (Abubakar *et al*., 1986). The use of Holstein Friesians has resulted in dramatic increases in milk production in recent decades. However, cattle in the tropics have, on average, lower milk yields and shorter lactations than dairy cattle in temperate countries; the difference is caused by both genetic and non-genetic factors (Rege, 1998). In Mexico, some researchers have compared Holstein Friesian and Brown Swiss cows under tropical and subtropical conditions based on reproductive and milk yield traits (Becerril *et al*., 1981; Calderón-Robles *et al*., 2011). Comparison of these two dairy breeds based on efficiency of milk production and live weight,

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however, are not available in the literature. Feed efficiency and energy balance traits are key traits for the biological and economic efficiency of dairy production (Koenen, 2001). The objective of the present study was to evaluate the effects of breed, calving season and lactation number on milk yield traits, efficiency of milk production and calving weight of Holstein Friesian and Brown Swiss cows kept under subtropical conditions of Mexico.

MATERIALS AND METHODS

Location and climate: The present study was carried out at Las Margaritas research station of the National Institute for Forestry, Agriculture and Livestock Research (INIFAP). The experimental site is located in the municipality of Hueytamalco, State of Puebla, Mexico, at 450 m above sea level. The climate is classified as subtropical humid (García, 1988). Average annual temperature is 20.8°C, the minimum temperature is 15.3°C in winter and the maximum temperature is 24.2°C in summer. Also, the region is characterized by abundant rainfall from July to October and a low temperature period with drizzle from November to the end of February. From March to June, high temperatures combined with low humidity and solar radiation generates stressful conditions.

Population of study: Productive records of 354 Holstein Friesian (n = 186) and Brown Swiss cows (n = 168) were used in the present investigation. The cows were daughters of 144 sires and 232 dams. The 232 dams were mated to the 144 sires through artificial insemination (mainly) and natural service. The 354 cows evaluated were born from 1986 to 2006 and calved from 1989 to 2010. Females of both breeds were managed together in the same way.

Breeding management: Heifers were first bred when they reached about 350 kg. Heat detection was performed 1 h in the morning (from 06:00 to 07:00) and one hour in the afternoon (from 17:00 to 18:00), with the help of a chin-ball bull. Breeding of cows was in the following manner: those coming on oestrus in the morning were served in the afternoon and those coming on oestrus in the afternoon were served the following day in the morning, approximately 12 h after visual observation of oestrus. Cows were confirmed pregnant by rectal palpation after 45 days of last service.

Feeding management: Cows were kept in an intensive rotational grazing system in which the principal feed was Star grass (*Cynodon plectostachyus*). Grazing and non-grazing periods for each pasture (1-2 ha each) lasted 2-3 and 35-40 days, respectively, depending on the season of the year (climate conditions). Stocking handled on average 2.5 animal units/ha/year throughout the study. During the cold season (November to February), each cow received 20-30 kg of fresh, chopped Japanese cane (*Saccharum sinense*) per day. Also, each lactating cow received 3.5 kg of a commercial supplement (16% crude protein and 70% total digestible nutrients) per milking (twice a day), while non-lactating cows received 2 kg of the same supplement per day.

Milking management: Calves were taken away from their dams 3 days after calving. Cows were managed according to the following groups:

- Lactating cows from calving to the fifth month of lactation
- Lactating cows from the sixth month of lactation to drying-off
- Dry-off cows

Milking of cows initiated 4 days after calving. Cows were milked twice daily, by machine, between 05:00 and 07:00 h and between 15:00 and 17:00 h. Measurement of the individual cow's milk yield was carried out automatically during each milking with Waikato type proportional flow meters. Total milk yield per day was calculated adding the milk yield of the first milking to the milk yield of the second milking. Lactating cows were dried off when they were seven month pregnant or when their milk yield was less than 2 kg/day.

Cow measurements: The variables measured on each cow were:

- Milk Yield per Lactation (MYL, kg), defined as the total kilograms of milk per cow per lactation
- Lactation Length (LL), defined as the number of days from calving to drying off
- Milk yield per day (kg/day), calculated as MYL/LL
- Milk Yield per Calving Interval (MYCI), calculated as MYL/calving interval (kg/calving interval)
- Cow Weight at calving (CW; kg)
- Efficiency of Milk Production (EMP)

Efficiency of Milk Production was calculated with the equation proposed by Demeke *et al*. (2004): $EMP = (MYCI \times 365) / CW^{0.75}$, where MYCI×365 standardize milk yield of cows with different calving intervals and $CW^{0.75}$ is the metabolic cow weight. Hence, efficiency of milk production is a measure of cow's milk yield efficiency in relation to her metabolic weight.

Data editing: All milk yield records were included irrespective of length, but records affected by illness or death were excluded. Ngere *et al*. (1973) demonstrated that the customary procedure of deleting short lactations when evaluating native breeds in India led to serious biases, which could affect conclusions drawn

Table 1: Descriptive statistics

Variable[a]	N	Mean	SD	CV	Min.	Max.
MYL	1229	3738.6	1130.3	30.2	1112.60	9305.5
MYD	1227	11.0	2.3	20.9	4.75	18.1
MYCI	929	8.9	2.0	22.5	2.60	15.7
EMP	890	31.1	6.4	20.6	9.50	51.4
LL	1229	344.6	100.4	29.1	186.00	857
CW	1164	497.7	61.9	12.4	246.00	730

[a]: MYL = Milk Yield per Lactation, MYD = Milk Yield per Day, MYCI = Milk Yield per Calving Interval, EMP = Efficiency of Milk Production, LL = Lactation Length, CW = Cow Weight at Calving; SD: Standard deviation; Min.: Minimum; Max.: Maximum

about breed or herd. For data editing, calving interval was limited from 300 to 550 days, eliminating records found out of this interval. Calving intervals smaller than 300 days probably indicate abortion, while intervals greater than 550 days might indicate an abnormal lactation period. Table 1 shows descriptive statistics for each trait. Overall mean values (±standard deviation) for milk yield per lactation, milk yield per day, milk yield per calving interval, efficiency of milk production, lactation length and cow weight were: 3738.6±1130.3 kg, 11.0±2.3 kg, 8.9±2.0 kg, 31.1±6.4, 344.6±100.4 day and 497.7±61.9 kg, respectively. Milk yield per lactation, lactation length and cow weight varied from 1112.6 to 9305 kg, 186 to 857 day and 246 to 730 kg, respectively.

Statistical analyses of data:

Preliminary models: Preliminary analyses for each trait were performed using the mixed procedure of SAS (Littell *et al*., 1996). The preliminary model to analyze calving weight and lactation length included the fixed effects of breed of cow (2 classes: Holstein and Brown Swiss), calving year (22 classes: 1989-2010), calving season (3 classes: cold, from November to February; dry, from March to June; and rainy, from July to October) and lactation number (4 classes: 1, 2, 3 and ≥4), plus all possible two-way interactions between these four effects. The preliminary model to analyze milk yield per lactation, milk yield per day and milk yield per calving interval included the fixed effects of breed of cow, calving year, calving season, lactation number, all possible two-way interactions between these four effects, linear and quadratic effect of lactation length and linear and quadratic effect of calving weight. The random effect in all preliminary models, other than the error term, was sire of the cow nested within breed of cow. Sequential analyses were run by removing from the full (preliminary) model those interactions and covariates that were not significant at $p \leq 0.05$. The DDFM = Satterth option of the Mixed procedure of SAS was used for computing the denominator degrees of freedom for the tests of fixed effects. The DDFM = Satterth option (a general Satterthwaite approximation) implemented here is intended to produce an accurate F approximation.

Final models: The definitive model for lactation length and calving weight included breed of cow, calving year, calving season and lactation number. Milk yield per day was analyzed with a final model that included breed of cow, calving year, calving season, lactation number, linear effect of lactation length and linear effect of calving weight. The final model for milk yield per lactation and milk yield per calving interval was similar to the one for milk yield per day, but also included the quadratic effect of lactation length. In addition, all final models included sire of the cow nested within breed of cow as a random effect. Differences among least squares means for each fixed effect were tested with the PDIFF (Probability of Difference) option of the mixed procedure of SAS.

RESULTS AND DISCUSSION

Levels of statistical significance of fixed effects for milk yield traits and cow weight are in Table 2. Breed of cow and calving season were highly significant sources of variation for all traits studied, except for lactation length, while calving year was highly significant for all milk yield traits and cow weight. The effects of linear lactation length and linear calving weight were highly significant for all milk yield traits. Least squares means and their standard errors for milk yield traits and cow weight, by breed of cow, calving season and lactation number, are shown in Table 3. Least squares means and their standard errors for milk yield traits and cow weight, by year of calving are not presented.

Breed effects: Holstein Friesian cows yielded 261, 0.8 and 0.7 kg more milk per lactation, per day and per calving interval, respectively, than Brown Swiss cows. In addition, Holstein Friesian cows were more efficient ($p<0.05$) to yield milk than Brown Swiss cows despite the fact that Holstein Friesians had heavier body weight at calving (21 kg difference; $p<0.05$) than Brown Swiss cows. Some studies have shown that heavier live weight affects dairy productivity through its effects on extra dietary energy requirements for maintenance and growth (Dempfle, 1986; Visscher *et al*., 1994). Consistent with present results, Koc (2007) reported that Holstein Friesians produced 1.83 kg more milk/day than Brown Swiss cows in Mediterranean climatic conditions of Turkey. In another study carried out in Italy, De Marchi *et al*. (2008) reported that Holstein Friesian cows produced 9% more milk per day than Brown Swiss cows. Bayram *et al*. (2009) found that Holstein Friesian cows had greater milk yield per lactation than Brown Swiss cows in Turkey, in agreement with the present comparison. More recently, Gergovska *et al*. (2011) reported that 305-day milk yield of Holstein Friesian cows was higher than that of Brown Swiss cows by 970 kg, concluding that the higher milk yield of Holstein Friesian cows was due to lower body condition score values at calving and to

Table 2: Levels of statistical significance of fixed effects for production traits

	Production trait[a]					
Fixed effect	MYL	MYD	MYCI	EMP	LL	CW
Breed of cow	0.0002	<0.0001	0.0009	0.0006	0.2236	<0.0001
Calving year	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Calving season	0.0027	<0.0001	0.0089	0.0103	0.2215	<0.0001
Lactation number	<0.0001	<0.0001	<0.0001	<0.0001	0.7395	<0.0001
Lactation Length (LL)	<0.0001	<0.0001	0.0084	0.0059	-	-
LL×LL	0.0224	-	0.0126	0.0107	-	-
Calving weight	<0.0001	<0.0001	<0.0001	<0.0001	-	-

[a]: MYL = Milk Yield per Lactation, MYD = Milk Yield per Day, MYCI = Milk Yield per Calving Interval, EMP = Efficiency of Milk Production, LL = Lactation Length, CW = Cow Weight at Calving

Table 3: Least squares means and standard errors for Milk Yield per Lactation (MYL), Milk Yield per Day (MYD), Milk Yield per Calving Interval (MYCI), Efficiency of Milk Production (EMP), Lactation Length (LL) and Cow Weight at calving (CW), by breed, calving season and lactation number

	Production trait					
	MYL	MYD	MYCI	EMP	LL	CW
Breed						
Holstein	3825±47.9[a]	11.3±0.13[a]	9.3±0.13[a]	32.4±0.45[a]	358±5.8[a]	507±3.4[a]
Brown swiss	3564±51.0[b]	10.5±0.14[b]	8.6±0.14[b]	30.1±0.47[b]	348±6.0[a]	486±3.6[b]
Calving season						
Cold	3768±44.2[a]	11.2±0.12[a]	9.2±0.12[a]	32.0±0.43[a]	349±6.1[a]	497±3.4[b]
Dry	3691±44.1[ab]	10.9±0.12[b]	8.8±0.13[b]	30.8±0.44[b]	360±6.2[a]	488±3.3[c]
Rainy	3623±42.7[b]	10.7±0.12[b]	8.8±0.12[b]	30.8±0.41[b]	350±5.7[a]	504±3.2[a]
Lactation number						
1	3409±45.7[c]	10.1±0.13[c]	8.3±0.12[c]	29.0±0.43[c]	357±6.1[a]	455±3.3[d]
2	3693±46.4[b]	10.9±0.13[b]	8.8±0.13[b]	30.8±0.46[b]	352±6.7[a]	483±3.5[c]
3	3856±52.1[a]	11.4±0.15[a]	9.3±0.15[a]	32.4±0.51[a]	353±7.6[a]	515±4.0[b]
≥4	3817±49.9[a]	11.3±0.14[a]	9.3±0.15[a]	32.6±0.50[a]	348±6.4[a]	532±3.6[a]

[a, b, c, d]: Means with different superscript are different (p<0.05)

greater and longer loss of body condition score at the beginning of lactation compared to that of Brown Swiss cows. In addition, it has been argued (Pryce *et al*., 1999) that selection for greater milk yield results in lower body condition score compared to cows with average genetic potential for milk yield. On the other hand, Busato *et al*. (2000) pointed out that differences in udder conformation and milking characteristics between these two dairy breeds could be the reason of milk yield differences. In a pasture-based seasonal milk production system under Swiss conditions, Thomet *et al*. (2010) observed that New Zealand Holstein Friesian cows produced more Energy Corrected Milk (ECM) in the second lactation than Swiss dairy breeds, including Swiss Fleckvieh and Brown Swiss (6017 vs. 5470 kg, p<0.001). As a consequence, the efficiency (ECM per metabolic body weight) was higher in New Zealand Holstein Friesian than in Swiss dairy cows in both years of the study (2007, 49.7 vs. 44.2, p<0.001; 2008, 55.6 vs. 46.6, p<0.001). Therefore, the authors concluded that New Zealand Holstein Friesians are more efficient than Swiss breeds, in agreement with present finding.

In contrast to comparisons of milk yield per lactation, milk yield per day, milk yield per calving interval, efficiency of milk production and calving weight, not significant difference was found between Holstein Friesian and Brown Swiss cows in lactation length (358±5.8 and 348±6.0 days, respectively). Italian researchers (De Marchi *et al*., 2008) also found that Holstein Friesian and Brown Swiss cows had similar lactation lengths, in accordance with present results. In view of the stressful environmental conditions that characterized the present study (e.g., high solar radiation and temperature, ample variety of parasites), the estimates of lactation length of Holstein Friesian and Brown Swiss cows are considered acceptable. Such estimates are within the range of corresponding mean estimates reported by Madalena *et al*. (1990), Tomar *et al*. (1998), Afridi (1999), Demeke *et al*. (2000), Kaya *et al*. (2003), Tadesse and Dessie (2003) and Koc (2011), who obtained lactation lengths of 365±20, 345±8, 331±18, 335±9, 336±1, 362±13 and 331±7 days, respectively, with Holstein Friesian cows.

Calving season effects: Cows that calved during the cold and dry seasons had similar milk yield per lactation (3768±44.2 and 3691±44.1 kg, respectively). However, milk yield per lactation was 145 kg greater (p<0.05) in cows that calved during the cold season compared to those that calved during the rainy season (3623±42.7 kg). Milk yield per day, milk yield per calving interval and efficiency of milk production were significantly greater in cows that calved during the cold season than in those that calved during the dry and rainy seasons. Cows that freshened during the rainy season had significantly greater calving weights than those that freshened during the cold and dry seasons. Cows that freshened during the cold season were heavier at calving (p<0.05) than cows that freshened during the dry season. Results from Italian (Licitra *et al*., 1998), Mexican (Carvajal-Hernández *et al*., 2002), Turkish (Koc, 2011) and Pakistani (Javed *et al*., 2004) studies with Holstein Friesian cows showed that winter (December to February) calving cows had similar milk yield per lactation to spring (March to April) calving cows, in conformity with present comparison. However, the calving season effect on milk yield per lactation observed in the present investigation is not in agreement with that of Afridi (1999), who informed that Holstein Friesian cows that calved during the spring season had significantly greater milk yield than those that calved during the winter season (3215 vs. 2891 kg). In a more recent study performed in Pakistan with imported Holstein Friesian cows from Denmark and their farm-born daughters (Bilal *et al*., 2008) no effect of calving season on milk yield was observed. For this last study, the values for milk yield among seasons were 3617.50±148.88, 3705.27±168.42, 3607.23±160.54 and 3615.07±151.78 kg for winter, spring, summer and autumn, respectively.

Non-significant differences were observed in lactation length between cows that calved during the cold (349±6.1 days), dry (360±6.2 days) and rainy (350±5.7 days) seasons in the current research. Carvajal-Hernández *et al*. (2002) and Bilal *et al*. (2008), for Holstein Friesian cows, Shubha Lakshmi *et al*. (2009), for Holstein Friesian×Sahiwal cows and Zulkadir *et al*. (2009), for Brown Swiss cows, reported that season of calving did not affect lactation length, in conformity with present findings.

Lactation number effects: In general, milk yield per lactation, milk yield per day, milk yield per calving interval, efficiency of milk production and cow weight at calving increased with increased lactation number. Cows of first lactation yielded less milk per lactation, per day and per calving interval and were less efficient than second-, third- and fourth-lactation cows and older ($p<0.05$). Second-lactation cows yielded less milk per lactation, per day and per calving interval and were less efficient than cows of third and fourth lactations and older ($p<0.05$). Milk yield per lactation, milk yield per day, milk yield per calving interval, efficiency of milk production and cow weight at calving did not significantly differ between third- and fourth-lactation cows. With Holstein Friesian cows reared under tropical conditions of Sudan, Gader *et al*. (2007) also found that third- and fourth-parity dams and kaya had greater milk yield per lactation and milk yield per day than first- and second-parity dams and that second-parity dams had greater milk yield per lactation and milk yield per day than first-parity dams, in agreement with the present research. Magalhães *et al*. (2006) and Guler *et al*. (2009), using Holstein Friesian cows, observed that the effect of lactation number on cumulative milk yield at 305 days and total test day milk yield showed an identical pattern to that on calving weight and milk yield traits evaluated in the present study. In Holstein Friesian cows under Mexican conditions, Palacios-Espinosa *et al*. (2001) observed higher milk production adjusted to 305 days as lactation number increased from one through three. On the contrary, Ngodigha and Etokeren (2009), working with crossbred cows of different Holstein Friesian inheritance (50, 75, 87.5 and 100%), found that first- (4554±469 kg), second- (5427±455 kg) and third-parity dams (5139±441 kg) yielded more milk than fourth-parity dams (2896±430 kg).

In the present study, dams of first, second, third and fourth parities did not differ in lactation length ($p>0.05$). Similarly, Carvajal-Hernández *et al*. (2002) found that parity number did not affect lactation length of Holstein Friesian cows under tropical conditions of Mexico. Ahmed *et al*. (2004) reported that parity number did not affect lactation length in Local Zebu×Holstein Friesian, Local Zebu×Sindhi and Sahiwal×Holstein Friesian cows maintained in Bangladesh. In contrast, Gader *et al*. (2007) noted that first-, second- and third-parity dams had greater lactation lengths than fourth-parity dams and Kaya *et al*. (2003) reported that first-parity Holstein-Friesian dams showed longer lactations than second-, third- and fourth-parity Holstein-Friesian dams.

CONCLUSION

Holstein Friesian cows had greater milk yield, weighed more at calving and were more efficient than Brown Swiss cows. Taking into consideration the environmental conditions and management and feeding practices of the present study, average milk production attained by these breeds is considered acceptable. Milk yield traits and cow weight showed a significant increasing trend from first to fourth lactation. Milk yield was maximum during the cold and dry seasons and minimum during the rainy season, indicating that calving season also has a great influence on this trait. Milk yield improvement in the experimental dairy population evaluated would require improving management practices, reducing environmental effects and/or identifying the best breeding animals for successful selection. When computing breeding values for selection purposes, milk yield traits evaluated here should be adjusted for environmental effects.

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