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Effects of production stage and fertility traits on milk production of pasture-grazed Holstein and Jersey cows in a Mediterranean-type climate region

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Abstract

The aim of this study was to compare the milk production of Holstein and Jersey cows on pasture as affected by parity, lactation stage, calving season, age at first calving, and calving interval. Test-day lactation records of 122 Holstein and 99 Jersey cows, varying from parities 1 to 6, were collected using standard milk recording procedures. Cows were managed and kept as one herd on kikuyu over-sown with ryegrass pasture and received 7 kg of concentrate (as fed) containing 170 g/kg crude protein per day. Across parities, the means for milk yield, milk fat, milk protein, dry matter intake, and body weight were 23.8 ± 6.2 and 17.9 ± 4.4 kg/day; 3.89 ± 0.03 and 4.66 ± 0.03%; 3.17 ± 0.02 and 3.59 ± 0.02%; 17.8 ± 2.6 and 14.4 ± 2.1 kg/day; and 567 ± 3.49 and 411 ± 3.84 kg for Holstein and Jersey cows, respectively. Milk yield increased by 26.5% in Holsteins and 23.7% in Jerseys from first to fourth lactation. Mean lactation number was 2.5 ± 0.15 and 3.0 ± 0.17; test-day milk yield for summer was 21.2 ± 0.28 and 16.5 ± 0.31 kg/day; and winter was 21.3 ± 0.28 and 16.4 ± 0.32 kg/day; age at first calving was 26.4 ± 0.3 and 26.2 ± 0.3; and inter-calving period was 13.9 ± 0.18 and 13.2 ± 0.17 months, for Holstein and Jersey cows, respectively. With inter-calving periods of 13 months, 13.1 to 15.0 and above 15 months, the 305-day Holstein cow milk yield was 7324 ± 181, 7768 ± 193, and 7927 ± 211 kg, whereas that of Jerseys was 5400 ± 135, 5621 ± 244, and 5724 ± 234 kg, respectively. In this study, Jerseys performed better than Holsteins in lactation number and calving interval. Holsteins, however, had a higher increase in milk yield from first to fourth lactation, whereas age at first calving did not differ.

Keywords: age at first calving, calving season, dry matter intake, inter-calving period, lactation stage, parity

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Introduction

Milk sales represent the largest proportion of income in a dairy farm, making milk production the major factor influencing the net return. Fertility traits such as age at first calving (AFC), inter-calving period (ICP), and days open (Bajwa *et al.,* 2004; Kunaka & Makuza, 2005; Pirzada, 2011; Nyamushamba *et al.,* 2014; Al-Samarai *et al.,* 2015) greatly affect milk production. Prolonged intervals in these traits are a constraint to farm profitability because of the high maintenance costs of non-productive animals (Muller, 2017). Other disadvantages associated with prolonged intervals include extra semen costs and extra labour charges for failed artificial inseminations, fewer replacement heifers, and higher involuntary culling of the cows because of failure to become pregnant. The expression of most fertility traits is attributed to environmental factors, management practices such as provision of nutritious feed, timely heat detection, and breeding.

Production stages such as lactation stage and parity also affect milk yield because milk production is a physiological process that is characterised by a rapid increase in milk yield in the first weeks post-calving (Keown & Van Vleck 1973; Drackley *et al.*, 2005), reaching a peak at four to eight weeks post-calving and declining afterwards until the cows are dried off (National Research Council, 1989). The composition of milk is not constant either. It changes throughout the lactation period, corresponding inversely to milk yield (Linn, 1988). With lactation number, multiparous cows produce more milk than their primiparous counterparts as their mammary glandular tissue is fully developed. Moreover, the nutrients consumed by multiparous cows are partitioned only towards maintenance and milk production, whereas primiparous cows also need nutrients for

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growth. A decline in milk yield is often observed from the fourth or fifth lactation because of the degeneration of the body systems that are associated with the recurring pregnancies (Nyamushamba *et al.,* 2014).

Using feeding systems, dairy production systems are classified into pasture-based and total mixed ration (TMR) systems (Gertenbach, 2007). Pasture-based cows produce less milk than those on the TMR system. However, a marked shift in dairy herds to areas that are more pasture-based, for example, Tsitsikama in the Eastern Cape of South Africa, has been observed (Theron & Mostert, 2009). Growing interest in pasture-based systems has also been reported in some parts of the United States, although the trend is not conclusive (Winsten *et al.,* 2010; Haan *et al.,* 2011). This is because the lower production costs on pastures that are managed efficiently yield better net farm profit than the TMR system (McCarthy *et al.,* 2007; Alvarez *et al.,* 2008; Theron & Mostert, 2009). Most farms in the Western Cape practice the TMR system (Gertenbach, 2007), even though the province has the largest producer numbers (348) and is the top milk-producing province in South Africa, with approximately 31% of country's total milk, followed by KwaZulu-Natal and the Eastern Cape (MilkSA, 2021). The use of the TMR system in the Western Cape is probably because the climate there is different from that of other parts of South Africa. It is typically Mediterranean, characterized by moist, cool winters, and hot dry summers. This poses a challenge to plant growth as the plants have to cope with excessive heat and drought in summer and cold temperatures during the growing season (Porqueddu *et al.,* 2016) requiring hardy grass species to be planted (e.g., kikuyu grass) to cope with these conditions. Understanding the effects of calving season on milk production of cows grazing on kikuyu pastures in the Western Cape may improve the use of pastures by milk producers in this province.

The importance of fertility traits, milk production stages, and calving season in the milk production potential of the cow cannot be overemphasised. It is therefore essential that their effect on milk production, especially that of pasture-grazed cows, should be quantified so that their impact on farm income is better understood. The aim of this study was to compare the milk production of Holstein and Jersey cows on pasture as affected by parity, lactation stage, calving season, age at first calving, and calving interval.

Materials and Methods

The study was conducted at Elsenburg Research Station, Western Cape Department of Agriculture, in South Africa. This study did not require ethical approval for use of experimental animals as it used data from an existing database. The use of data was approved by the Information Officer for the Supply of Biological Specimens and other Data (Ref. No. 2015/001), Directorate: Animal Sciences, Western Cape Department of Agriculture, South Africa. Data consisted of lactation records of 122 Holstein and 99 Jersey cows, recorded from October 2005 to September 2014. These included cow birth date, calving date, lactation number, body weight (BW), milk yield (MY), percentage milk fat (MF), and percentage milk protein (MP), which were collected according to the National Milk Recording Scheme procedures, i.e., 10 recording dates per year.

Elsenburg is in the winter rainfall region of South Africa. According to the monthly weather reports obtained from the Agricultural Research Council (2018), the average rainfall there was 625 mm per annum over the experimental period of January 2004 to December 2014. The highest rainfalls were received from May to August. The lowest were in December to March, and vice versa with both minimum and maximum temperatures (Tables 1 and 2).

Cows were kept on a 45-hectare, kikuyu over-sown with ryegrass pasture, which contained on average 184 g/kg (dry matter; DM) of crude protein. The pasture was divided into camps in which cows grazed as one herd in one camp and were moved to the next when forage was insufficient. Limestone ammonium nitrate fertiliser was applied after moving the cows and the camp was allowed to rest and recover before being grazed again. Before the rainy season (April), cows were removed from pasture and the pasture was over-sown with ryegrass and allowed to grow until spring. During this period, cows were offered a pasture replacement mix of oat hay, lucerne, and soybean oilcake meal at a ratio of 55:30:15 ad libitum. In summer, the pasture was irrigated once a week. Pasture samples were collected monthly from 2011 to 2014 and proximate analysis was conducted (Table 3). Lactating cows were supplemented with 7 kg of a commercial concentrate mixture containing 170 g/kg (as fed) of crude protein that was split into two equal portions and offered to cows individually after each milking. Upon drying-off, cows were put on kikuyu pasture and received no supplements. Three weeks before the expected calving date, a steam-up feeding programme for dry cows was started. Feeding consisted of *ad libitum* oat hay, supplemented with a dry-cow concentrate mixture containing anionic salts to prevent the possibility of milk fever at calving. Concentrates were fed according to a step-up feeding system in which dry cows received 1 kg/d for the first week, 2 kg/d during the second week, and 3 kg/d during the third week until calving. After calving, the concentrate supplement was increased to 7 kg/cow/d.

Table 1 Monthly weather averages at Elsenburg (Western Cape) from 2004 to 2014 (adapted from Agricultural Research Council monthly weather data, 2018)

	Minimum temp	Maximum temp	Minimum RH	Maximum RH	Rain	Wind speed
January	14.82	29.74	27.95	66.72	13.02	3.01
February	14.83	29.64	28.43	67.00	18.28	2.68
March	13.24	28.11	28.93	67.16	18.96	2.59
April	11.17	25.08	29.13	67.35	43.70	2.53
May	9.42	20.38	38.72	68.73	77.46	2.26
June	7.79	17.78	46.95	77.22	114.77	2.42
July	7.13	18.14	45.89	77.04	97.06	2.50
August	7.24	17.45	47.20	77.60	89.04	2.65
September	7.83	19.36	43.15	76.02	62.41	2.57
October	9.76	22.84	36.15	74.65	46.56	2.44
November	11.47	24.95	34.51	74.43	49.13	2.93
December	13.52	28.04	31.60	72.90	12.67	2.86

RH: relative humidity, Temp: temperature

Table 2 Seasonal weather averages at Elsenburg (Western Cape) from 2004 to 2014 (adapted from Agricultural Research Council monthly weather data, 2018)

	Autumn	Winter	Spring	Summer
Minimum temperature (°C)	11.28	7.38	9.69	14.35
Maximum temperature (°C)	24.52	17.79	22.38	29.09
Minimum relative humidity (%)	32.26	46.68	37.93	28.37
Maximum relative humidity (%)	67.75	77.29	75.04	66.67
Rain (mm)	46.71	100.29	52.70	15.00
Wind speed (km/hour)	2.46	2.52	2.65	2.84

Table 3 Average monthly nutrient composition of the Elsenburg kikuyu/ryegrass pasture from 2011 to 2014

Average/month	DM	CP (%)	Fat (%)	NDF (%)	Ca	P	Ash (%)
October	22.2	16.8	3.3	53.8	0.5	0.4	9.5
November	21.9	18.4	3.2	54.4	0.5	0.4	9.5
December	21.9	18.3	3.2	55.4	0.5	0.4	10.0
January	21.5	18.0	3.1	55.9	0.5	0.5	10.4
February	21.9	17.5	2.9	55.4	0.4	0.4	10.6
March	21.4	17.8	3.1	53.7	0.4	0.5	9.6
Summer Average	**21.8**	**17.8**	**3.1**	**54.8**	**0.5**	**0.4**	**9.9**
April	21.2	19.2	3.4	53.8	0.4	0.5	9.8
May	20.7	18.3	3.1	53.1	0.4	0.4	10.7
June	19.4	19.7	3.3	53.0	0.5	0.4	11.2
July	18.4	20.7	3.6	53.0	0.5	0.6	11.5
August	19.8	18.7	3.4	53.5	0.4	0.5	10.8
September	20.8	17.0	3.3	54.2	0.5	0.4	10.3
Winter Average	**20.0**	**18.9**	**3.4**	**53.4**	**0.4**	**0.5**	**10.7**

DM: dry matter intake, CP: crude protein, NDF: neutral detergent fibre, Ca: calcium, P: phosphorus

Cows were machine-milked twice a day and milk yield (MY)/day was the sum of the morning and afternoon milkings. Milk samples for MF and MP analyses were collected from each cow during the morning and afternoon milkings on milk recording test-days, which were at approximately five-week intervals. The morning and afternoon milk samples were pooled per cow and analysed using a Milko-Scan FT6000 (FOSS, Hillerød, Denmark). Total lactation MY was adjusted to 305 d, using the test interval method (Sargent, 1968; ICAR, 2017) as follows:

$$MY = (I_0M_1 + I_1) \times ((M_1 + M_2)/2) + I_2 \times ((M_2 + M_3)/2) + I_n\text{-}1 \times ((M_n\text{-}1 + M_n)/2) + I_nM_n$$

where: M_1, M_2, M_3, M_n = kg milk yield in the 24 hours of the recording day; I_1, I_2, I_{n-1} = intervals between recording dates in days; I_0 = interval between the lactation start date and the first recording date in days; and I_n = interval between the last recording date and the end of the lactation period in days.

Cow parity varied from 1 to 6. As parities progressed, the number of observations decreased. Cows from parities four to six were then grouped together. Data from cows with fewer than six test-day records per lactation were removed from the dataset. This resulted in a total of 4576 test-day records, i.e., 2315 records for Holstein and 2261 records for Jersey cows. To determine the change in performance over a lactation period, lactation was divided into four stages by creating class intervals from the days in milk as follows: calving to 30 d, post calving transition stage; 31–100 d, early lactation stage; 101–200 d, mid-lactation stage; and < 201 d, late lactation stage.

Calving was year-round with a voluntary waiting period of approximately 60 d before first insemination. Heat detectors were put on cows after inspection of heat cycling by a veterinarian and they were inseminated with imported semen 12 h after observing the first standing heat, i.e., according to the 'am-pm and pm-am' rule. Bull selection for individual cows was through a computerized mating programme. To determine the effect of CS on milk production, calving dates were divided into two calving seasons, namely summer (October–March) and winter (April–September) and the lactation records were classified according to these two seasons.

After birth, replacement heifers were kept in individual pens until three months old, after which they were moved to an open camp to learn to graze. In individual pens, they were offered colostrum within 6 h of birth, introduced to a calf starter diet after a week, and weaned from milk at six weeks old. In the camp, they were supplemented with a calf growth meal until they were six months old. From six months until mating, the heifers grazed on pasture and were offered a TMR formulated to satisfy their nutritional requirement during feed scarcity. Heifers were mated at the minimum age of 13 months or when they reached weights of 300 kg for Holsteins and 200 kg for Jerseys. Age at first calving (AFC) was calculated as the number of months from the date of birth of the cow to her first calving date. The AFC was then divided into intervals to determine its effect on the subsequent 305-d milk yield. The intervals were as follows: < 23.0 months; 23.1–25.0 months; 25.1 – 29.0 months; and > 29.0 months of age.

Calving interval was calculated as the number of days between subsequent calving dates, starting for each cow from lactation one. The ICP preceding the lactation was used to determine the effect of the length of the ICP on milk production in the subsequent lactation. The ICP ranges were created as follows: > 13.0 months; 13.1–15.0 months; and > 15.0 months (prolonged ICP).

Statistical analyses were performed using the repeated measures analysis of variance with the PROC MIXED procedure in the Statistical Analysis System (SAS) software package of SAS Enterprise Guide version 7.1. The analysis used a compound symmetry covariance structure for the residuals over time within cows. The equation used for statistical analysis was as follows:

$$Y_{ijklmno} = \mu + B_i + P_j + LS_k + CS_l + AFC_m + ICP_n + (B\times CS)_{il} + (B\times AFC)_{im} + (B\times ICP)_{in} + (B\times CS\times LS)_{ikl} + (B\times AFC\times P)_{ijm} + cow_o(B_i) + \varepsilon_{ijklmno}$$

Body weight and milk production traits ($Y_{ijklmno}$) were measured at fixed test-days in each parity. To account for individual variation in experimental units, cow within breed was fitted as a random effect. The fixed effects were breed (B_i), lactation stage (LS_k), calving season (CS_l), AFC_m, and ICP_n, whereas parity (P_j) was a repeated measure. The two and the three-way interaction effects were B×CS, B×AFC, B×ICP, B×CS×LS, and B×AFC×P.

Results and discussion

The mean test-day BWs, mature BWs, and estimated DMIs of Holstein and Jersey cows were 567 ± 3.49 kg and 411 ± 3.84 kg; 589 ± 5.84 kg and 428 ± 5.34 kg; and 17.8 ± 0.11 kg/d and 14.4 ± 0.12 kg/d, respectively. The overall test-day means for kg MY, %MF, and %MP of Holsteins were 23.8 ± 0.22 kg, 3.89 ± 0.03%, and 3.17 ± 0.02%, whereas those of Jerseys were 17.9 ± 0.24 kg, 4.66 ± 0.03%, and 3.59 ± 0.02%, respectively, indicating the suitability of Jerseys for component pricing. When expressed as mean daily kg yield for the overall test-days, Holsteins produced on average more kg of MF (0.92 ± 0.01 and 0.83 ± 0.01 kg/d) and more kg of MP (0.75 ± 0.01 and 0.64 ± 0.01 kg/d) than Jerseys, respectively. This is equivalent to approximately 10% more MF (kg) and 15% more MP (kg) per day than Jersey cows. Holsteins produced on average 7217 ± 64.2 kg and Jerseys 5349 ± 70.1 kg of milk/cow when adjusted to a 305-d lactation yield, indicating that Jerseys produced on average 74.1% of the amount of milk that Holsteins produced. A comparable ratio (73%) was observed in South African commercial herds (Anonymous, 2016), in which Holstein and Jersey cows were reported to produce 7937 kg and 5791 kg of milk/cow per lactation. These findings indicated that Holsteins were a better breed for liquid pricing than Jerseys.

On average Jerseys had more (*P* =0.04) lactations (3.0 ± 0.17) than Holsteins (2.5 ± 0.15). This is in agreement with the findings of several authors who used records of cows from the performance scheme databases in their countries, for example, 2.88 and 3.09 in South Africa (Theron & Mostert, 2009); 2.54 and 3 in North Carolina, United States (Capper & Cady, 2012); and 2.4 and 3.0 for registered herds; and 2.7 and 3.2 for commercial herds in South Africa (Anonymous, 2016) for Holstein and Jersey cows, respectively.

In both breeds, milk production increased with parity, but milk yield of cows with parities between four and six did not differ (Figure 1). Cows in these parities were thus grouped together into one parity to make a group of parity four and higher (parity 4+) cows in further statistical analysis for all measured traits. The rise in MY suggested an increase in the development and capacity of the mammary glandular tissue of multiparous cows over that of the primiparous cows. Moreover, the dry matter intake of both breeds increased with parity (Table 1), suggesting that the excess feed consumed was assigned to milk production. Several authors have reported a positive relationship between dry matter intake and milk yield. In Ireland, Krpálková *et al.* (2021) reported the highest milk yield with the highest feed intake in Holstein cows that were kept in individual stalls and received a TMR diet. In their meta-analysis from feeding trials involving Holstein cows conducted in the United States and Canada, Hristov *et al.* (2004) found that stage of lactation improved the prediction of milk yield from nutrient intake. The increase in MY with parity was observed to reach peak by the fourth or fifth lactation, followed by a decline (Bajwa *et al.*, 2004; Amimo *et al.*, 2007; Jingar *et al.*, 2014; Nyamushamba *et al.*, 2014). In South African dairy herds, Muller & De Waal (2013) reported a peak lactation at third parity in both breeds, followed by decline from fourth parity, with Holsteins reaching production levels 14% lower than that of their first lactation by the seventh lactation, whereas Jerseys' milk was still 6.6% higher than their first lactation in their tenth lactation. Vijayakumar *et al.* (2017) also reported the highest MY during the third lactation in Holstein cows in Korea, followed by a decline in the fourth lactation. In both Holstein and Jersey cows, the decline can be associated with degeneration of the body systems over recurring pregnancies (Nyamushamba *et al.*, 2014). The absence of a declining trend in milk production from the fourth to the sixth parity in the current study could be associated with the decrease in the number of observations as parities progressed. Combined parity five and six observations were 8.7% for Holsteins and 10.7% for Jerseys as a percentage of total observations. The large standard error of means observed in parities five and six (Figure 1) may be an indication that the sample size was small and therefore not representative of the true mean.

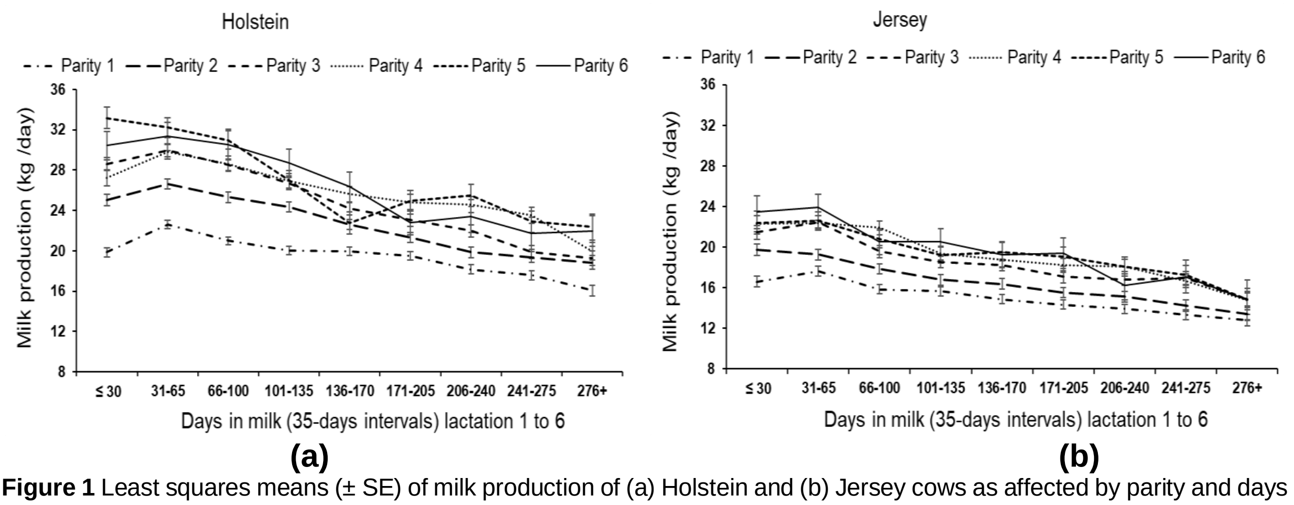

Figure 1 Least squares means (± SE) of milk production of (a) Holstein and (b) Jersey cows as affected by parity and days in milk

The increase in MY from first lactation to parity 4+ was higher in Holsteins (26.5%) than in Jerseys (23.7%). Using data of fortnightly test-day milk yields of Karan Friesland cows in India, comparable findings (25.2%) were reported by Jingar *et al.* (2014), i.e., 11.8 kg for primiparous and 15.77 kg for combined parities

4+, but only on initial milk yield after calving. The lower lactation numbers in the two breeds are concerning as they suggest a loss of ± 25% in milk sales. A productive lifespan of at least four lactations (de Vries, 2006; Sawa *et al.*, 2013) can improve income as the cow can produce more milk during her lifetime and this reduces replacement costs because fewer heifers need to be reared to replace the cows that leave the herd (Mohd Nor *et al.,* 2014; de Vries & Marcondes, 2020). A longer productive life may also result in more calves being born; surplus heifers can be sold for additional farm income (Muller & de Waal, 2013).

In Holsteins, MY increased soon after calving (transition period) and reached a peak yield during the early lactation stage of 31–65 d in milk. This was followed by a gradual decrease in subsequent stages (Table 1). In Jerseys, however, MY during the transition and early lactation stages did not differ (Table 1), suggesting that Jersey cows reached the peak MY in the first four weeks post-calving. According to the National Research Council (1989), milk production usually peaks at 4–8 weeks post-calving and starts declining thereafter. In mid- to late lactation, partitioning of nutrients moves away from milk production so that body reserves are replenished for the next calving (Garnsworthy, 1988).

In both breeds, %MF increased up to the second lactation and started to decline from the third lactation. Percentage MP did not differ between primiparous and second lactation Holsteins, but decreased from the third parity, whereas in Jerseys it increased up to the third parity and remained constant thereafter. With the increase in MY with parity, a decrease in %MF and %MP is expected as MY is negatively correlated to the solid components (Linn, 1988; Kunaka & Makuza, 2005; Sneddon *et al.,* 2015; Campbell & Marshall, 2016; Anonymous, 2017). The increase in MY, however, compensates for the decrease in the percentage of solid components, resulting in a higher MF (kg) and MP (kg) yield as parities progress (Table 1).

The lowest %MF and %MP produced in both breeds was in the early lactation stage, coinciding with peak MY. With the decrease in MY, both traits increased from mid-lactation, reaching the highest level during late lactation. Although Jersey MY was slightly higher during the transition period compared to early lactation, %MF and %MP were higher in the transition period compared with the early lactation stage in both breeds. The higher %MF during the transition period is suggestive of the mobilisation of lipids in response to the high energy requirements of the fresh cow. Lipid mobilisation results in an increase in the concentration of non-esterified fatty acids (NEFA) in the bloodstream (Bielak *et al.,* 2016). The NEFA may be utilised by peripheral tissues as a source of energy and by the mammary gland for milk fat synthesis (Block, 2010). Adewuyi *et al.* (2005) reported that ~40% NEFA are utilised for milk fat synthesis in the first days of lactation. The higher %MP can be attributed to the colostrum that may still be present in the transition milk (Tsioulpas *et al.,* 2007). The result is therefore a higher percentage of milk components in the transition period, followed by a decline during the first two months of lactation, and a slow increase again as lactation progresses (Linn, 1988). Because of the decrease in MY with progressing lactation stage, the MF (kg/day) and MP (kg/d) also decreased with lactation stage in both breeds (Table 1).

The calving season ($P = 0.94$) and the interaction effect of breed × calving season ($P = 0.53$) did not affect the mean test-day MY, being 21.2 ± 0.28 and 21.3 ± 0.28 kg/d in Holsteins, and 16.5 ± 0.31 and 16.4 ± 0.32 kg/d in Jerseys for summer and winter, respectively. The interaction effect of breed × calving season × days in milk (lactation stage) was, however, significant ($P < 0.05$). In both breeds, cows that calved in winter showed an increasing MY from transition to early lactation and a more pronounced peak yield in early lactation, followed by a steep decline until the cows were dried off (Figure 2). The decrease in mean MY from early lactation to late lactation was from 26.2 ± 0.44 to 16.0 ± 0.53 kg/d in Holsteins and 20.0 ± 0.48 to 12.2 ± 0.58 kg/d in Jerseys, i.e., 39% decrease in both breeds. For cows that calved in summer, a 28% decrease in mean MY was observed in both breeds, i.e., from 24.6 ± 0.44 to 17.8 ± 0.51 kg/d in Holsteins and 19.3 ± 0.45 to 14.0 ± 0.50 kg/d in Jerseys, possibly indicating improved feeding conditions towards the end of the lactation period in the winter rainfall area. Because of this, the lactation curve of the cows that calved in summer tended to be flatter (Figure 2), indicative of lactation persistency compared with those that calved in winter. Because cows with high lactation persistency are reported to be less susceptible to nutritional disorders and possible more fertile as a result thereof (Hickson *et al.,* 2006; Mostert *et al.,* 2008; Tullo *et al.,* 2014), summer can be seen as an ideal calving season in the Western Cape.

Age at first calving (AFC) of Holstein and Jersey cows in this study did not differ ($P = 0.62$) at 26.4 ± 0.3 and 26.2 ± 0.3 months, respectively. In contrast to this, in Italy, Dalla Riva *et al.* (2014) observed a younger AFC in Jerseys (26.0 months) than in Holsteins (28.4 months). Anonymous (2016) also reported a younger AFC in Jerseys compared to Holsteins (26 and 28 months in commercial herds in South Africa), but in agreement with this study reported no breed differences (26 months) in registered herds. Another study concurring with the current study was by Beavers & Van Doormaal (2015) in Canada, who reported an average AFC of 25.8 months for both breeds.

The 29+ month AFC, primiparous Holsteins produced more milk compared with their counterparts in different AFC groups (Table 2). Thereafter, performance in relation to AFC was inconsistent, resulting in no difference in average lifetime yield with AFC in this breed (Table 2). In Jerseys, AFC had no effect on MY during the first and second parity (Table 2). Compared with other AFC intervals, Jersey cows whose AFC was 29+ months showed a marked increase in MY in the third and over-four (4+) lactations, resulting in a higher average lifetime MY in this group (Table 2).

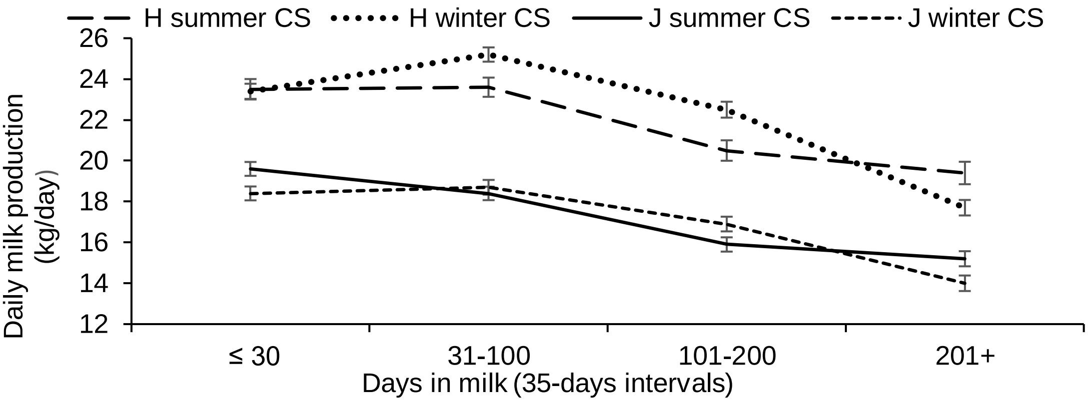

Figure 2 Least squares means (± SE) of daily milk production of Holstein and Jersey cows as affected by calving season and days in milk
H: Holstein, **J:** Jersey, **CS:** calving season

For both breeds, an AFC of 23.1–25 months old can be recommended as this may improve farm income by lowering the replacement costs. These heifers may also spend a greater proportion of their life producing milk, consequently, returning profit to a dairy farm business (Gröhn & Rajala-Schultz, 2000; Muller *et al.*, 2015).

Table 5 Least squares means (± SE) of 305-day milk production (kg) of Holstein and Jersey cows as affected by age at first calving and parity

	Parity	< 23.0	23.1–25.0	25.1–29.0	29+	P
Holstein MY	Parity1	6 088 ± 255[b]	5 984 ± 157[b]	5 928 ± 106[b]	6 849 ± 200[a]	<0.05
	Parity2	7 325 ± 317[a]	6 924 ± 184[a]	7 067 ± 142[a]	7 247 ± 243[a]	>0.05
	Parity3	7 392 ± 372[bc]	7 964 ± 239[a]	7 815 ± 169[ab]	7 169 ± 294[c]	<0.05
	Parity4	7 704 ± 351[b]	7 947 ± 222[ab]	8 186 ± 186[a]	8 032 ± 261[ab]	<0.05
	Avg lifetime MY	7 127 ± 203[a]	7 205 ± 125[a]	7 249 ± 93[a]	7 324 ± 157[a]	>0.05
Jersey MY	Parity1	4 439 ± 226[a]	4 651 ± 171[a]	4 612 ± 131[a]	4 719 ± 200[a]	>0.05
	Parity2	5 103 ± 316[a]	5 331 ± 204[a]	5 013 ± 141[a]	5 046 ± 233[a]	>0.05
	Parity3	5 529 ± 340[ab]	5 698 ± 234[ab]	5 503 ± 161[b]	5 980 ± 278[a]	<0.05
	Parity4	5 974 ± 332[ab]	5 934 ± 198[b]	5 766 ± 157[b]	6 477 ± 285[a]	<005
	Avg lifetime MY	5 261 ± 190[ab]	5 404 ± 129[a]	5 224 ± 93[b]	5 556 ± 155[a]	<0.05

[a-c] Means within rows with different superscripts differ at P <0.05
MY: milk yield, Avg: average

Holsteins had a higher inter-calving period (ICP) than Jerseys (13.9 ± 0.18 and 13.2 ± 0.17 months, respectively; P = 0.01). Parity did not have an effect on the ICP (*P* = 0.64). Numerous authors have also reported a longer ICP in Holsteins than in Jerseys, i.e., Capper & Cady (2012) in North Carolina, United States, 14.1 and 13.7 months; and Dalla Riva *et al.* (2014) in Italy, 432 d (14.3 months) and 385 d (12.7 months). In cows participating in the National Dairy Animal Improvement Scheme in South Africa, Mostert *et al.* (2010) reported a longer ICP in Holsteins (398, 394, and 395 d) compared with Jerseys (389, 385, and 389 d) for the first three calving intervals, respectively. Holsteins are often reported to have a longer and more intense negative energy balance (NEB) post-calving (Rastani *et al.,* 2001; Friggens *et al.,* 2007). Excessive NEB is associated with delayed ovulation (Podpečan *et al.,* 2007), a possible reason for the longer ICP observed in this breed.

Table 4 The mean (± SE) test-date production parameters and estimated daily feed intake of Holstein and Jersey cows by parity and lactation stage

	Parity										
	1		2		3		4+		P-values		Interactions
	H	J	H	J	H	J	H	J	Breed	P	B × P
No. of records	891	737	579	541	395	437	450	546			
BW (kg)	510^{d} ± 3.49	372^{h} ± 3.87	560^{c} ± 3.59	404^{g} ± 3.94	588^{b} ± 3.68	427^{f} ± 3.99	612^{a} ± 3.71	441^{e} ± 3.99	<0.05	<0.05	<0.05
DMI (kg)	15.7^{d} ± 0.11	12.9^{g} ± 0.12	17.6^{c} ± 0.12	14.0^{f} ± 0.13	18.5^{b} ± 0.13	15.1^{e} ± 0.14	19.3^{a} ± 0.14	15.7^{d} ± 0.14	<0.05	<0.05	<0.05
Milk (kg)	20.0^{d} ± 0.23	15.7^{g} ± 0.26	23.2^{c} ± 0.27	17.1^{f} ± 0.28	25.4^{b} ± 0.30	19.1^{e} ± 0.30	26.7^{a} ± 0.31	19.9^{d} ± 0.30	<0.05	<0.05	<0.05
MF (%)	3.88^{e} ± 0.03	4.58^{c} ± 0.03	3.96^{d} ± 0.03	4.71^{a} ± 0.03	3.88^{e} ± 0.04	4.68^{b} ± 0.04	3.84^{f} ± 0.04	4.67^{b} ± 0.04	<0.05	<0.05	<0.05
MP (%)	3.19^{d} ± 0.02	3.51^{c} ± 0.02	3.21^{d} ± 0.02	3.59^{b} ± 0.02	3.15^{e} ± 0.02	3.63^{ab} ± 0.02	3.14^{e} ± 0.02	3.65^{a} ± 0.02	<0.05	<0.05	<0.05
MF (kg/d)	0.77^{g} ± 0.01	0.71^{h} ± 0.01	0.91^{d} ± 0.01	0.80^{f} ± 0.01	0.97^{b} ± 0.01	0.89^{de} ± 0.01	1.02^{a} ± 0.01	0.93^{cd} ± 0.01	<0.05	<0.05	<0.05
MP (kg/d)	0.63^{e} ± 0.01	0.55^{f} ± 0.01	0.74^{c} ± 0.01	0.61^{e} ± 0.01	0.79^{b} ± 0.01	0.69^{d} ± 0.01	0.83^{a} ± 0.01	0.72^{c} ± 0.01	<0.05	<0.05	<0.05

	Lactation stage (days in milk)										
	<30		31–100		101–200		201+		P-values		Interactions
	H	J	H	J	H	J	H	J	Breed	LS	B × LS
No. of records	228	204	581	561	798	776	708	720			
BW (kg)	555^{c} ± 3.76	407^{e} ± 4.12	552^{c} ± 3.57	399^{f} ± 3.92	569^{b} ± 3.54	410^{e} ± 3.89	594^{a} ± 3.57	429^{d} ± 3.90	<0.05	<0.05	<0.05
DMI (kg)	14.1^{f} ± 0.15	11.7^{g} ± 0.16	18.4^{c} ± 0.12	14.8^{e} ± 0.13	19.4^{a} ± 0.12	15.7^{d} ± 0.12	19.2^{b} ± 0.12	15.5 ± ^{d} 0.13	<0.05	<0.05	<0.05
Milk (kg)	25.3^{b} ± 0.33	19.9^{de} ± 0.35	26.5^{a} ± 0.26	19.5^{e} ± 0.27	23.3^{c} ± 0.28	17.1^{f} ± 0.25	20.3^{d} ± 0.26	15.3^{g} ± 0.26	<0.05	<0.05	<0.05
MF (%)	4.03^{d} ± 0.04	4.57^{c} ± 0.04	3.66^{f} ± 0.03	4.50^{c} ± 0.03	3.81^{e} ± 0.03	4.70^{b} ± 0.03	4.05^{d} ± 0.03	4.88^{a} ± 0.03	<0.05	<0.05	<0.05
MP (%)	3.20^{e} ± 0.02	3.51^{c} ± 0.03	2.94^{f} ± 0.02	3.40^{d} ± 0.02	3.14^{e} ± 0.02	3.64^{b} ± 0.02	3.41^{d} ± 0.02	3.83^{a} ± 0.02	<0.05	<0.05	<0.05
MF (kg/d)	1.01^{a} ± 0.01	0.91^{c} ± 0.02	0.97^{b} ± 0.01	0.87^{d} ± 0.01	0.88^{d} ± 0.01	0.80^{a} ± 0.01	0.81^{e} ± 0.01	0.74^{f} ± 0.01	<0.05	<0.05	0.39
MP (kg/d)	0.80^{a} ± 0.01	0.70^{cd} ± 0.01	0.78^{a} ± 0.01	0.66^{e} ± 0.01	0.73^{bc} ± 0.01	0.62^{f} ± 0.01	0.69^{d} ± 0.01	0.58^{g} ± 0.01	<0.05	<0.05	0.70

$^{a-h}$ Means within rows with different superscripts differ at P <0.05
BW: body weight, **DMI:** total dry matter intake, **H:** Holstein, **J:** Jersey, **MF:** milk fat, **MP:** milk protein

Table 6 Least squares means (± SE) of 305-day milk production (kg) of Holstein and Jersey cows as affected by inter-calving period and parity

	Parity		<13.0 months	13.1–15.0 months	>15.0 months	P
Holstein MY	Primiparous	6 091 ± 77				
	Parity 2		7 928 ± 148[b]	7 151 ± 177[ab]	7 281 ± 195[a]	<0.05
	Parity 3		7 360 ± 181[b]	7 993 ± 227[a]	8 003 ± 236[a]	<0.05
	Parity 4		7 683 ± 213[b]	8 161 ± 174[a]	8 498 ± 201[a]	<0.05
	Avg lifetime MY	6 091 ± 77[c]	7 324 ± 181[b]	7 768 ± 193[a]	7 927 ± 211[a]	<0.05
Jersey MY	Primiparous	4 614 ± 86				
	Parity 2		5 075 ± 127[a]	5 119 ± 236[a]	5 123 ± 220[a]	>0.05
	Parity 3		5 445 ± 144[b]	5 707 ± 301[ab]	5 925 ± 246[a]	<0.05
	Parity 4		5 678 ± 135[b]	6 037 ± 195[a]	6 125 ± 236[a]	<0.05
	Avg lifetime MY	4 614 ± 86[c]	5 400 ± 135[b]	5 621 ± 244[a]	5 724 ± 234[a]	<0.05

[a-c] Means within rows with different superscripts differ at P <0.05
MY: milk yield, Avg: average

In both breeds, cows with an ICP of less than 13 months consistently had a lower milk yield in all parities and consequently a lower lifetime yield compared with cows with ICPs of 13.1–15.0 and >15.0 months (which were similar, P >0.05) (Table 3). The lower milk yield with shorter ICP suggests insufficient accumulation of body reserves, which is often associated with fewer days open or a shorter dry period. Therefore, an ICP of 13 months as recommended in most studies cannot be seen as suitable for Holstein and Jersey cows reared on pasture. An ICP of 13.1+ months can be recommended for Holstein and Jersey cows in a pasture-based system.

Conclusion

Holstein and Jersey cows differ in performance, with Jersey cows showing superiority over Holsteins in lactation number and inter-calving period. Holsteins, however, had a higher increase in milk yield from first to fourth lactation compared to Jerseys, whereas age at first calving does not differ. Although calving season did not affect the mean test-day milk yield in the two breeds, it affected the shape of the lactation curve, with summer-calving cows having a flatter lactation curve than winter-calving cows. Improving the productive lifespan to a minimum of four lactations, allowing the cows an inter-calving period of 13.1–15 months, and breeding the heifers to calve when they are at least 23.1–25 months old could have a positive effect on farm income.

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Conflict of Interest Declaration

The authors certify that they have no affiliations with any organization or entity with financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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