Comparative performance of dairy cows in low-input smallholder and high-input production systems in South Africa

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Abstract

The aim of this study was to benchmark the performance of dairy cows in the low-input smallholder system against their counterparts in the high-input system, in South Africa. Data comprised of cow performance records from the national dairy recording scheme. Performance measures included production (305-day yields of milk, fat and protein), lactation length, Somatic cell count (SCC) and reproductive traits, represented by age at first calving (AFC) and calving interval (CI). Least squares means of each trait were compared between the two systems, and lactation curves for production traits and SCC were plotted for each production system. Mean yields of milk, fat and protein were significantly ($P<0.05$) lower in the smallholder (4,097±165, 174±5.1 and 141±4.5 respectively) compared to the high-input system (6,921±141, 298±4.7 and 245±4.1 respectively). Mean lactation length was significantly ($P<0.05$) shorter for the smallholder (308±15.1) than the high-input system (346±12.8). Log-transformed somatic cell count (SCS) was, however, significantly ($P<0.05$) higher in the smallholder (2.41±0.01) relative to the high-input system (2.27±0.01). Cows in high-input herds showed typical lactation curves, in contrast to the flat and low peaking curves obtained for the smallholder system. Cows on smallholder herds had their first calving significantly ($P<0.05$) older (30±0.5) than those in the high-input system (27±0.5). There was, however, no significant difference ($P<0.05$) in CI between the two systems. These results highlight large room for improvement of dairy cow performance in the smallholder system and could assist in decision-making aimed at improving the productivity of the South African dairy industry.

Keywords: Lactation curve, production, reproduction, somatic cell count

Introduction

The importance of livestock production for food security and socio-economic development has been widely recognized (Ndambi *et al.,* 2007; Swanepoel *et al.*, 2010). In this regard, development of dairy production systems could be considered as an effective means to improve food security and income generation.

Dairy farming is an important socio-economic sector in South Africa (SA), consisting of approximately 2.7 million dairy cows (DAFF, 2016), with the main breeds being Ayrshire, Guernsey, Holstein and Jersey (Maiwashe *et al.,* 2006). However, the domestic supply of milk has not been able to meet the continuously increasing national demand. According to DAFF (2016), the importation of milk and milk products increased by 12.7%, from 35 674 tons during 2013, to 40 199 tons during 2014.

The South African dairy industry is heterogeneous, ranging from a low-input low-output smallholder system to a high-input, highly productive production system. The smallholder system is characterized by small herd sizes of between 2 and 50 cows per herd and low levels of production management. Feeding systems on these herds are generally constrained, influenced by agroecological factors and the farmer's socio-economic status. Natural pasture is the main feed source in smallholder systems, with limited supplementation. The high-input system, on the other hand, is highly developed and characterized by large herd sizes, exceeding a hundred cows per herd, with high levels of feeding and management (Lacto Data, 2016). The main feeding systems for dairy cattle on high-input herds are total mixed ration (TMR), supplemented pasture-based systems or a combination of both (Theron and Mostert, 2009).

Efforts have been in place for decades to improve dairy production in South Africa. A national dairy animal improvement Scheme (NDAIS) was established in SA in 1917 (Banga, 2000). This scheme was initially exclusive to stud and high-input commercial dairy cattle farmers. However, policy changes were initiated in recent years to include smallholder farmers in the scheme, with the aim of recording individual cow performance and ultimately implementing herd improvement programs (Banga, 2000).

Information on the performance of the smallholder sector is virtually non-existent. This is in contrast to the high-input system, which has been studied extensively and for which most phenotypic, genetic and economic parameters have been reported. This study forms part of a broader project, which aims to evaluate alternative smallholder dairy herd production models in South Africa. The aim of the current study was to benchmark the productive and reproductive performance, as well as udder health status, of dairy cows on smallholder herds against their counterparts in the high-input commercial production system.

Materials and Methods

Herds from both production systems were widely distributed in the various agro-ecological zones across South Africa. Data comprised of 305-day lactation and test-day records of multi-breed dairy cows (Holstein, Jersey, Ayrshire, Guernsey, Dairy Shorthorn, Brown Swiss, Crossbreds) from smallholder (SH) and high-input (H) herds participating in the National Dairy Animal Improvement Scheme (NDAIS) during the period 2004 and 2016. Lactation yields of milk, fat and protein were standardized to 305 days by considering production at 305 days in milk for lactations longer than 305 days and actual production for lactations shorter than 305 days. All cows that did not meet the following criteria were removed from analyses: missing milk, fat, protein or SCC records, missing birth date, calving date or having AFC less than 18 months or more than 55 months of age and test day data recorded less than 5 days after calving. A random sample of 10% of the high-input herds was selected for analysis, due to the large size of the dataset. The lactation length was measured as the number of days between calving date and the last censor lactation date within parity. The distribution of somatic cell count (SCC) (cells/ml) was skewed; hence it was transformed to $\log_{10}$ (SCC) or somatic cell score (SCS). The Statistical Analysis System version 9.4 (SAS Institute Inc. 2016) was used in data editing and removal of outliers. The final edited data set respectively consisted of 3,723 and 33,686 for 305-day lactation records, 18,972 and 106,446 test-day records of 1,450 and 28,677 cows from 57 smallholder and 103 high input herds respectively. The structures of the 305-day lactation and test-day datasets, after editing, are presented in Table 1.

Table 1 Structure of 305-day lactation and test-day data-set for smallholder and high-input production systems after editing

Dataset	Components	Smallholder	High input system
305 days lactation records			
	Milk yield (kg)	3,723	62,917
	Fat yield (kg)	3,580	59,524
	Protein yield (kg)	3,555	60,225
Test-day records			
	Milk yield (kg)	18,972	106,446
	Fat (%)	17,106	105,377
	Protein (%)	16,945	105,674
	Somatic cell count (cell/ml)	17,231	103,640
Reproductive records			
	Age at first caving	1,450	28,677
	Calving interval	658	18,973

Statistical analyses

The mean cow performance as measured by production (305-day yields of milk, fat and protein), lactation length, reproduction (age at first calving and calving interval) and udder health (SCS) were adjusted for the fixed effects and compared between the two systems, using the generalized linear model (GLM) procedure of the Statistical Analysis System (SAS, 2016). The model used is presented below in a matrix notation:

$$y = \mu + Xb + \varepsilon \qquad (1)$$

$\boldsymbol{where}$:

$\boldsymbol{y}$: is a vector of an observation for a performance trait; $\boldsymbol{\mu}$: is the overall population mean (performance traits); $\boldsymbol{b}$: is a vector of the fixed effects; $\boldsymbol{X}$: is an incidence matrix relating observations to fixed effects and $\boldsymbol{\varepsilon}$: is a random residual error, which, is assumed to be normally, independently and identically distributed with mean 0 and variance $\boldsymbol{\sigma_e^2}\left(\boldsymbol{i.e.e \sim N(0, I\sigma_e^2)}\right)$.

The fixed effects for production, lactation length and CI were herd year season (HYS) of calving, breed, production system and parity (excluded in the evaluation of CI). For AFC, the fixed effects were herd year season (HYS) of birth, breed and production system. The fixed effects for SCS were herd test-date, parity, lactation stage, breed and production system. The number of the contemporary groups varied for different traits and ranged from 181 to 973 and 836 to 1915, in smallholder and high-input systems, respectively.

Lactation curves for the production traits and SCS were plotted for each production system, using the test-day data. The curves were obtained by regressing the means of each performance trait on days in milk.

Results

This study aimed to benchmark the performance of smallholder dairy cows against their counterparts in the high-input production system. Unequal records and breeds used may have influenced the results of this study. These results provide baseline information on the production performance of dairy cows in the two production systems. The estimated least squares means with standard errors for the studied traits are presented in Table 2.

Table 2 Least squares means and standard errors (LSM ± SE) for, 305-day yields of milk, fat and protein, somatic cell score, age at first calving and calving interval for cows in smallholder (SH) and high-input (H) commercial systems in South Africa

System	Milk yield (kg)	Fat yield (kg)	Protein yield (kg)	LL (days)	SCS	AFC (months)	CI (days)
SH	4,097±165[a]	174±5.1[a]	141±4.5[a]	308±15.1[a]	2.41±0.01[a]	30±0.5[a]	444±6.9[a]
H	6,921±141[b]	298±4.7[b]	245±4.1[b]	346±12.8[b]	2.27±0.01[b]	27±0.5[b]	433±6.3[a]

Means within the same column with different subscripts are significantly different ($P<0.05$)

On average, dairy cows in the high-input system produced 40.8%, 41.7% and 42.5%, more milk, fat, and protein (kg), respectively, per 305-day lactation than those in the smallholder system. Fig 1 to 3 presents the respective average lactation curves of monthly test-day milk yield and composition (fat and protein percent) in the two production systems. Milk yield lactation curve (Fig 1) for cows in the smallholder had a much lower peak, compared to their counterpart in the high-input production system. As expected, fat and protein percentage (Fig 2 and 3), showed an opposite pattern to milk yield.

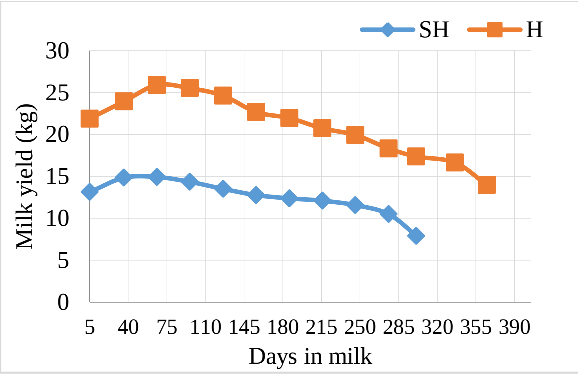

Fig 1 Lactation curves for the average test-day milk yield of smallholder (SH) and high-input (H) dairy cows

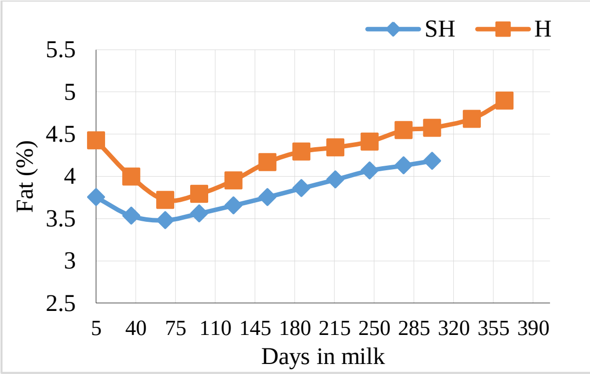

Fig 2 Lactation curves for the average test-day fat content of smallholder (SH) and high-input (H) dairy cows

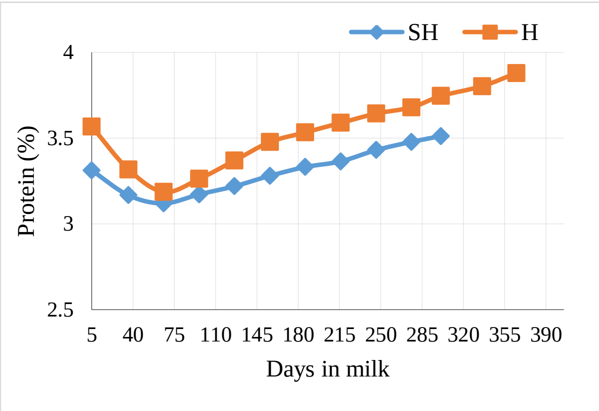

Fig 3 Lactation curves for the average test-day protein content of smallholder (SH) and high-input (H) dairy cows

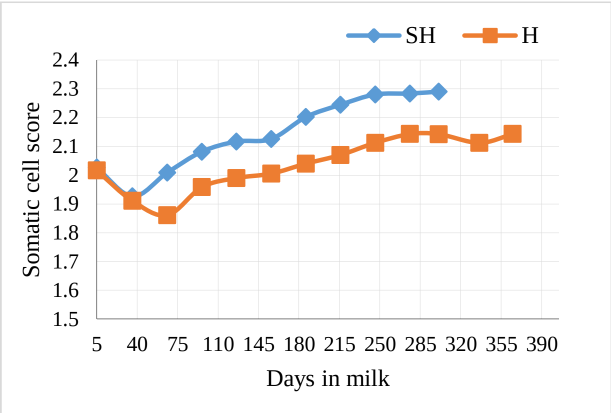

Fig 4 Lactation curves for the average somatic cell score of smallholder (SH) and high-input (H) dairy cows

The means of SCS was significantly ($P<0.05$) higher by 5.7% in the smallholder system (2.41±0.01), compared to the high-input system (2.27±0.01). These means are equivalent to the means SCC (cells/ml) of $257x10^3$ and $186x10^3$, for smallholder and high-input systems, respectively. Lactation curves of SCS decreased in the first 10 weeks after calving and then increased with progressing lactation in both systems, with a higher peak observed in the smallholder system (Fig 4).

Mean AFC differed significantly (P>0.05), with heifers in the smallholder system calving for the first time at an older age (30±0.5 months), compared to those in the high-input system (27±0.5 months). Means for CI did not differ significantly (P>0.05) between the two systems.

Discussion

Optimum production performance of a dairy cow is a pre-requisite for profitable and sustainable farming. For this reason, smallholder dairy cows' performance needs to be benchmarked against its competitive counterpart to determine their production potential, identifying production lag and setting up goals to assist in management for improvement of farming business. Benchmarking may entail a number of standard reports comparing cows' production and reproductive performance (Frandsen, 2015).

Milk production may be measured per lactation (usually standardized to 305 days) or as daily yield (Mostert, 2007). Cows in the smallholder system had produced significantly (P>0.05) less milk and milk components than those in the high-input system Cows in the smallholder system also produced less kilogram of milk, fat and protein per 305-day lactation compared to estimates reported in previous studies for South African dairy cattle. Theron and Mostert (2009) obtained least squares means (kg) of 5,347±1 156 and 8,147±2,260 for milk yield, 251±54 and 310±83 for fat yield and 200±43 and 262±70 for protein yield for South African Jersey and Holstein breeds, respectively. Recently, Goni (2014) reported least squares means (kg) of 5,398±95 and 6,141±10 for milk yield, 246±3.0 and 272±4.0 for fat yield and 194±2 and 246±3 respectively for Jersey and Fleckvieh x Jersey cows in South African herds. On the other hand, the estimated means 305-day milk, fat and protein yields (kg), for the high-input system are within the estimates reported by Theron and Mostert (2009) and generally higher than those reported by Goni (2014).

The flat and low peak lactation curves of cows in the smallholder system are a typical manifestation of inadequate feeding management (Burke *et al.,* 2010). Usually, such cows are in poor body condition with low body reserves at calving and are also not fed adequately during lactation. Even if they have the genetic potential for high production, cows may fail to express such potential due to insufficient energy or protein intake (Remppis *et al.,* 2011; Urdl *et al.,* 2015). The demand for energy is particularly high within 100 days after calving, when peak milk yield normally occurs. If this energy demand exceeds dry matter intake, as commonly in smallholder systems, this will affect both milk production and the animal's body condition. Delaby *et al.,* (2009) highlighted the sensitivity of milk yield to variation in feed intake and body reserves of dairy cows and indicated that feeding strategies have profound effects on milk quantity and quality, particularly in terms of peak yield and lactation. The observed lactation curves reflected the better feeding strategies in the high-input system.

Lactation length (LL) is an indicator of the persistency of milk production (Syrstad, 1993), which, is of particular importance in the tropics. The harsh tropical production environment adversely affects milk yield, which often results in high proportions of short lactations (Hossein-Zadeh, 2013). The mean lactation lengths of cows in both systems were relatively longer than the standard 305-day lactation periods. However, the mean lactation length differed significantly (P>0.05) between the studied systems. Cows in high-input herds, on average, milked for 38 days more than those in the smallholder system.

The low production performance of cows in the smallholder system is thus attributable to the flat and relatively short lactation curves. Peak production is one of the most important factors influencing lactation yield (Němečková *et al.*, 2015). There is also a positive association between the length of lactation and production (Alphonsus and Essien, 2012).

The routine recording of somatic cell count (SCC) in dairy recording schemes provides a means to reduce economic losses through the monitoring of udder health, milk quality and genetic selection (Mostert, 2007; Logar and Jeretina, 2015). High levels of SCC affect the price paid for milk and increase milk wastage. Elevated levels of SCC are also associated with higher culling rates (Sewalem *et al.*, 2006), and thereby increase replacement costs. Banga *et al.*, (2014) found SCC to be among the most important traits in the breeding objectives of South African Holstein and Jersey cattle. The cows in the smallholder system had 5.7% higher lactation average SCC than those in the high-input system. The observed mean SCC of 257×10^3 cells/ml is higher than the recommended threshold (200×10^3 cells/ml), indicating a high risk of udder infection among cows in the smallholder herds. On the other hand, the mean SCC for the high-input system was less than 200×10^3 cells/ml, indicating a lower rate of udder infection.

The difference in udder health between the two systems was apparent in the trends of SCS lactation curves. The elevated levels of SCS, in the current study, could be associated with the mammary gland defense mechanism, following parturition. As lactation progresses, the risk of udder infection increases and this may lead to extremely high levels of SCC, if cow udder health is not properly managed. Elevated levels of SCS observed in the smallholder system could be attributed to poor udder health management, which may also contribute to the lower production of cows on these herds, compared to those in the high-input system.

A number of measures, including AFC, CI, inseminations per conception, conception rate and non-return rate have been used to evaluate the reproductive performance of dairy cattle (Nieuwhof *et al.*, 1989;

Cassandro, 2014). Age at first calving and CI were used in the current study as they were the only ones available from the routinely recorded data. They are indicators of the female's age at reproductive maturity as well as its ability to conceive, calve and re-calve in the prevailing environment.

The mean AFC observed in the high-input system (27±0.48 months) is lower, while that for the smallholder system (30±0.47 months) is higher than the estimate of 29.4±5.2 months, reported by Muller *et al.*, (2014) for South African Holstein heifers and 26.2±3 months reported by Goni (2014) in a crossbred Fleckvieh and Jersey breed in South Africa. The mean AFC (months) for cows in the present study (30±0.47 and 27±0.48) were higher than the optimum age range of 22.5 to 23.5 months for a maximum lifetime profit (Meyer *et al.*, 2004; Do *et al.,* 2013).

Declining female fertility, indicated by an increasing trend in calving interval, has previously been cited as a problem in South African dairy cattle herds (Makgahlela *et al.,* 2008). Poor body condition as a result of a negative energy balance at calving, is associated with a poor postpartum ovarian activity or poor fertility. The poor body condition at calving of cows in the smallholder system, which can be inferred from the flat lactation curves, points to impaired fertility. This may partly explain the longer calving for cows in this system, compared to those on high-input herds.

In conclusion, these results have highlighted a comparably lower production performance, poor under health due to high SCC, and late AFC in smallholder system, compared to the high input system. Longer CI was observed in cows in the smallholder compared to the high-input system, although the difference was not significant. These results now provide baseline information on these indicators of cow performance, which is essential for identifying key focus areas or opportunities to improve smallholder dairy production. In addition, herds in each production system can be benchmarked on these performance indicators, in order to determine and monitor their performance vis-à-vis the average for the production system. Smallholder farmers need to select sires of appropriate genetic merit and adopt improved feeding strategies to increase cows' production and reproductive performance. Improved heifer rearing will result in a reduction in AFC, while optimum body condition score at calving will result in cows achieving high-peaking and longer lactations, as well as shorter CI. The smallholder farmers need to follow sound udder health management practices to reduce the relatively high level of SCC. Further research is underway to evaluate alternative management strategies to improve the performance of the smallholder dairy system.

Acknowledgment

The authors acknowledge the support from the University of Pretoria and the South African, Agricultural Research Council-Animal Production Institute.

Conflict of interest

The authors declare that they have no conflict of interest.

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