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MILK PRODUCTION TRAITS AMONG INDIGENOUS AND CROSSBRED DAIRY CATTLE IN SENEGAL

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ABSTRACT

Milk production and milk composition of various cattle breeds and their crosses in the North Central Peanut Basin of Senegal have been analysed. In total, 6082 records were collected from 1447 cows. But finally, only 1923 test-day records of milk volume were evaluated from 319 cows with 370 lactations during a longitudinal survey. A subset of 227 cows was used to determine the milk composition of the main breed-groups that were present and which were clustered into four groups: Indigenous zebus (Zebu Gobra; Zebu Maure), Indigenous zebu by Guzerat (Indigenous zebu cross with 25% to 50% Guzerat), Indigenous zebu by *Bos taurus taurus* (Indigenous zebu cross with 25% to 50% *Bos taurus taurus* where the *Bos taurus taurus* includes breeds such as Montbeliarde and Holstein-Friesian) and High *Bos taurus taurus* (cows with a high component of *Bos taurus taurus*, typically 75% to 100% of previous *Bos taurus taurus*). The daily milk yield, cumulative milk yield of 305 days, milk fat and protein percentages were determined for each cluster. The daily milk yield varied from 1.43 L/day in indigenous zebus to 7.04 L/day in High *Bos taurus taurus.* In general, the daily milk yield increased with the number of parturitions. Indigenous zebus showed the lowest 305-day milk yield (466 L and 496 L for first and later lactations, respectively) whilst High *Bos taurus taurus* cows showed the highest milk production (1408 L and 2108 L for first and later lactations, respectively). Fat percentage increased from the primiparous to the multiparous cows. Primiparous Indigenous zebus by *Bos taurus taurus* cows showed the highest fat content (5.10%), followed by Indigenous zebus (4.44%). The average calving interval ranged from 519 days for Indigenous zebus by *Bos taurus taurus* to 580 days for Indigenous zebus. The average lactation length for all cows was 370 days.

Key words: Dairy cows, lactation, milk yield, milk quality, breed differences, Senegal

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INTRODUCTION

Livestock production plays a significant role in the economy of almost all countries in Africa, in which it represents on average 20% to 40% of the agricultural percentage of the gross domestic product (GDP) [1]. In Senegal, a country located in West Africa, livestock production in 2013 represented about 35% of the added value of agriculture and 8% of the GDP, with milk production being the main output [2]. This milk production derives mainly from a low-input production system, with some more intensive operations. Milk production from dairy cows in Senegal in 2013 was 0.20 million tonnes [3]. This was well below the estimated national consumption of 0.44 million tonnes of milk equivalent (the quantity of fluid milk utilized in a processed dairy product, often expressed on a milkfat basis) [3]. This has led to dairy imports covering 58 % of the national demand for milk [4]. The value of dairy imports affects significantly the trade balance of Senegal. The total cost of dairy imports was 75.5 million US$ in 2015 [5]. Furthermore, high population growth combined with a change in eating habits, particularly in urban areas; result in higher demand for milk and milk products in Senegal [6]. Sustainable increase in the productivity of Senegalese dairy cattle breeds is therefore needed to meet the increasing demand for milk [7].

Low national milk production mainly results from a combination of the use of cattle with low genetic potential for milk, and unfavorable environmental conditions, including restricted feed, diseases, and heat stress [8]. To improve the productivity of the dairy cows, new breeds of cattle have been introduced, mainly through artificial insemination (AI) campaigns, resulting in the coexistence of various crosses between local cattle (Gobra, Maure, N'Dama, Djakoré) and exotic cattle (For example, Holstein, Guzerat, Montbeliard, Gir, Jersey) [9]. However, few studies have determined the performance of the various cattle breeds or the economics of dairy production under the Senegalese production system [8, 10].

The Senegal Dairy Genetics Project (SDG) [11] was established to identify the best breeds or cross-breeds of dairy cattle in the low-input dairy systems in Senegal from the viewpoint of household profitability and dairy cattle productivity. The overall objective of this work was to determine the differences in milk production traits among indigenous breeds and crossbreds dairy cattle in Senegal.

MATERIALS AND METHODS

Project sites

The project was conducted at two sites (Thies and Diourbel) in the agro-pastoral production system (Peanut Basin) of Senegal from 2013 to 2015. The sites were selected for the Senegal Dairy Project due to their high diversity of dairy cattle breed-types. In the Thies region, the study site included the areas of Thies, Khombole, and Tivaouane, while in the Diourbel region, the study site included the areas of Mbacke and Touba. These sites are characterized by a Sudano-Sahelian climate: hot and dry, with a fairly short rainy season of 3 to 4 months and a long dry season ranging from October to June. The average rainfall is about 300 to 500 mm annually [12]. The natural vegetation is dominated by the genus *Acacia* and is largely transformed by agriculture into crop plants [12]. The human population in Thies and Diourbel regions consists mainly of people from the ethnic groups of Wolof (62%), Serere (33%) and Fulani (4%) [12].

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Milk recording

For milk yields, data were collected during a recording period of 20 months between September 2013 and April 2015 from 220 households located in the two project sites. Households were visited 12 times over the 20 month recording period (at approximately equal intervals), with milk yields recorded at each visit. These comprised morning and evening milking records collected by project enumerators. At some farms, the second sample per day was taken by the farmer. To stimulate milk letdown, cows were first suckled by the calves for 1 to 2 minutes. Then, the cows were milked by hand. Milk suckled by the calves was not estimated. Therefore, the milk yields represent milk –offtake (and not total milk production). The milk yield was measured with 1 or 5 l containers. In total, 6082 records were collected from 1447 cows.

Milk fat and protein were analysed, using a Lacticheck TM-01 RapidRead portable ultrasonic analyser (Page & Pedersen International Ltd., Hopkinton, MA, USA) between September 2013 and July 2014 from 190 households located in the two project sites. In total, 493 milk samples were collected from individual cows.

Other descriptive data

For all cows present in the study at the start of the longitudinal survey, the farmers provided basic demographic information such as perceived breed, age, parity, and last calving date, based on recall from 1 to 2 years back (as no farmers practiced written recording). As the longitudinal survey progressed, varied data was collected at the time of the household visits, including calving date.

Breed composition

To more accurately determine breed composition, 628 cows comprising mostly lactating cows and pregnant heifers were genotyped with the Illumina 50K single-nucleotide polymorphism (SNP) chip (Illumina Inc., San Diego, CA, USA), and the genome information was used to determine the possible breed proportions with the aid of a genotyped pool of reference cows. Breed group assignment from the SNP analyses was done using Bayesian Analysis of Population Structure (BAPS) v6.0 [13]. Four breed groups were finally defined (Indigenous zebus, Indigenous zebus by Guzerat, Indigenous zebus by *Bos taurus taurus* (*B.t.taurus*), High *B.t.taurus*), based on the cows' allele combinations and frequencies (Table 1).

Data description and analysis

The average herd sizes in the Thies and Diourbel regions were 21.4 ± 1.9 and 22.4 ± 2.4 cows, respectively. On average 27% of the cows present at recording were lactating (the range between cycles being from 20% to 37%) and 25% were milked (the range between cycles being from 19% to 35%). In general, the various taurine (*Bos taurus taurus*) x zebu (*Bos taurus indicus*) crossbred cows showed higher percentages of lactating cows (from 35% to 38%) than local zebu cows (23%).

The average number of test-day records per cow per lactation in the analysis dataset was 5.52 in the Thies region and 6.27 in the Diourbel region. Records of cows with at least one test-day record for milk quality and/or volume, genotype information and known date of last

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calving (either via farmer recollection or recorded during the longitudinal monitoring period) were included in the final analysis. If the date of the last calving was known only by month and year, the date was set to the first day of the month. Only test-day records of less than 365 days in milk (DIM) were used for estimation of the lactation curves. A completely unknown date of last calving (for cows born prior to the start of the longitudinal monitoring period) was the single most limiting factor in the use of test-day records as part of the analysis. The records of cows with missing last calving date were therefore not used in the analysis.

Only lactation records with at least five observed test-day records were included in the first dataset (Data 1 in Table 1), which consisted of 1923 test-day milk yield records from 370 lactations and 319 cows in four breed groups. Data 1 was used to determine the length of lactation and the calving interval for the various breed groups to estimate the lactation curves and cumulative 305-day milk yields.

The length of lactation was calculated as the number of days between the farmer-given dates of last calving and cow dry-off. For cows with two lactations during the recording period, the mean length of lactation was used for calculating the breed group means. The calving interval (CI) was calculated as the number of days between two dates of calving for cows with more than one known date of calving. The last known date of calving would have to have occurred during the recording period, while the previous date of calving could have occurred before the recording period (based on farmer's recollection) or during the recording period. Missing calving (dry-off) date information reduced the data considerably in this specific analysis.

The daily milk yield (DMY) was calculated as the sum of morning and evening milking on the test-day. If the record from either morning or evening milking was missing, the DMY was estimated using a modified method described by Liu *et al*. [14], as explained in the International Committee for Animal Recording [15] with PROC GLM (SAS Institute Inc., Cary, NC, USA) [16]. The intercept and slope for the regression method were estimated separately to obtain partial DMYs from the morning or evening milking by breed groups.

Estimation of the lactation curves was performed with the Wilmink function [17], using PROC NLIN [16]. The parameters for the Wilmink function were estimated separately for each combination of breed group and parity effect at two levels: first and later parities. Due to a small amount of data we used 0.05 as the value of k from Wilmink [17], which fits the peak yield to 50 days from calving. Due to the relatively small average number of test-day records per cow per lactation and in many cases more than one successive observation missing, the cumulative 305-day milk yield was calculated by breed group and lactation, using the estimated Wilmink function parameters.

The second dataset (Data 2 in Table 1) was a subset of Data 1 and consisted of 227 cows with a single test-day record for both milk quantity and quality. Data 2 was used to analyse the fat and protein contents of milk and phenotypic correlations of test-day milk yields and compositional traits. The Tukey test was used to compare the compositional traits for the various breed types. The analyses were performed with IBM SPSS Statistics for Windows, Version 20.0 [18].

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RESULTS AND DISCUSSION

Milk yield

The DMYs derived from the cows with milk quality data were relatively low (Table 2). They varied from 1.43 L/day in Indigenous Zebus to 7.04 L/day in High *B.t.taurus*. In general, the DMY increased with the number of parturitions, except in High *B.t.taurus* and Indigenous zebus by Guzerat. Crossing Indigenous zebu cows with improved zebu types like Guzerat adapted to tropical climate did not demonstrate an advantage overcrossing with improved *B.t.taurus*, as previously shown in a study on cattle crossbreeds in Cameroon [19].In general, crossbreeds in West Africa produce 3 to 8 L/day [18, 19], which is above the results obtained in this study, likely because of differences in feeding and milking management. For instance, in a study carried out in a dairy cattle research station in Cameroon, the litter was always changed to avoid infections, a regular diet made of concentrate and cut grass was given and water provided *ad libitum* [19]. The production level of pure to almost pure imported taurine breeds was similar to the 6.5 L/day found in the Fatick and Kaolack regions of Senegal [20]. This is likely due to the low level of energy intake resulting from heat stress and low food quality in the study sites [21]. Specific breeds such as the Holstein are very sensitive to the level of energy intake, due to their high milk production [21]. This sensitivity also increases with the number of parturitions [22]. Therefore, in the agro-pastoralist system of Senegal, the seasons of calving and water availability are important factors for milk production [23].

The 305-day milk yields (not including milk suckled by the calves) are shown in Table 3. Most of the cows in first or later parturition belonged to the zebu group (41.67% and 48.66%, respectively) followed by the crosses between zebus and *Bos Taurus taurus* (27.08% and 26.20% respectively). The milk production level varied with the breed group. The Indigenous zebus group showed the lowest 305-day milk yield in the first and later lactations (466 L and 496 L), followed by the Indigenous zebus by Guzerat (468 L and 668 L) (Table 3). The highest milk yield was found in the High *B.t.taurus* group (1410 L and 2108 L), which is expected given these breeds i) have been strongly selected for milk production and ii) are generally subjected to higher management levels in Senegal, particularly feeding[24]. In Senegal, Gobra is usually involved in crossbreeding mainly because of its low milk production level (2 L/day on average) [25]. Apart from Gobra, the indigenous breeds usually involved in crossbreeding programs in Africa mainly include zebus such as Azawak in Mali, Burkina Faso and Niger (4.23 to 8.89 L/day) [26], Red Fulani in Cameroon and Nigeria (2 to 2.99 L/day) [27]. Some taurines such as Borgou (0,83 L/day) and Lagunaire (0,36 L/day) in Benin are also used [28]. According to the previous results, indigenous zebus such as Azawack present comparable milk production level as crossbreeds [26]. Therefore, selection and conservation of indigenous breeds can also lead to a sustainable agriculture in Africa. In addition, those cows play key roles in traditional societies such as risk coverage, value reserves or patrimony [29]. They are usually involved in dowries or funerals and many tribes are identified by their indigenous breeds [29].

Due to the low number of cows in the other breed groups, lactation curves are presented only for primiparous and multiparous Indigenous zebus cows (Fig. 1). The peak yield was obtained approximately on day 40: 1.90 L for first lactation cows and 2.10 L for later lactation cows. Hence, the first lactation peak yield was 90.5% of the later lactation cows' peak yield. Previous studies have shown that the first lactation peak yield is normally between 70% and 80% of later lactation peak yields [30].

In the present study, the difference was much smaller for the zebu cows. This may indicate that production in zebu cows is limited, especially in later lactations, by poor body condition, inadequate feed intake, low ration energy density or other management deficiencies.

The persistence between 80 DIM and 270 DIM was 94% for later lactation cows and 95% for first lactation cows, showing the flatness of the lactation curve.

Milk content traits

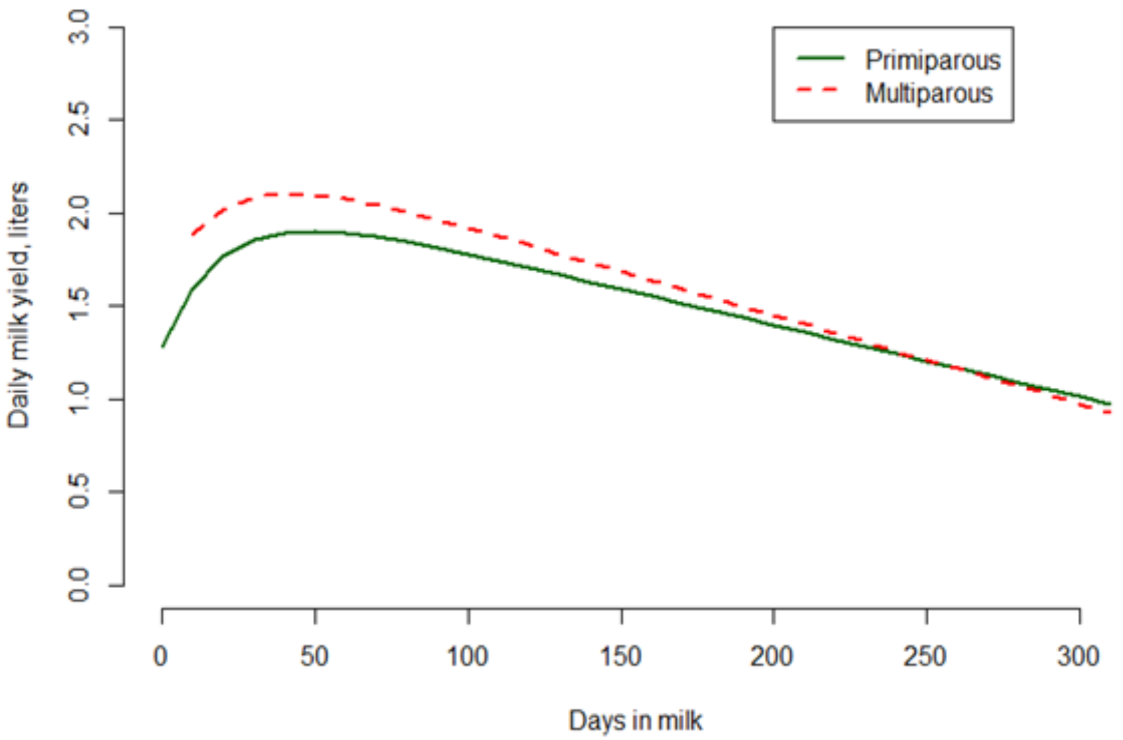

Figure 1: Estimated lactation curves for 305 days (Wilmink function) for zebu breeds

The fat percentage increased from the primiparous to the multiparous cows, especially in the High *B.t.taurus* group, in which the fat content was the highest among the multiparous lactations (5.61%). However, none of these differences was statistically significant. In primiparous cows the fat content in milk was highest in Indigenous Zebus by *B.t.taurus* cows (5.10%) (Table 2) followed by the Indigenous zebus group (4.44%). High *B.t.taurus* cows showed the lowest fat percentage (3.58%) in primiparous cows. The protein content was similar in all the breed groups, ranging from 3.48% to 3.67% in primiparous cows and from 3.60% to 3.70% in multiparous cows. In general, the protein content of cow's milk exhibited little variability between zebu and taurine breeds [31]. This is in agreement with the results found in the current study. The protein content was comparable to the one found for Boran

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and Nguni cows in South Africa [31]. Somewhat higher protein contents (4.5%) were, however, reported from Friesian crosses in Tanzania [22].

Indigenous Zebus and Indigenous Zebus by *B.t.taurus* cows showed the highest fat percentages in the first lactation. Other indigenous African breeds, such as the Africaner, Nguni or Boran, showed comparable levels of fat percentage in their milk [31]. However, the fat percentage is also highly affected by dietary factors, such as roughage, forage: concentrate ratio and level of starch in the ration [32].

Indigenous zebus by *B.t.taurus* and High *B.t.taurus* cows were the most productive cows. The content traits were not significantly different between breed groups in either the first or the second lactation. High dry-matter content and especially a high protein content compared to fat content are crucial to the production of fermented milk, which is the most common processed milk product on small-scale farms and small cooperatives in Senegal [33]. Protein contents depend essentially on sufficient energy level of the feed ration combined to a fat level of less than 5% of the dry matter and presence of digestible amino acids like methionine and lysine [34].

Correlations between fat or protein percentages and milk yield were performed on a breed-group basis (Table 2). Fat and protein percentages were negatively correlated with the milk yield for multiparous cows, except in the High *B.t.taurus* group, where the fat percentage was positively correlated (0.13) with the milk yield. Cows with one parturition showed fat percentages weakly and positively correlated with milk yield in Indigenous zebus and Indigenous zebus by Guzerat (0.16 and 0.11, respectively) and negatively correlated in Indigenous Zebus by B*.t.taurus* and the High *B.t.taurus* group (-0.46 and -0.76, respectively). Generally, the phenotypic correlation between fat and protein contents is positive and the fat percentage is higher than the protein percentage [35].In the present study, the fat and protein percentages were negatively correlated in the Indigenous zebus and Indigenous zebus by Guzerat groups and positively correlated in the Indigenous zebus by *B.t.taurus* and High *B.t.taurus* groups.

Calving interval and lactation length

The average CIs, calculated from cows with at least two recorded calving dates, were long (538±187 days for all cows), varying from 519±192 (Indigenous zebus by *B.t.taurus*) to 580±222 days (Indigenous Zebus) (Table 4). In general, as also shown by the current study, indigenous breeds have relatively long CIs. Gobra and N'Dama breeds in sub-Saharan Africa presented CIs from 18 to 24 months while for Gudali in Cameroon, 18.7 months on average was observed [36, 37]. Similar results were found for N'Dama cattle in the Ivory Coast and for Sanga cattle in Ghana [38, 39]. This can be explained by the low-input systems in which Indigenous zebus are commonly kept. As a result, cows are not in the proper body condition to conceive [20]. Furthermore, the longer CIs in Indigenous zebus are also a consequence of a longer lactation anoestrus following the obligatory presence of the calf for milking [40].

The reported lactation lengths were also long, on average, 370±122 days for all cows-especially for the High *B.t.taurus* breed group (468±194 days). In alignment with the results presented in this study for the Indigenous Zebus by *B.t.taurus* crosses, a lactation length of

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386.5 ± 61.2 days for N'Dama x Montbeliard crosses in the Ivory Coast have been found [38]. Extended lactations may occur due to longer calving intervals.

CONCLUSION

There were large and significant differences between breed types in DMY and 305- day milk yield in Senegal. High *B.t.taurus* crosses showed the highest milk production among other crosses or pure zebu breeds. Hence, cross-breeding with taurine breeds, combined with appropriate dairy cattle management strategies, remains an easy and fast tool for increasing the productivity of milk production in Senegal.

The productivity of dairy cattle in Senegal could be improved by shortening the average CI. This requires adequate amounts of feed available for the cow to enable an earlier return to heat after calving. The results presented here have contributed to an analysis of the household profit and cost-benefit of keeping different breed types. Improved profitability of household dairy enterprises in Senegal will lead to increased income of the dairy cattle keepers and other dairy value chain actors, as well as contribute to food security. Implementation of a sustainable genetic improvement program that ensures the availability and accessibility of the most appropriate dairy cattle breed-types will play an important role in achieving this overall goal.

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Table 1: **Distribution of recorded cows in different breed clusters based on genomic information**

Genotype information	Breed group	Number of cows	
		Data 1	Data 2
0.88--0.99 L	Zebus	146	128
0.39--0.86 L; 0.13--0.61Z	Zebu x Guzerat crosses	74	31
0.38--0.84 L; 0.13--0.61 T	Zebu x Bos taurus taurus crosses	80	49
0--0.36 L; 0.63--0.98 T	High Bos taurus taurus	19	19
	Total	319	227

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Table 2: Test-day means (in block diagonals) and correlations (in block off-diagonals) for milk yield (in litres), fat and protein contents in different breed clusters and parturitions

		First parturition			Second and later parturitions		
Breed	Trait	Milk yield (L)	Fat %	Protein %	Milk yield (L)	Fat %	Protein %
Zebu 23/42[Δ]	Milk yield, L	1.43 [a,1]			1.91 [a,1]		
	% Fat	0.159	4.44 [a,1]		-0.135	5.13 [a,1]	
	% Protein	-0.455*	-0.147	3.67 [a,1]	-0.109	0.525**	3.70 [a,1]
Zebu x Guzerat crosses 08/15	Milk yield, L	1.87 [a,1]			1.62 a,1		
	% Fat	0.110	4.27 [a,1]		-0.248	5.20 a,1	
	% Protein	-0.859**	-0.21	3.69 [a,1]	-0.299	0.310	3.66 [a,1]
Zebu x Bos taurus taurus crosses 07/21	Milk yield, L	2.33 [a,1]			6.21 [b,2]		
	% Fat	-0.464	5.10 [a,1]		-0.070	4.79 [a,1]	
	% Protein	0.179	0.552	3.48 [a,1]	-0.229	0.230	3.56 [a,1]
High Bos taurus taurus 07/07	Milk yield, L	7.04 [a,2]			6.02 [a,2]		
	% Fat	-0.760*	3.58 [a,1]		0.131	5.61 [a,1]	
	% Protein	-0.519	0.035	3.62 [a,1]	-0.194	0.105	3.60 [a,1]

[Δ] Number of records in first/second lactation
*: Significant correlation (P < 0.05); **: Very significant correlation (P < 0.01)
1, 2: Breed comparison of milk content during the same lactation; the same number indicates no significant difference
a,b: Comparison of milk content during first, second and later lactations in the same breed; identical letters indicate no significant difference

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Table 3: Estimated 305-day milk yield by breed using the Wilmink method

	First parturition					Later parturition				
	[1]NA	[2] %	[3]NO	[4]%	Milk (l)	NA	%	NO	%	Milk (l)
Zebu	40	41.67	190	39.83	466	91	48.66	456	45.06	496
[a]ZebuxGuzerat crosses	22	22.92	110	23.06	468	38	20.32	205	20.26	668
[b]Zebu x Bos taurus taurus	26	27.08	132	27.67	1368	49	26.20	298	29.45	1488
[c]High Bos taurus taurus	8	8.33	45	9.43	1410	9	4.81	53	5.24	2108

[1] Number of animals
[2,4]Percentages relatively to the total number of animals and observations recorded respectively
[3]Number of observations

Table 4: Lactation lengths and calving intervals (Data A) in different breed clusters

	Length of lactation			Calving interval		
Breed group	N	Mean	SD	N	Mean	SD
Zebu	43	359	92	55	580	222
Zebu x Guzerat crosses	21	385	91	32	534	193
Zebu x Bos taurus taurus crosses	39	372	132	57	519	192
High Bos taurus taurus	06	468	194	12	561	187

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