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Factors affecting milk quality of crossbred dairy cows in automated Herringbone milking system

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ABSTRACT

The aim of the study was to investigate the effect of factors affecting milk quality of crossbred dairy cows milked in automated Herringbone milking system. The study was conducted on 37 crossbred Karan Fries cows of different parities, stages of lactation and udder types for 3 months. The milk quality was assessed based on milk composition, on-line electrical conductivity (EC) and peak conductivity, somatic cell count (SCC) and standard plate count (SPC) of milk samples. The results showed that there was no change in milk composition in terms of fat and SNF except in different parity groups. The milk conductivity was significantly higher in the late stage of lactation. However, no change in SCC values was observed. The udder types showed significant increase in EC values in udders with poor structure and loose attachment. The SCC values were also significantly higher for such udder types. The SPC was significantly higher when the number of milkings on each liner exceeded 2000 milkings/ liner. The SCC was had a positive correlation with EC and SPC. The correlation between SPC and SCC was highly significant whereas, EC was moderately correlated with SPC. It can be concluded that the milk quality of crossbred dairy cows was significantly affected by parity, stages of lactation, udder type and liner usage in automated parlours. Therefore, effective management strategy needs to be taken to improve the quality of milk taking into consideration on-line EC, SCC and SPC.

Key words: Crossbred dairy cows, Electrical conductivity, Herringbone milking system, Milk quality, Somatic cell count, Stages of lactation, Standard plate count

The dairy industry is gradually incorporating novel approaches and latest technologies of managing and milking dairy herds. Mechanization in milking is a major breakthrough in this sector (Jacobs and Siegford 2012). A fully integrated milking parlour offers high throughput, efficient labour usage and provides calm, comfortable and harmonious milking environment (Mein and Reid 1996). However, it may compromise the quality and hygienic standards of milk if standard operating procedures are not followed (Nalla 2015).

In the earlier reports, issues such as increased somatic cell counts (SCC), electrical conductivity (EC) and standard plate counts (SPC) in the raw milk were reported (Klungel *et al*. 2000, Rasmussen *et al*. 2002). Similar research elucidated that the milk quality of farms with mechanized milking was more dependent on the quality of overall management of the cows rather than the type of milking (Berglund *et al*. 2002). Significant relationship was observed between over-milking and SCC and EC values (Espada and Vijverberg 2002). The SPC value in milk resulting from sub-standard milking operations was also high (Oliver 2010). Therefore, milk quality becomes an important issue on the mechanized farms with a very little information. The present work aimed to study the various factors affecting milk quality of crossbred cows in automated herringbone milking parlour under Indian farming and environmental conditions.

MATERIALS AND METHODS

Animals and management: The present study was conducted on 37 crossbred Karan Fries (Tharparker × HF) cows maintained at the Livestock Research Centre, ICAR-National Dairy Research Institute, Karnal, Haryana for a period of 3 months. The cows were in different parity, stage of lactation and udder type. All the experimental animals were kept in loose housing system under group management practice during the entire period of the trial. The animals were monitored through automatic animal identification system consisting of neck transponder, portal identification antenna, system controller and software based herd management programme on a personal computer (PC). There was provision of automatic feeding through four feed dispensers installed within the shed to supply the

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concentrate requirement of animals. The green fodders grown in the institute farm were supplied according to the seasonal availability. *Ad lib.* water was available in the open shed where animals stayed all the time except during milking. Milking of animals was done in low-line 8 × 2 Herringbone milking parlour having automatic cluster remover (ACR) settings. All the machine milking regulations were followed and milking was done thrice a day.

The experimental animals were grouped under different parity i.e. 1 to 4; stages of lactation i.e. early stage- up to 100 days in milk, mid stage- from 100 to 200 days in milk and late stage- more than 200 days in milk; and udder type i.e. type A, B and C. The description of various udder types is given below.

Description for type of udders

Type of udder	Description
A	Highest quality, held up high, snug and close to the body, above the hocks in the rear and level across the floor and forward to a firmly attached front. From the rear, the udder should have an extremely strong cleft.
B	Hangs either at or just slightly lower than level with the hocks. It is slightly lower in the front suspension with an intermediate attachment.
C	When viewed from the rear is slight to below the hocks, and the cleft will be slight to weak. The front attachment is loosely connected and beginning to hang low.

Milk collection and system cleaning: Milk from different animals was collected in milk receiver having 70 liters capacity that was transferred to BMC tank with the help of milk pump. The milking clusters, milk line and milk delivery/transport line was cleaned-in-place (CIP) with a programmed automated cleaning system. This computerized cleaning system automatically controls the cleaning session.

Milk sampling: Milk sampling was carried out in the morning milking session and the milk samples were obtained from individual cows by the help of sampler, which was attached to milk meter at the time of sampling. After collection, the samples were taken to the laboratory for analysis. Analysis of milk composition was done by automatic milk analyzer (Funke Gerber Lactostar®). The somatic cell count was estimated by the help of DeLaval cell counter (DCC) by means of disposable SCC cassette. The SCC cassette had fluorescent dye propidium iodide (PI) immobilized in the interior flow channels of the cassette. When the cassette was loaded with approximately 60 µl of the sample, the PI dissolved and mixed with the sample, staining the nuclei of the somatic cells. The stained milk sample was automatically transferred to the measurement chamber where the fluorescent image was recorded. The volume measurement was approximately 1 µl in the cassette measuring window. The measuring range of the counter was from 10,000 to 40,00,000 somatic cells/ml. Electrical conductivity (EC) was measured for individual cows with the help of milk meter on the test day.

The samples for SPC were collected after 1,000, 1,500, 2,000 and 2,500 milkings/liner. The quality of raw milk was estimated on the basis of pooled milk samples from the bulk milk storage tank. The samples were collected hygienically from a well mixed milk in sterile milk collection bottles during the afternoon milking session. The collected samples were placed in ice box immediately and taken to the microbiology laboratory for further estimation of the bacterial count. The samples from cluster liners were collected from six different points (Cluster No. 1, 2, 7, 8, 9 and 16) by the help of swab method of sample collection 1 h before the start of afternoon milking session. A sterile swab was wiped over the entire surface of the liner and dipped in a sterile test-tube containing 25 ml of 0.9% normal saline solution. The test-tubes were immediately placed in the ice box and taken to microbiology lab for making culture on sterile culture plates (Disposable petri-plates).

Statistical analysis: The data were analyzed using SAS version 9.3. The comparison between different parity, stage of lactation and udder types on milk quality was done using General Linear Model procedure (GLM). Pearson correlation coefficient was performed to find out correlation between somatic cell count, electrical conductivity and standard plate count.

RESULTS AND DISCUSSION

The milk quality of crossbred dairy cows in automated Herringbone milking parlour was determined in different parities, stages of lactation and udder types. The overall least square means of Fat%, SNF%, Protein% and Lactose% were 3.58±0.05, 8.94±0.06, 3.62±0.05 and 4.75±0.04, respectively (Table 1). The overall mean on-line electrical

Table 1. Effect of parity, stages of lactation and udder types on milk composition (mean±SE) of crossbred dairy cows.

Parameters	N	Fat%	SNF%	Protein%	Lactose%
Parity					
1	30	4.07 ± 0.10^{B}	9.34 ± 0.12^{C}	3.59±0.10	4.79±0.07
2	39	3.59 ± 0.09^{A}	9.01 ± 0.10^{BC}	3.43±0.08	4.65±0.06
3	24	3.34 ± 0.11^{A}	8.84 ± 0.13^{AB}	3.75±0.11	4.85±0.08
4	18	3.30 ± 0.14^{A}	8.59 ± 0.16^{A}	3.73±0.13	4.72±0.10
Stage of lactation					
Early	42	3.55±0.08	8.86±0.10	3.69 ± 0.08^{a}	4.78±0.06
Mid	42	3.50±0.08	8.95±0.09	3.43 ± 0.08^{b}	4.76±0.06
Late	27	3.69±0.11	9.01±0.13	3.75 ± 0.10^{a}	4.72±0.08
Udder type					
A	42	3.42±0.10	8.87±0.12	3.78±0.10	4.89 ± 0.07^{b}
B	39	3.73±0.08	8.96±0.10	3.57±0.08	4.62 ± 0.06^{a}
C	30	3.58±0.09	9.00±0.11	3.52±0.09	4.75 ± 0.07^{ab}
Overall	111	3.58±0.05	8.94±0.06	3.62±0.05	4.75±0.04

Values with different superscripts in capital letters (AB) in a column differ significantly at $P<0.01$ and in small letter (ab) at $P<0.05$.

Table 2. Effect of parity, stages of lactation and udder types on on-line electrical conductivity, peak conductivity and somatic cell count in milk

Parameter	N	Electrical conductivity (ms/cm)	Peak conductivity (ms/cm)	SCC (×10⁵)
Parity				
1	60	6.08±0.08	6.62±0.08	1.31±0.07
2	78	6.14±0.07	6.64±0.06	1.43±0.06
3	48	6.09±0.08	6.61±0.08	1.37±0.07
4	36	6.33±0.11	6.75±0.10	1.50±0.09
Stage of lactation				
Early	84	5.99 ±0.07^A	6.55 ±0.06^A	1.31±0.06
Mid	84	6.03 ±0.06^A	6.55 ±0.06^A	1.40±0.05
Late	54	6.45 ±0.08^B	6.87 ±0.08^B	1.50±0.07
Udder type				
A	84	6.17 ±0.08^a	6.62±0.07	1.20 ±0.07^A
B	78	6.02 ±0.07^a	6.60±0.06	1.33 ±0.06^B
C	60	6.28 ±0.07^b	6.74±0.07	1.68 ±0.06^C
Overall	222	6.16±0.04	6.66±0.04	1.40±0.04

Values with different superscripts in capital letters (AB) in a column differ significantly at P<0.01 and in small letter (ab) at P<0.05.

conductivity, peak conductivity and somatic cell count in the milk of cows milked in automated herringbone parlour were 6.16±0.04, 6.66±0.04 and 1.40±0.04, respectively (Table 2). Similar results were reported by Dang and Anand (2007) in the crossbred cows milked in Vario-tandem parlour. Syridion *et al*. (2012) reported lower conductivity values (5.29±0.13 ms/cm) in milk sample of Karan Fries cows milked in machine milking which might be due to differences in the temperature of measured milk. However, the results of overall mean somatic cell count in their study was similar to the present study.

Effect of parity: The effect of parity of a cow on milk composition is presented in Table 1. It was found that parity of cows significantly (P<0.01) affected the fat and SNF content in milk. The milk obtained from first calvers showed significantly higher fat percent in their milk compared to second, third and fourth parity animals. Similarly, SNF content was also significantly higher in primiparous cows than later parities. However, protein and lactose content in milk did not differ among parities. Craninx *et al.* (2008) reported similar effect of parity on milk composition in dairy cows. Gurmessa and Melaku (2012) also reported higher fat percentage in primiparous Holstein cows compared to multiparous animals (3.61±0.75 vs 3.30±1.78). Similar results were reported by Yadav *et al.* (2013) in Murrah buffaloes. The higher fat and SNF in milk of primiparous cows is being reported due to difference in milk production as fat and SNF are inversely related to milk yield.

The effect of parity on on-line electrical conductivity, peak conductivity and somatic cell count in the milk are presented in Table 2. The average on-line electrical conductivity as well as peak electrical conductivity did not differ in different parities. Likewise, no effect of parity was seen on milk SCC. Similar results were reported by Syridion *et al*. (2012) in Karan Fries cows in different parities (1 to 4). However, Sheldrake *et al.* (1983) reported that mean EC increases in later lactations without affecting SCC. Wilson *et al.* (1995) reported higher SCC with parity is associated with lower milk production in dairy goats. Similarly, Bartlett *et al.* (1990) and Kavitha *et al.* (2009) also reported increased SCC in dairy cows and buffaloes of higher parities due to intra-mammary infections.

Effect of stage of lactation: The effect of lactation stage on average milk composition is presented in Table 1. The fat and SNF content of milk was numerically higher in late stage of lactation. Higher values of these milk components may be due to lower milk production in late stages. The results were similar to the reports of Gurmessa and Melaku (2012) and Stoop *et al.* (2009) in Holstein cows. The lactose content in our study was similar in all stage of lactation, which was in agreement to Pollott (2004) who reported that lactose secretion rate remains nearly constant throughout the entire lactation in dairy cows. Yadav *et al.* (2013) reported significant (P<0.05) increase in lactose during last trimester of lactation in Murrah buffaloes. The difference in results may be due to breed differences and managemental practices at the farm level.

The effect of stage of lactation on on-line electrical conductivity, peak conductivity and somatic cell count in the milk of crossbred cows in automated Herringbone milking parlour is presented in Table 2. The average and peak on-line electrical conductivity in different stages of lactation differed significantly (P<0.01) and was lower in early and higher in late stages of lactation. However, the mean SCC value did not differ in different lactation stages. Atasever and Erdem (2009) also reported a similar trend in healthy cows with a little lower values. The higher values of EC in late lactation may be because of glandular infection due to lactation stress which disrupts the basement membrane of the alveoli leading to ionic flux (Syridion 2012). Mansor (2012) reported that concentration of chloride ions in milk increases as lactation progresses, which might be a reason for higher EC values observed in the present study. The SCC count was similar in these cows of different lactation stages in the present study. Similar results were reported by Singh and Ludri (2001) in crossbred cows in different stages of lactation. However, Bartlett *et al.* (1990) reported that SCC increases at the end of lactation, which was due to increased prevalence of infection and permanent glandular damage from previous infections.

Effect of type of udder: The effect of udder types i.e. A, B and C types of udders on average milk composition is presented in Table 1. It was found that type of udder did not affect milk composition except lactose. Alawa and Oji (2008) reported minimal changes in fat, total solids and ash content in milk of Red Skoto goats with poor udder structure and attachment. In their reports it was found that milk composition in terms of SNF and protein may change due to increase in cell count characteristics in poor quality milk. The cell count in the present study was within the normal limits.

The effect of udder type on on-line electrical conductivity, peak conductivity and somatic cell count in the milk of crossbred cows in automated herringbone milking parlour is presented in Table 2. The average conductivity was significantly (P<0.01) higher in poorly attached udders (type C). However, the peak conductivity did not change in all types. The somatic cell count also differed significantly (P<0.01) and was lowest in firmly attached udder (type A). The results suggested that udder that are low and loose in attachment may harbour organisms causing mammary infections which affect the quality of production. Janzekovic *et al.* (2009) also reported that large and hanging udder allow easier transmission, penetration and procreation of bacteria leading to higher conductivity values. Norberg (2005) reported that factors other than mastitis, like breed, parity, lactation stage, milking interval and milk composition may also affect EC of milk. Galfi *et al.* (2015) reported that changes in EC values is due to increase concentration of Na^+ and Cl^- in the milk. The udder and teat morphology also affect milk SCC significantly (Juozaitiene *et al.* 2006). In their reports, the best quality milk was found in the cows with the optimal description of fore udder attachment (extremely snug and strong), rear height (extremely high), cleft (extremely strong) and depth (extreme height) with significantly lower SCC in milk. Uzmay *et al.* (2003) reported that Holstein cows with pendulous udders have higher SCC value and are at higher risk to subclinical mastitis.

Effect of number of milkings/liner: The effect of the number of milkings on each liner based on standard plate count of the milk samples taken from pooled raw milk and cluster liner is presented in Table 3. The standard plate count was significantly (P<0.01) higher when the number of milkings on each liner exceeded 2,000 milkings/liner. The legal maximum limit of standard plate count based on PMO (Pasteurized Milk Ordinance) (USA) guidelines in a raw milk sample is 100,000 cfu/ml. A standard plate count of $\leq 1\times10^5$ colony forming units (CFU) per ml has been globally accepted for good quality raw milk (Kivaria *et al.* 2006). However, Murphy (1997) reported that a realistic and achievable goal for SPC should be less than 10,000 cfu/ml. The total bacterial counts in raw milk in present study was within acceptable limits. The study suggests that if standard milking and cleaning procedures are followed at each milking, the milk obtained may be of the acceptable grade but we should target lower plate count which can be achieved only by optimizing the age of liners.

The SPC per liner ($\times 10^4$) was almost 4.4 times higher at 2,500 milkings as compared to 1,000 milkings. The plate count showed a significant (P<0.01) difference in the number of colony forming units on each liner as the number of milkings increased. The rise in SPC with the increase in number of milkings per liner may be due to liner damage making it unhygienic. The present study gives the more accurate information based on changes in standard plate count, both in the pooled milk sample and on the surface of liners for estimating the effect of liners.

Correlation between somatic cell count, electrical conductivity, and standard plate count: The results of correlation analysis among somatic cell count (SCC), electrical conductivity (EC) and standard plate count (SPC) are presented in Table 4. In the present study, the somatic cell count had a positive correlation with electrical conductivity and standard plate count. The correlation between standard plate count and somatic cell count was highly significant (P<0.01) indicating that rise in their count will reflect poor quality of production. Although, rise in EC values should be further confirmed for other possible reasons causing increase in EC values. However, the electrical conductivity was moderately correlated with standard plate count with a correlation coefficient of 0.412. The moderate but non-significant correlation estimate for EC and SPC values indicates that plate count method should be further tested for involvement of pathogens truly responsible for raising EC. Kasikci *et al.* (2012) reported significant and positive correlation between SCC, EC and SPC with a highest correlation estimate between SCC and SPC (r=0.682). Vilas *et al.* (2016) reported positive and moderate correlation between EC and SCC (r=0.41) in dairy cows. The results in our study were in agreement to the reports of above researchers. However, contrary to our reports, Syridion *et al.* (2012) reported a high correlation between EC and SCC (r=0.723) values in crossbred cows fed with ration having anionic and cationic alterations.

The present study envisaged that the milk quality of crossbred dairy cows was significantly affected by parity, stages of lactation, udder type and liner quality in automated Herringbone milking parlour. The crossbred cows with poor udder attachment should be separately milked, not allowing them to enter the milking parlour where pooling of milk is done. Also, the cluster liners should be changed at regular intervals for hygienic milking operations. These managemental strategies will help in improving the milk

Table 3. Standard plate count of samples taken from pooled raw milk and cluster liners

Parameter	Number of milkings on each liner			
	1000 (6)	1500 (6)	2000 (6)	2500 (6)
Pooled milk (cfu/ml × 10^4)	1.07 ± 0.16^A	1.32 ± 0.17^A	2.54 ± 0.29^B	3.40 ± 0.27^C
Cluster liner (cfu/liner × 10^4)	24.75 ± 4.53^A	38.67 ± 4.55^{AB}	51.75 ± 5.93^B	109.63 ± 14.17^C

Values with different superscripts in a row differ significantly at P<0.01. Figure in parentheses indicates number of samples.

Table 4. Correlation between somatic cell count, electrical conductivity and standard plate count in milk samples

	SCC	EC	SPC
SCC	1		
EC	0.287	1	
SPC	0.588**	0.412	1

** Correlation coefficient is significant at 0.01 level (1-tailed).

quality, especially in an automated milking system and milking parlours.

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