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Effect of parity, stage of lactation and udder type on milkability of crossbred dairy cows milked in automated Herringbone milking parlour*

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ABSTRACT

The aim of the study was to investigate the effect of parity, stage of lactation and udder type on milkability of crossbred dairy cows milked in automated Herringbone milking system. Crossbred cows (218; Karan Fries and Karan Swiss) of different parities, stages of lactation and udder types were milked in 8×2 low-line automated Herringbone milking parlour having automatic cluster removal (ACR) settings for a period of 3 months. The milkablity of cows in automated herringbone milking parlour was based on parameters such as total milk yield, milk yield/session, machine-on time, yield first 2 min, and milk flow rates generated automatically in herd management Software during each session of milking. The results showed that milkability of cows was affected significantly based on parity and stage of lactation. The udder types had no effect on milkability except type D (pendulous) udders having least flow rate, which caused increased machine-on time. The overall mean milk flow rates over different intervals during the first two minutes of milking differed significantly in parity and udder types. Similarly, significant differences were observed in the flow rates over different intervals of milking.The milking efficiency benchmarks in terms of cow throughput and milk harvesting efficiency with 2 operators in the milking pit were 69.75±0.57 cows/ h and 305.21±2.75 kg/h, respectively. The operators had idle time during milking in batches of around 4.28 minutes/batch. It can be concluded from the present study that the milkability of crossbred dairy cows was significantly affected by parity, stage of lactation and type of udder in automated Herringbone milking parlour.

Key words: Crossbred cows, Herringbone parlour, Milkability, Parity, Stage of lactation, Udder type

Milking is a labour intensive task on dairy farms and requires over half of the annual labour inputs on well managed dairy farms (Taylor *et al*. 2009). Over the last few decades, with the ever increasing demand of milk, Indian dairy sector has become more commercialized resulting in increase of average herd size. The population of crossbred cows has also grown at a much faster rate than the indigenous stock (GOI 2016). To manage and milk such herds, state-of-the-art milking parlours equipped with automated milking and recording system are being adopted which limits the herd milking times and labour inputs. However, use of these milking systems depends on the individual cow milkability which influences the production and the economy of rearing (Miseikiene *et al*. 2014, Antalik and Strapak 2011).

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Dairy farmers place considerable emphasis on milkability, because cows which are not good milkers create hindrance in the milking process of the herd, especially in the milking parlours (Krogmeier *et al*. 2006). Significant variability in milkability of individual cows on the basis of their breed (Oltenacu and Broom 2010, Juozaitiene *et al*. 2016), parity and stage of lactation have been reported which influences milking efficiency and consequently labour productivity (Edward *et al*. 2013, Berry *et al*. 2013, Miseikiene *et al.* 2014, Edward *et al.* 2014).Therefore, the effect of these factors should be studied in our crossbred cows under Indian farming and environmental conditions so that suitable animals for parlour based machine milking could be made and this would also help in improving the efficiency of milking parlour. In this attempt, the present study was conducted to evaluate milkability based on parity, stage of lactation and udder type in automated herringbone milking parlours provided with software based herd management system in local crossbred cows.

MATERIALS AND METHODS

Animals and management: The study was conducted on crossbred cattle herd consisting of 218 Karan Fries (Tharparker × HF) and Karan Swiss (Brown Swiss × Sahiwal) cows maintained at the Livestock Research Centre, National Dairy Research Institute, Karnal, Haryana. All the experimental animals were kept in the similar loose housing system under group management practice during the entire period of trial. The animal house was constructed based on modern housing design, in which the sheds were at elevated heights for effective ventilation and there was provision of feeding stations with four feed dispensers installed within to supply the concentrate requirement of animals. These feed dispensers were equipped with sensor based identification of animals to supply the required amount of concentrate mixture. *Ad lib.* green fodder grown in the institute farm, were supplied according to the seasonal availability. No concentrate was supplied at the time of milking of animals in parlour. *Ad lib.* water was available in the open shed where animals stayed all the time except during milking.

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 personal computer (PC). The PC was connected to system controller through software programme sync and ISO-interface. The programme sync reflected the database in the processor with the database in the PC. 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.

All experimental animals were grouped under different parity i.e. parity 1 to parity 4; stage 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, C and D. The description of various udder types is given in Table 1.

Recording of parameters: The milkability traits were studied for 3 months based on observations generated automatically in herd management software of the automated milking system. following parameters were recorded.

- *Total milk yield (kg):* The daily milk yield recorded for all the 3 sessions of milking for individual cows.
- *Milk yield/session (kg)*: The amount of milk produced in the morning session of milking.
- *Yield first 2 min (kg)*: The milk obtained during the first 2 min of milking displayed by the sotware.
- *Machine-on time (min):* The time taken to complete the milking i.e. from the time of cluster attachment till the clusters were detached automatically from the udders.
- *Milk flow profile (kg/min)*: The milk flow was recorded as the flow of milk obtained in terms of average flow rate, peak flow rate and flow during 0–15, 15–30, 30–60 and 60–120 sec of milking which was displayed on the programmed windows.

The parlour performance was determined by the help of time taken in various milking operations accomplished by the help of operators/milkers efficient enough to handle the system. Following parameters were considered to determine the performance of Herringbone milking parlour.

- *Total milking time (min)*: Total time taken to milk all the cows in different batches of 16 animals in 2 × 8 herringbone milking parlour.
- *Cow throughput (per 2 person per hour)*: It refers to the total number of cows that were milked in an hour using 2 operators in the milking pit.
- *Total parlour milking rate (yield/hour and yield/cow)*: It refers to the total amount of milk that was milked in an hour in 2 × 8 milking parlour. It can also be defined as the total amount of milk harvested per cow in 2 × 8 herringobne milking parlour.
- *Average gate-attach (min)*: The average time from the entrance gate opened until last cluster release, measured for all batches in the session.
- *Milking time per batch of cows (min)*: It refers to the time taken in milking a unit batch of sixteen cows in 2 × 8 herringobne milking parlour. This includes the average machine on-time (last cluster take-off) and operator's working time/batch.
- *No. of batches milked (per hour)*: It refers to the number of batches that can be milked in an hour in 2 × 8 herringobne milking parlour.
- *Milking irregularities and incidents (%)*: The milking irregularities encountered during milking were cluster reattachments, cluster slips and detection of blood in the milk causing blood alarm.

Statistical analysis: To find out the milkability of crossbred dairy cows and to compare the performance between different experimental groups, the primary and secondary data on different parameters i.e. parity, stage of lactation and type of udder were generated, organized and subjected to statistical analyses using general linear model procedure in SAS version 9.3.

Table 1. Description of udders types

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 at the front suspension with an intermediate attachment.
C	When viewed from the rear is slightly to below the hocks, and the cleft will be slight to weak. The front attachment is loosely connected and beginning to hang low.
D	Very deep, hanging well below the hocks, with a cleft that's very weak to nonexistent. The front suspension is extremely loose, hanging well below the midsection of the cow, and the udder is absent of structure, shape and conformation.

RESULTS AND DISCUSSION

The milkability 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 total milk yield per day, milk yield per session (morning), machine-on time, yield first 2 min, average milk flow and peak milk flow were 13.41±0.31 kg, 6.12±0.14 kg, 5.35±0.08 min, 2.09±0.05 kg, 1.14±0.03 kg/ min and 2.20±0.06 kg/min, respectively (Table 2). Our results were lower than those reported by Antalik and Strapak (2011) in Slovak Simmental dairy cows, Dodenhoff and Emmerling (2009) in Fleckvieh dairy cows and Dodenhoff *et al.* (1999) and Strapak *et al.* (2011) in Holstein dairy cows.The overall mean milk flow rate in 0–15, 15–30, 30–60 and 60–120 sec of cluster attachment were 0.08±0.01, 0.94±0.05, 0.97±0.04, 1.17±0.05 kg/ min, respectively (Table 3). The results of milk flow rate showed an increasing trend from the time of cluster attachment which was in agreement to the reports of Ginsberg *et al.* (2011) who surveyed 32 Israeli farms using similar herd

Table 2. Effect of parity, stage of lactation and udder type on milkability of crossbred dairy cows milked in automated Herringbone milking parlour

Parameter	N	Total milk yield/ day/animal (kg) Mean±SE	Milk yield/ session (kg) Mean±SE	Machine-on time (min) Mean±SE	Milk yield first 2 min (kg) Mean±SE	Average milk flow (kg/min) Mean±SE	Peak milk flow (kg/min) Mean±SE
Parity							
1	78	11.63^{A} ±0.54	5.35^{A} ±0.24	4.93^{A} ±0.15	1.81^{A} ±0.09	1.04^{A} ±0.05	2.00^{a} ±0.10
2	59	12.48^{B} ±0.49	5.71^{B} ±0.22	5.07^{B} ±0.13	1.91^{AB} ±0.08	1.13^{BC} ±0.05	2.15^{ab} ±0.09
3	37	13.84^{B} ±0.61	6.32^{B} ±0.28	5.69^{C} ±0.17	2.22^{B} ±0.10	1.10^{AB} ±0.06	2.21^{ab} ±0.11
4	44	15.70^{C} ±0.51	7.11^{C} ±0.23	5.69^{C} ±0.14	2.41^{C} ±0.09	1.30^{C} ±0.05	2.43^{b} ±0.10
Stage of lactation							
Early	78	15.45^{A} ±0.43	7.05^{A} ±0.19	5.99^{A} ±0.18	2.32^{A} ±0.07	1.19^{A} ±0.04	2.46^{A} ±0.08
Mid	58	13.29^{B} ±0.51	6.04^{B} ±0.23	5.36^{B} ±0.14	2.10^{B} ±0.09	1.17^{A} ±0.05	2.03^{B} ±0.10
Late	82	11.50^{C} ±0.41	5.28^{C} ±0.19	4.68^{C} ±0.11	1.84^{C} ±0.07	1.07^{B} ±0.04	2.11^{B} ±0.08
Udder type							
A	96	13.47±0.41	6.14±0.18	4.95^{A} ±0.11	2.20±0.07	1.25^{a} ±0.04	2.43^{a} ±0.08
B	62	13.14±0.42	5.95±0.19	5.10^{A} ±0.12	2.14±0.07	1.19^{a} ±0.04	2.30^{ab} ±0.08
C	47	13.49±0.49	6.14±0.22	5.01^{A} ±0.13	2.05±0.08	1.17^{a} ±0.05	2.34^{a} ±0.09
D	13	13.55±1.00	6.27±0.45	6.33^{B} ±0.27	1.96±0.17	0.97^{b} ±0.10	1.72^{b} ±0.19
Overall	218	13.41±0.31	6.12±0.14	5.35±0.08	2.09±0.05	1.14±0.03	2.20±0.06

Means bearing different superscript in upper case letters in column differ significantly at 1% level (P<0.01) and in lower case letter at 5% level (P<0.05).

Table 3. Effect of parity, stage of lactation and udder type on milk flow rate at different intervals in crossbred dairy cows milked in automated Herringbone milking parlour

Parameters	N	Flow rate (kg/min)				
	Mean ± SE	0–15 sec Mean ± SE	15–30 sec Mean ± SE	30–60 sec Mean ± SE	60–120 sec Mean ± SE	Overall
Parity						
1	78	0.05 ^{A} ±0.01	0.74 ^{A} ±0.09	0.87 ^{A} ±0.07	1.05 ^{A} ±0.08	0.68 ^{A} ±0.04
2	59	0.08 ^{AB} ±0.01	0.93 ^{B} ±0.08	0.92 ^{A} ±0.06	1.20 ^{B} ±0.08	0.78 ^{AB} ±0.03
3	37	0.11 ^{B} ±0.02	0.97 ^{B} ±0.10	0.91 ^{A} ±0.07	1.17 ^{B} ±0.10	0.79 ^{AB} ±0.04
4	44	0.10 ^{B} ±0.01	1.13 ^{B} ±0.09	1.18 ^{B} ±0.06	1.26 ^{B} ±0.08	0.92 ^{B} ±0.03
Stage of lactation						
Early	78	0.08 ^{a}±0.01	0.80 ^{Ab}±0.07	1.05 ^{bc}±0.05	1.28 ^{Ac} ±0.07	0.80±0.03
Mid	58	0.08 ^{a}±0.01	0.97 ^{Bb}±0.08	0.98 ^{b}±0.06	1.23 ^{Ab} ±0.08	0.82±0.03
Late	82	0.09 ^{a}±0.01	1.06 ^{Bb}±0.07	0.89 ^{b}±0.05	1.00 ^{Bb} ±0.07	0.76±0.03
Udder						
A	96	0.11 ^{B}±0.01	1.15 ^{A}±0.07	1.05±0.05	1.31±0.06	0.91^{A} ±0.03
B	62	0.08 ^{A}±0.01	1.08 ^{A}±0.07	1.07±0.05	1.26±0.07	0.87 ^{A} ±0.03
C	47	0.07 ^{A}±0.01	0.86 ^{AB}±0.08	0.95±0.06	1.15±0.08	0.76 ^{AB} ±0.03
D	13	0.08 ^{A}±0.02	0.69 ^{B}±0.16	0.79±0.12	0.96±0.16	0.63 ^{B} ±0.07
Overall	218	0.08^{a} ±0.01	0.94^{b} ±0.05	0.97^{b} ±0.04	1.17^{c} ±0.05	0.79±0.02

Means within a column bearing different superscript (A, B) differ significantly at 5% level (P<0.05)& within row bearing different superscript (a,b) differ significantly at 5% level (P<0.05).

management software system.

Effect of parity: The highest (15.70±0.51 kg/day; 7.11±0.23 kg/session) milk yield was produced by the dairy cows in fourth parity; whereas, the lowest (11.63±0.54 kg/ day; 5.35±0.24 kg/ session) milk yield was produced by the cows in their first parity.There was significant difference (P<0.01) in milk yield among the parities. The mean machine-on time was found to be significantly (P<0.01) higher for animals in third (5.69±0.17 min) and fourth (5.69±0.14 min) parity. Similarly, the yield first 2 min of milking was also significantly (P<0.01) higher in cows in later lactations. The average milk flow rate was significantly (P<0.01) higher in multiparous cows in fourth parity. The peak milk flow rates were also significantly (P<0.05) different among parities. The results of the present study were in agreement with Dodenhoff and Emmerling (2008) who reported that Fleckvieh dairy cows reached higher milk yields in later parities. Similar to our observations, Jinger *et al.* (2014) and Japheth *et al.* (2015) also reported significant (P<0.01) influence of parity on milk yield in Karan Fries cows. Longer machine-on time in later parities was due to greater amount of milk produced compared to animals in early parity. The yield first 2 min was higher due to difference in flow rates among parities. The animals in second and third parity had similarity in their milkability traits, except mean machine-on time which brought differences in their milk yield. Edward *et al.* (2014) reported that the amount of milk harvested in the first 2 min as an indication of the milk held in the cistern at the start of milking. A greater proportion of milk held in the cistern is beneficial to milking efficiency (Edwards *et al.* 2013, 2014). The study showed that as the amount of milk increased with parity, there was improvement in the milkability of animals which may be due to increased amount of cisternal milk in these animals. Similar results were reported by Dodenhoff *et al.* (1999) and Strapak*et al.* (2011) in Holstein dairy cows which were in later parity. The primiparous cows showed lowest values of the milkability traits mentioned. Tancin *et al.* (2006) compared the milkability of Holstein cows at udder and quarter levels and found significant differences in milk yield and machine-on time in primiparous and multiparous cows. However, in their study, parity did not influence average and peak milk flow rates in these cows.

The overall effect of parity on flow rates during the first 2 min of milking differed significantly (P<0.05) with lowest flow rate in the first parity (0.68±0.04 kg/min) and highest flow rate (0.92±0.03 kg/min) in fourth parity animals (Table 3). The flow rate in 0–15 sec of milking differed significantly (P<0.05) in primiparous cows (0.05±0.01 kg/min) than in multiparous cows belonging to third and fourth parity (0.11±0.02 and 0.10±0.01 kg/min, respectively). The milk flow rate in 15–30 sec of milking was significantly (P<0.05) lower in first parity (0.74±0.09 kg/min). The milk flow rate in 30–60 sec of milking was similar among first, second and third parities (varied from 0.87±0.07 to 0.92±0.06 kg/min) but the cows in fourth lactation had significantly (P<0.05) higher (1.18±0.06 kg/ min) flow rate. The flow rate over 60–120 sec of milking were similar among parities except those in first parity animals. A steep rise in milk flow rate during 60–120 sec of milking was recorded irrespective of parities. The initial lower flow rate in first-calvers may be due to slower teat stimulation compared to other parities. The variation of flow rate in 30–60 sec may be due to greater amount of cisternal milk and faster milk let-down as reported by previous researchers (Edwards *et al*. 2013, Szentleleki*et al*. 2015). The flow rate in 60–120 sec of milking may be the time when animal achieved highest flow rate and hence, should be monitored for any deviation caused due to discomfort of the animal in the milking area or change in milking routine. The results of present study were in agreement to Livshin *et al*. (2005) who reported the percent slow starter cows (initial low milk flow rate) more in first-calvers than multiparous cows (51.2 vs 31.1%). Miseikiene *et al.* (2014) reported that cows with lower initial milk flow rate after cluster attachment, had higher milking time, a relatively low flow during the first two minutes of milking, low peak flow and longer time to reach it than cows that had high flow rate, when compared for similar yield per milking. In our study also, it was seen that the animals who had low flow initially had lower two minutes milk yield, lower average and peak flow. Therefore, initial milk flow may serve as valuable predictor of cow's milkability (Weiss *et al.* 2003, Livishin *et al*. 2005).

Effect of stage of lactation: The effect of stage of lactation on milkability of cows is presented in Table 2. The total milk/day/animal, milk/session (morning), machine on-time and yield during first 2 min were significantly (P<0.01) higher during the early stages of milk production (15.45±0.43 kg/day, 7.05±0.19 kg/session, 5.99±0.19 min, 2.32±0.07 kg, respectively) than in mid and late stages. The average flow rate was significantly (P<0.01) higher during early and mid stages (1.19±0.04 and 1.17±0.05 kg/min, respectively) in comparison to late stage of lactation. The peak milk flow was significantly (P<0.01) higher in early stages of lactation (2.46±0.08 kg/min) which tended to reduce in later part of lactation and was similar in mid and late stages. The milking characteristics varies according to the stages of lactation due to change in milk production with advancing lactation (Gurmessa and Melaku 2012). Similar results were reported by Strapak *et al.* (2011) and Sandrucci *et al.* (2007) in Holstein dairy cows. Antalik and Strapak (2011) reported that in Slovak Simmental dairy cows, the lowest values of total milk yield and average milk flow rate were found in cows more than 200 days in milk. However, contrary to our results, they reported highest values of milk flow rates in cows from 100 to 200 days in milk rather than the cows in the beginning of lactation. This may be due to difference in level of production of the animals which was lower in early lactation and greater in mid lactation (12.44±3.25 vs 11.47±4.22 kg, respectively).

The overall effect of stage of lactation on milk flow rate was similar in early, mid and late stages which varied from 0.76±0.03 to 0.82±0.03 kg/min (Table 3). The initial flow rate (15–30 sec) was significantly (P<0.05) higher (1.06±0.07 kg/min) in late stage of lactation and reduced over subsequent intervals of milking. Significant (P<0.05) differences were seen at 60–120 sec of milking with higher milking rate in early and mid stages. It was also found that interaction effect between different flow rates in different stages of lactation showed significant difference (P<0.05). The higher initial flow rate in late lactation indicated faster teat stimulation resulting in release of cisternal milk. However, later the flow rate diminished due to delayed milk ejection and lesser amount of alveolar milk, compared to early and mid stages resulting in higher milking rate (Caja *et al*. 2004). Similar results were reported by Tancin *et al.* (2006) at udder and quarter levels in Holstein cows. Edwards *et al*. (2014) reported shape of the milk flow profile curve changes with stages of lactation and varied between heifers and mature cows. The difference in the milk flow rates may also be due to varying stimulation provided by the milking machine to these cows in different stages of lactation (Mein and Reinemann 2007, Bruckmaier and Hilger 2001, Schukken *et al.* 2005).

Effect of udder type: The effect of udder type on average milkability of cows is presented in Table 2. The total milk/animal/day as well as milk/session (morning) did not show any significant differences in all types of udders. However, machine-on time was significantly (P<0.01) higher (6.33±0.27 min) in animals with type D udders. These animals were also found to have significantly (P<0.05) lower average and peak milk flow rates (0.97±0.10 and 1.72±0.19 kg/min, respectively). Since, the milk yields were similar in all categories of animals, lower average and peak flow rates may be due to type D udders (pendulous, poor conformation), which may not be suitable for being milked with milking machine. In a similar study on East Friesian crossbred dairy ewes, McKusick *et al*. (2000) found that poor udder conformation and teat placement increase parlour throughput time because such ewes were found to have low milk flow rate and extra labour was required to massage or lift the udder to completely evacuate it. Menu (2010) in his recommendations to dairy farmers reported that failure of the milking machine to completely remove the available milk from the cow's udder may be due to several reasons and poor udder conformation is one of them.

The overall milk flow rate during first 2 min based on udder types A, B, C and D were found to have significant differences (P<0.05) with udder type D having lower flow rate (0.63±0.07 kg/min) as compared to others (Table 3). The initial flow rate was also found to be lower in animals with type D udders. The results were in agreement with the findings of Miseikiene *et al.* (2014), who reported that cows with lower milk flow initially after cluster attachment, had higher milking time, a relatively low milk flow during the first 2 min of milking, low peak flow and longer time to reach it than cows that had a high flow rate, when compared for similar yield per milking. The results in our study, based on the above findings and reports of previous researchers showed that milking of animals with lower flow rate as in type D udder in parlours designed for batch milking may not be suitable (such as automated Herringbone milking parlour) as they may affect the parlour performance as well as the milking efficiency of the milker.

Performance in milking parlour: The performance of lactating crossbred dairy cows in Herringbone parlour is presented in Table 4. The results showed that morning session was more time consuming (66.62±1.11 min) due to significantly (P<0.01) higher yield in this session compared to afternoon and evening sessions. The cow throughput in double 8 Herringbone milking parlour having 16 units for attachment at a time, with 2 operators in the milking pit was 69.75±0.57 cows/h (range 62.89 to 73.20 cows/h, depending on yield/cow). Similarly, the milk harvesting efficiency i.e. yield/h under standard pre-milking practices was 305.21±2.75 kg/h (range 264.17 kg to 379.92 kg/h). The operators were strictly monitored to follow set pre-

Table 4. Performance of crossbred dairy cows in automated Herringbone milking parlour

Parameter	Milking session			
	Morning (69) Mean±SE	Afternoon(69) Mean±SE	Evening (69) Mean±SE	Overall†(69) Mean±SE
Total yield/day (kg)	418.96^{A}±6.11	255.14^{B}±6.11	249.93^{B}±6.11	924.02±10.59
Total milking time (min)	66.62^{A}±1.11	56.99^{B}±1.11	57.12^{B}±1.11	180.73±1.92
No. of cows milked /2 person/h	62.89^{A}±0.99	73.20^{B}±0.99	73.17^{B} ±0.99	69.75±0.57
Milk yield/h (kg)	379.92^{A}±4.77	271.53^{B}±4.77	264.17^{B}±4.77	305.21±2.75
Milk yield/cow (kg)	6.05^{A}±0.05	3.72^{B}±0.05	3.62^{B}±0.05	13.39±0.08
Milking time/batch (min)	9.37^{A}±0.13	7.04^{B}±0.13	7.30^{B}±0.13	7.90±0.07
Avg. gate attached (min)	4.30±0.11	4.48±0.11	4.29±0.11	4.36±0.07
No. of batches milked/h	4.08^{A}±0.07	4.82^{B}±0.07	4.77^{B}±0.07	4.55±0.04
Operator working time/batch (min)	3.62±0.03	3.59±0.03	3.64±0.03	3.62±0.02
Cluster reattach (%)	7.06±0.42	7.87±0.42	6.58±0.42	7.17±0.24
Cluster slips (%)	2.81^{A}±0.17	0.91^{B}±0.17	0.88 ^{B}±0.17	1.53±0.10
Blood alarm (%)	0.09±0.04	0.10±0.04	0.08±0.04	0.09±0.02

Means bearing different superscripts in a row differ significantly at 1% level (P<0.01). †Performance in milking parlour based on all 3 sessions of milking.

milking procedures to ensure clean and hygienic milking. The time required to complete these work routines i.e. pre-milking udder washing, fore-stripping, cluster attachment and post-milking teat spray before milking each batch was 0.544±0.004, 1.179±0.006, 1.589±0.015, 0.303±0.003 min, respectively. The results indicated that the operators had idle time during milking in batches which was around 4.28 min/batch. In a similar study on Herringbone milking parlour by Edward *et al.* (2013) in Holstein dairy cows, it was found that cow throughput and milk harvesting efficiency increased with increasing parlour size (12 to 32 cluster units) with throughput ranging from 42 to 129 cow/h and milk harvesting efficiency from 497 to 1430 kg/h (1–2 operators). It was also suggested that greater throughput can be achieved with decrease in operator's idle time. O'Brien *et al.* (2012) reported less operator idle time in larger parlours. In a comparative study on the basis of parlour sizes, it was found that exit and post-milking teat spray time differed between parlour sizes, with a linear association between them. However, this should not be related to parlour size on a per cow basis and holds true where milking is done in batches. Our results also revealed that although double 8 Herringbone milking parlour can be easily managed by a single skilled person, still 2 persons will improve the efficiency of the milking parlour by decreasing the time consumed per operator in pre-milking procedures. It may therefore be suggested to increase the cluster units i.e. size of the parlour with same number of operators working in pit to achieve greater throughput by decreasing the operator idle time/batch of cows milked.

The present study envisaged that the milkability of cows in automated Herringbone milking parlour was affected significantly by parity and stage of lactation. The crossbred cows during early stage of lactation in their fourth parity performed best in the milking parlour. The udder types had no effect on milkability except cows having pendulous udders with poor conformation.

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