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Impact of environmental factors on milk constituents and yield traits in Murrah buffaloes

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ABSTRACT

The present study was carried out to analyse milk constituents and yield traits using 1,582 first lactation monthly test day records of 224 Murrah buffaloes, calved between 2006 and 2014. The overall least-squares means of monthly test day milk constituent traits, viz. fat, protein, lactose, solids-not-fat (SNF) and total solids (TS) were 7.96 ±0.07, 3.86±0.02, 5.63±0.02, 9.97±0.01 and 17.75±0.07%, respectively. The overall least-squares means of monthly test day milk constituent yield traits, viz. milk yield, fat yield, protein yield, lactose yield, SNF yield and TS yield were 6.95±0.15 kg, 549.76±12.97 g, 269.17±6.12 g, 392.52±8.65 g, 681.02±14.97 g and 1231.00±27.46 g, respectively. The estimates of milk constituent traits were found higher in autumn and lower in summer season, except SNF (%) that was found higher in rainy season. All the yield traits were found higher in winter and autumn season and lower in rainy season. Milk protein (%) was significantly higher during early stage (<90 days) and decreased along with stage of lactation. On the other hand, milk lactose (%) was minimum during early stage of lactation and increased thereafter. All the yield traits were significantly higher during early stage and decreased with the stage of lactation. All the milk constituent traits were higher in buffaloes calved up to the age of 51 months; whereas, buffaloes calved after 51 months of age had higher yield traits. Phenotypic correlations revealed that, milk fat, lactose and TS per cent had very low and negative correlation with monthly test day milk yield. The milk fat (%) had very high and positive correlation with TS (%), indicating that, buffaloes with higher fat content may be selected for higher TS content in milk. Data on variation of milk constituent and yield traits over the years, seasons, stages of lactation and age of buffaloes can be utilized to improve quality as well as quantity of milk in breed improvement programmes.

Key words: Environmental factors, Milk constituents, Murrah buffalo, Test day

Buffaloes are cynosure of Indian dairy industry. Total buffalo population in India is 108.70 million and contributes 51% of the total milk produced in the country (BAHS 2015). Buffalo milk is richer in milk constituents such as fat (%), protein (%) and solids-not-fat (SNF) (%) in comparison to cow milk. Till date, milk yield of dairy animals has received major emphasis among production traits throughout the world; whereas, milk constituent traits received less attention in breed improvement programmes. The nutritional value of the milk mainly depends on the milk constituents like fat, protein and lactose. Therefore, milk constituents must be given proper weightage along with milk yield while planning breed improvement strategy. The milk constituents vary during entire lactation and are governed by both genetic makeup of animals and environmental factors such as season, stage of lactation and age of animal. To minimize the impact of environmental factors, it is essential to quantify the effect of each environmental factor and to adjust its effect for formulating management and breeding strategies to improve the quality as well as quantity of buffalo milk. The present study was thus undertaken to quantify variation in milk constituents and yield traits over the year, season, stage of lactation and age of buffaloes; and to assess the relationship among milk constituents and yield traits in Murrah buffaloes.

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MATERIALS AND METHODS

Data source: First lactation monthly test day records (1,582) of 224 Murrah buffaloes, calved between 2006 and 2014 at ICAR-National Dairy Research Institute, Karnal, were analysed. Adult lactating buffaloes were maintained under loose housing system in the farm. Buffaloes were provided with *ad lib.* green fodder and roughages. Concentrate ration was provided according to milk yield to meet the production requirement of buffaloes. Monthly test day (date of milk testing) records of milk fat, protein, lactose, solids-not-fat (SNF) contents and milk yield were collected. Total solids (TS) content were derived by taking

summation of fat and SNF content. Ten monthly test days with the interval of 28–35 days were considered. The milk constituent traits analysed in the study were fat (%), protein (%), lactose (%), SNF (%) and TS (%), and the milk constituent yield traits were milk yield, fat yield, protein yield, lactose yield, SNF yield and TS yield. The milk constituent yield traits were estimated using the formula: MCY = MC × MY × 10; where MCY is the milk constituent yield trait in grams, MC is the respective milk constituent trait in percentage and MY is milk yield in kg on that particular test day.

Statistical analysis of data: The statistical analysis of milk constituent and yield traits was carried out in three steps. Initially, the effect of environmental factors such as year of calving, season of test day recording, stage of lactation and age at first calving (AFC) on milk constituent and yield traits was assessed using GML procedure (PROC GLM) of SAS 9.3 software (SAS 2012). Secondly, the effect of environmental factors such as year of calving, season of test day recording and AFC was assessed on each test day (TD1 to TD10) milk constituent and yield traits separately using the above software package. In the last, the relationships among all the milk constituent and yield traits were assessed by estimating Pearson's correlation coefficient between the phenotypic values using CORR Procedure (PROC CORR) of SAS 9.3 software. The years of calving from 2006 to 2014 were taken in the analysis. Each year was sub-classified in to four seasons as winter (December to March), summer (April to June), rainy (July to September) and autumn (October to November). Buffaloes were classified based on mean and standard deviation of AFC, as well as different stages of lactation. The buffaloes were classified in to three age groups, viz. < 42 months, 42 - 51 months and > 51 months. Three stages of lactation, viz. ≤ 90 days, 91–180 days and >180 days were considered for the classification of buffaloes. The fixed model used to assess the influence of non-genetic factors on overall test day milk constituent and yield traits was:

$$Y_{ijklm} = \mu + Yr_i + S_j + SL_k + A_l + e_{ijklm} \quad (I)$$

and the fixed model used to assess effect of non-genetic factors on each test day milk constituent and yield trait was

$$Y_{ijkl} = \mu + Yr_i + S_j + A_k + e_{ijkl} \quad (II)$$

where, Y_{ijklm} or Y_{ijkl}, one of the milk constituent and yield traits. The fixed effects were the i^{th} year (Yr_i), j^{th} season of test day recording (S_j), k^{th} stage of lactation (SL_k) and l^{th} (or k^{th} age group in model II) age group (A_l). The residual effect (e_{ijklm} or e_{ijkl}) was assumed to be normally and independently distributed with a mean of '0' and an unknown variance of σ_e^2.

RESULTS AND DISCUSSION

Milk constituent traits: The least-squares means for all the milk constituent traits derived using model I are presented in Table 1. The overall least-squares means for

Table 1. Least-squares means for milk constituent traits during first lactation in Murrah buffaloes

Effect	N	Fat (%)	Protein (%)	Lactose (%)	SNF (%)	TS (%)
Overall (μ)	1,582	7.96±0.07	3.86±0.02	5.63±0.02	9.79±0.01	17.75±0.07
Year of calving		NS	***	***	***	*
2006	142	8.04±0.10	4.40^{e}±0.03	5.35^{a}±0.03	9.77^{ab}±0.02	17.81^{ab}±0.11
2007	282	7.90±0.07	3.82^{bc}±0.02	5.27^{a}±0.02	9.68^{a}±0.01	17.58^{a}±0.07
2008	112	7.68±0.11	3.59^{a}±0.03	5.39^{a}±0.03	9.73^{a}±0.02	17.41^{a}±0.12
2009	412	8.00±0.06	3.73^{ab}±0.02	5.69^{bc}±0.01	9.77^{ab}±0.01	17.77^{ab}±0.06
2010	285	7.98±0.07	3.73^{ab}±0.02	5.73^{cd}±0.02	9.76^{ab}±0.01	17.74^{ab}±0.07
2011	8	8.48±0.40	3.80^{bcd}±0.12	5.78^{cd}±0.10	9.72^{a}±0.08	18.20^{b}±0.42
2012	90	7.93±0.12	3.74^{ab}±0.04	5.59^{b}±0.03	9.88^{bc}±0.02	17.80^{ab}±0.13
2013	241	8.04±0.07	3.95^{cd}±0.02	5.87^{d}±0.02	9.79^{ab}±0.02	17.83^{ab}±0.08
2014	10	7.63±0.36	4.00^{d}±0.11	6.03^{e}±0.09	9.98^{c}±0.07	17.62^{a}±0.38
Season of test day recording		NS	**	***	*	NS
Winter	619	7.99±0.08	3.89^{b}±0.02	5.61^{a}±0.02	9.79^{b}±0.02	17.78±0.08
Summer	413	7.87±0.08	3.81^{a}±0.03	5.62^{a}±0.02	9.77^{ab}±0.02	17.65±0.09
Rainy	310	7.94±0.09	3.87^{a}±0.03	5.61^{a}±0.02	9.82^{b}±0.02	17.75±0.09
Autumn	240	8.05±0.10	3.88^{a}±0.03	5.69^{b}±0.03	9.77^{a}±0.02	17.82±0.10
Stage of lactation (days)		NS	***	*	NS	NS
≤ 90	462	7.96±0.08	3.90^{ab}±0.02	5.61^{b}±0.02	9.78±0.02	17.74±0.08
91-180	524	7.96±0.08	3.87^{b}±0.03	5.62^{a}±0.02	9.78±0.02	17.74±0.09
>180	596	7.97±0.08	3.81^{a}±0.02	5.66^{ab}±0.02	9.80±0.02	17.76±0.08
Age at first calving (months)		*	NS	NS	NS	**
<42	550	7.96^{ab}±0.08	3.86±0.03	5.64±0.02	9.80±0.02	17.76^{a}±0.08
42-51	625	8.07^{b}±0.07	3.87±0.02	5.63±0.02	9.80±0.01	17.87^{b}±0.08
>51	407	7.86^{a}±0.08	3.85±0.03	5.62±0.02	9.77±0.02	17.62^{a}±0.09

*Significant (P<0.05); **Significant (P<0.01); ***Significant (P<0.001); NS (P>0.05); ^{a,b,c,d,e}Means within each column not bearing a common superscript differ significantly at P<0.05.

milk fat, protein, lactose, SNF and TS were 7.96±0.07, 3.86±0.02, 5.63±0.02, 9.79±0.01 and 17.75±0.07%, respectively. Nearly similar estimates of milk fat and SNF per cent were reported by Verma (2012) and Chitra (2015) and slightly lower estimates than present study were reported by Dubey *et al*. (2007) in Murrah buffaloes. The analysis of variance (ANOVA) revealed that year of calving had highly significant (P<0.001) influence on milk protein, lactose and SNF per cent, and significant (P<0.05) influence on TS per cent. The season of test day recording had highly significant influence on milk protein (P<0.01) and lactose per cent (P<0.001), and significant (P<0.05) influence on SNF per cent. The stage of lactation had highly significant (P<0.001) influence on milk protein (%) and significant (P<0.05) influence on milk lactose (%). The AFC had highly significant (P<0.01) influence on milk TS (%) and significant (P<0.05) influence on milk fat (%). Dubey *et al*. (2007) reported significant influence of year of calving and stage of lactation on all milk constituent traits in Murrah buffaloes.

Milk fat (%) was found highest (8.48±0.40) for the buffaloes calved during 2011 and lowest (7.63±0.36) during 2014, although the effect was not significant. Milk protein (%) varied significantly from 3.59±0.03 to 4.40±0.03 during 2008 and 2006. Milk lactose and SNF per cent were found minimum (5.27±0.02 and 9.68±0.01) during 2007 and maximum (6.03±0.09 and 9.98±0.07) during 2014. Milk TS (%) varied from 17.41±0.12 to 18.20±0.42 during 2008 and 2011. The differences in milk constituent traits over the years may be attributed to differences in feeding and management practices besides the variability of herd size over the years. Milk protein, lactose and SNF per cent varied significantly among different seasons. Milk protein per cent was found lower in summer season (3.81±0.03) and higher in other three seasons (3.87 to 3.89). Milk lactose per cent was found higher in autumn season (5.69±0.03) and lower in rest of the seasons (5.61 and 5.62). Milk SNF per cent was found higher in rainy season (9.82±0.02) and lower and almost similar in autumn and summer seasons (9.77). Milk fat and TS per cent were found higher (8.05±0.10 and 17.82±0.10) in autumn season and lower (7.87±0.08 and 17.65±0.09) in summer season, though the influence was not found significant. Perusal of the analysis revealed that, all the milk constituent traits were found higher in autumn and winter seasons and lower in summer season; except SNF per cent that was higher in rainy season and lower in summer and autumn seasons. The seasonal differences of milk constituent traits may be attributed to the differences in quality and quantity of available fodder and climatological variations in different seasons which have direct impact on milk composition. Regarding the effect of stage of lactation, the milk protein per cent was found significantly higher (3.90±0.02) during early stage (< 90 days) and decreased thereafter during advance lactation. On the other hand, milk lactose per cent was found minimum (5.61±0.02) during early stage of lactation and

Table 2. Least-squares means for milk constituent yield traits during first lactation in Murrah buffalloes

Effect	N	Milk yield	Fat yield	Protein yield	Lactose yield	SNF yield	TS yield
Overall (μ)	1,582	6.95±0.15	549.76±12.97	269.17±6.12	392.52±8.65	681.02±14.97	1231±27.46
Year of calving		***	***	***	***	***	***
2006	142	6.70^{b}±0.23	533.30^{ab}±19.59	296.72^{cd}±9.24	358.94^{ab}±13.06	653.47^{b}±22.61	1187.00^{ab}±41.47
2007	282	7.27^{bc}±0.16	569.48^{bc}±13.39	277.42^{cd}±6.32	382.62^{bc}±8.93	703.52^{bc}±15.46	1273.00^{bc}±28.34
2008	112	6.82^{b}±0.25	521.34^{ab}±21.22	245.56^{abc}±10.01	367.91^{ab}±14.15	663.42^{b}±24.51	1185.00^{ab}±44.93
2009	412	7.87^{c}±0.13	630.08^{c}±11.03	294.32^{d}±5.21	448.12^{c}±7.36	768.67±12.74	1399.00^{c}±23.36
2010	285	5.98^{ab}±0.16	475.01^{ab}±13.12	222.67^{ab}±6.19	341.57^{ab}±8.75	583.58^{ab}±15.15	1059.00^{ab}±27.77
2011	8	4.63^{a}±0.93	387.86^{a}±78.35	175.55^{a}±36.96	268.85^{a}±52.24	448.90^{a}±90.46	836.76^{a}±165.88
2012	90	7.38^{bc}±0.29	588.16^{bc}±24.27	274.65^{bcd}±11.45	412.98^{bc}±16.18	729.65^{bc}±28.02	1318.00^{bc}±51.38
2013	241	6.86^{bc}±0.17	553.50^{bc}±14.54	271.29^{cd}±6.86	402.30^{bc}±9.70	671.71^{bc}±16.79	1225.00^{bc}±30.79
2014	10	9.08^{d}±0.83	689.09^{d}±70.05	364.37^{e}±33.05	549.44^{d}±46.70	906.26^{d}±80.88	1595.00^{d}±148.30
Season of test day recording	NS	NS	NS	NS	NS	NS	NS
Winter	619	7.11±0.17	564.20±14.60	277.48±6.89	398.73±9.73	696.31±16.86	1261.00±30.91
Summer	413	6.89±0.19	536.85±15.67	263.27±7.39	388.40±10.45	674.05±18.10	1211.00±33.18
Rainy	310	6.73±0.20	534.10±16.80	261.54±7.93	378.92±11.20	661.79±19.40	1196.00±35.58
Autumn	240	7.08±0.23	563.88±19.10	274.41±9.01	404.05±12.74	691.93±22.06	1256.00±40.44
Stage of lactation (days)		***	***	***	***	***	***
≤ 90	462	7.57^{b}±0.17	598.60^{b}±14.71	294.93^{b}±6.94	424.91^{b}±9.81	740.26^{b}±16.99	1339.00^{b}±31.14
91-180	524	7.47^{b}±0.19	591.15^{b}±15.95	290.18^{b}±7.52	421.36^{b}±10.63	731.73^{b}±18.41	1323.00^{b}±33.76
>180	596	5.82^{a}±0.18	459.53^{a}±15.18	222.41^{a}±7.16	331.31^{a}±10.12	571.07^{a}±17.52	1031.00^{a}±32.13
Age at first calving (months)	***	***	***	***	***	***	***
<42	550	6.60^{a}±0.18	524.85^{a}±15.62	254.94^{a}±7.37	373.31^{a}±10.41	647.54^{a}±18.03	1172.00^{a}±33.06
42-51	625	6.76^{a}±0.17	540.70^{a}±14.16	261.79^{a}±6.68	381.76^{b}±9.44	662.76^{a}±16.35	1203.00^{a}±29.99
>51	407	7.50^{b}±0.19	583.73^{b}±16.22	290.80^{b}±7.65	422.50^{c}±10.82	732.76^{b}±18.73	1316.00^{b}±34.34

***Significant (P<0.001); NS (P>0.05); ^{a,b,c,d,e}Means within each column not bearing a common superscript differ significantly at P<0.05.

increased thereafter. Milk fat, SNF and TS per cent were found higher during late stage of lactation (> 180 days); however, the effect was not significant. As far as effect of AFC is concerned, all the milk constituent traits were found higher in buffaloes calved up to the age of 51 months, although effect was found significant on milk fat and TS per cent only. Similar seasonal variation in milk protein and lactose per cent were reported by Yadav *et al*. (2013), however, in contrast to present study, they reported higher milk fat per cent during summer season and lower in winter season.

Milk constituent yield traits: The overall least-squares means for test day milk yield, fat yield, protein yield, lactose yield, SNF yield and TS yield were 6.95±0.15 kg, 549.76±12.97 g, 269.17±6.12 g, 392.52±8.65 g, 681.02±14.97 g and 1231.00±27.46 g, respectively (Table 2). Nearly similar estimates of milk yield and fat yield were reported by Kumar (2015) in Murrah buffaloes. The ANOVA from model I revealed that year of calving, AFC and stage of lactation had highly significant (P<0.001) influence on all the yield traits, whereas, season of test day recording had nonsignificant influence on all the yield traits.

The milk constituent yield traits depend on both milk yield and respective milk constituent. As the milk yield has more variability than milk constituents, therefore all the milk constituent yield traits were influenced more by milk yield of buffalo and had nearly similar trend as of milk yield with respect to different environmental factors. All the yield traits were found maximum during 2014 and minimum during 2011. All the yield traits were found higher in winter and autumn seasons and lower in rainy season, although the effect was nonsignificant. As far as the effect of stage of lactation is concerned, all the yield traits were found significantly higher during early stage of lactation and decreased during advance lactation. All the yield traits including milk yield had opposite trend to the milk fat, lactose, SNF and TS per cent, as all the yield traits decreased during late stage of lactation with concomitant increase in milk fat, lactose, SNF and TS per cent. However, both milk protein per cent and protein yield decreased with the advance of lactation. Regarding the effect of AFC, all the yield traits were found higher in old age calvers (>51 months), whereas early age calvers (<42 months) had lower yield traits, that was contrast to the effect of age on milk constituent traits.

Milk production traits over the test days: Least-squares means of all milk production traits in different test days derived using model II are depicted in Figs 1– 6. It revealed

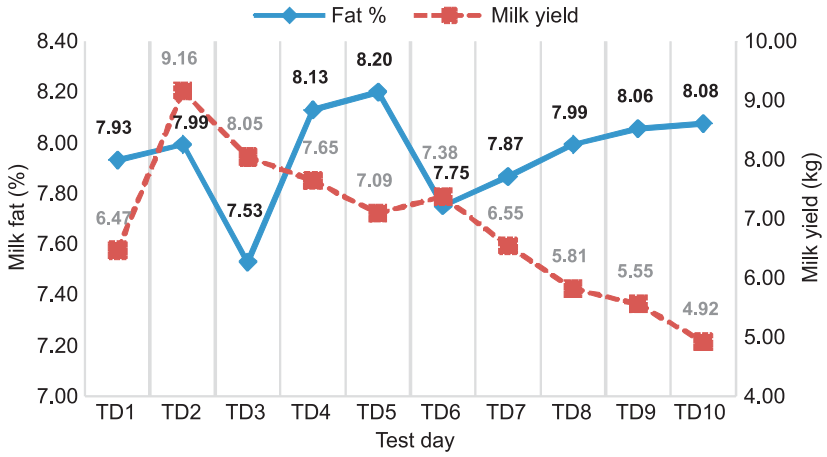

Fig. 1. Milk fat per cent and milk yield during the first lactation in Murrah buffaloes.

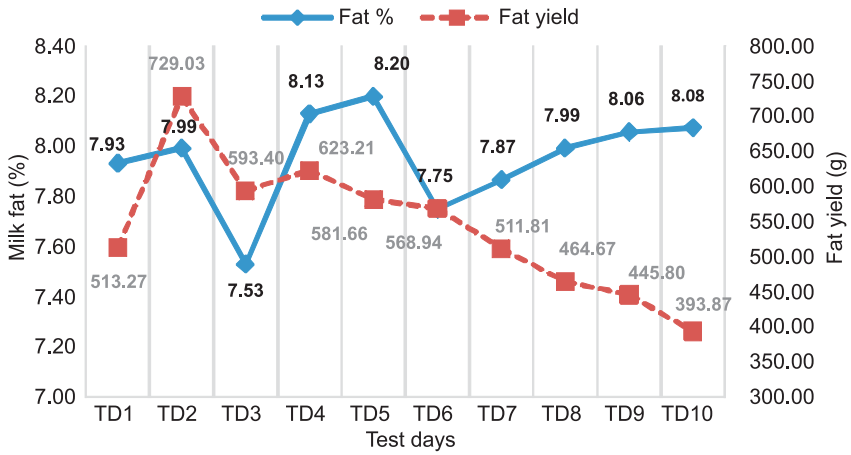

Fig. 2. Milk fat% and fat yield during the first lactation in Murrah buffaloes.

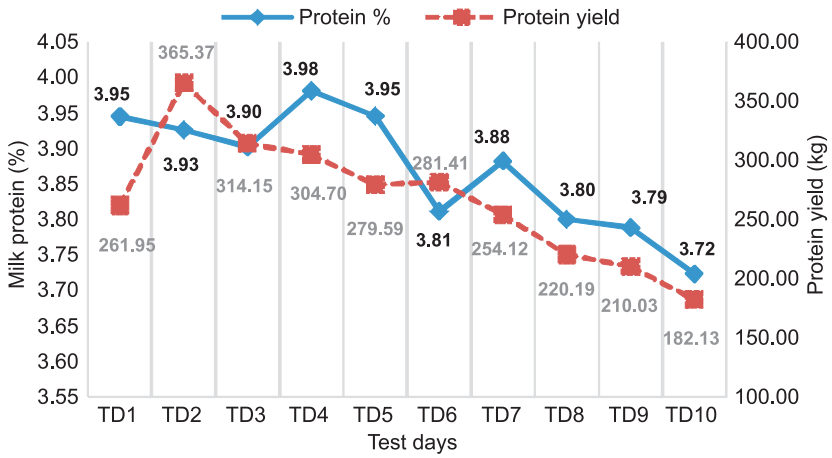

Fig. 3. Milk protein% and protein yield during the first lactation in Murrah buffaloes

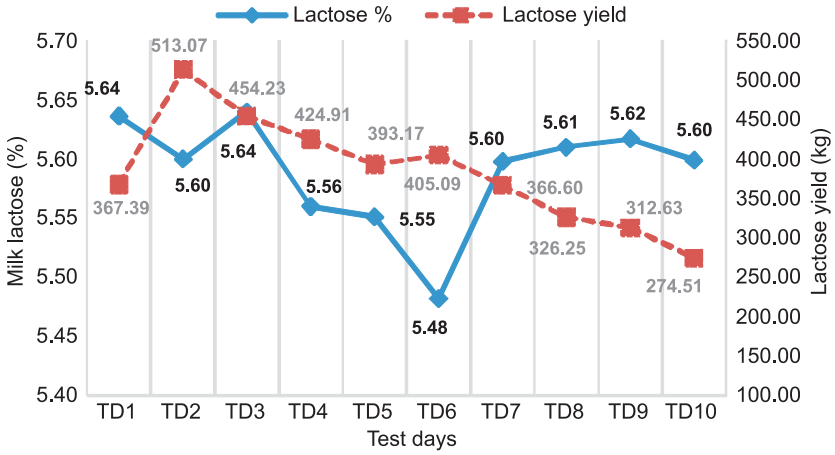

Fig. 4. Milk lactose% and lactose yield during the first lactation in Murrah buffaloes

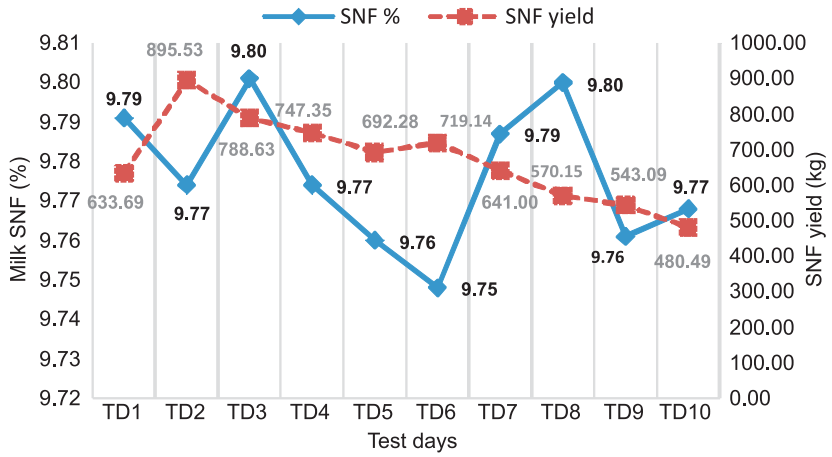

Fig. 5. Milk solids-not-fat (SNF)% and SNF yield during the first lactation in Murrah buffaloes

that milk fat% had opposite trend to the milk yield over the test days (Fig. 1). The milk fat% initially decreased up to the test day 3 then increased up to test day 9 and 10. On the other hand, milk yield increased up to test day 2 and then decreased up to the test day 10. The milk protein per cent also had opposite trend to milk fat per cent over the test days and increased up to test day 4 and then decreased over the test days. The milk lactose per cent decreased up to the test day 6 and then increased over the test days. The trends of milk SNF and TS per cent in different test days were not

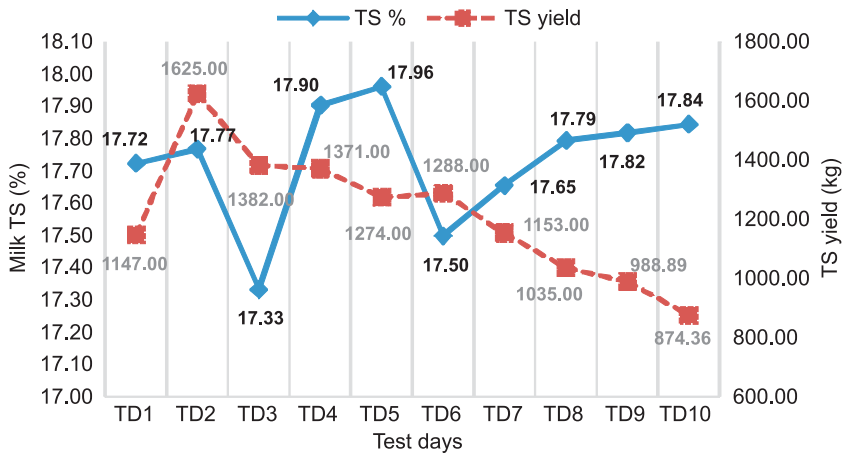

Fig. 6. Milk total solids (TS)% and TS yield during the first lactation in Murrah buffaloes.

Table 3. Pearson correlation coefficients between milk production traits on Murrah buffaloes

	Protein %	Lactose %	SNF %	TS %	Milk yield	Fat yield	Protein yield	Lactose yield	SNF yield	TS yield
Fat%	0.233**	0.264**	0.186**	0.982**	-0.039	0.283**	0.016	0.003	-0.028	0.118**
Protein%		0.302**	0.131**	0.246**	0.005	0.076**	0.247**	0.050*	0.011	0.042
Lactose%			0.330**	0.312**	-0.017	0.072**	0.057*	0.139**	0.002	0.035
SNF%				0.366**	0	0.065**	0.028	0.052*	0.055*	0.061*
TS%					-0.037	0.280**	0.021	0.012	-0.016	0.123**
Milk yield						0.938**	0.965**	0.986**	0.998**	0.985**
Fat yield							0.924**	0.940**	0.940**	0.983**
Protein yield								0.964**	0.965**	0.960**
Lactose yield									0.987**	0.980**
SNF yield										0.987**

**Significant (P<0.01).

found in accordance with the milk fat per cent. However, minimum SNF per cent was observed during the test day 6 and minimum TS per cent was observed during the test day 3. All the yield traits had similar trend over the test days as of milk yield.

Relationship among the milk production traits: Phenotypic correlations between all the milk constituent and yield traits are depicted in Table 3. It revealed that milk fat, lactose and TS per cent had low and negative correlation with test day milk yield, that support the opposite trends of milk fat, lactose and TS per cent observed against milk yield during the entire lactation. The milk fat per cent had very high correlation (0.982) with TS per cent, indicating higher TS per cent can be achieved while selecting buffaloes for higher milk fat per cent. The correlations among milk fat, protein, lactose and SNF per cent was low and positive.

Present study quantified the differences in milk constituent and yield traits, and revealed that all the milk constituent traits were influenced by year, season, stage of lactation and age of buffaloes, and yield traits were influenced by year, stage of lactation and age of buffaloes. Milk constituent and yield traits were observed higher during winter and autumn seasons. During early stage of lactation milk protein per cent and all the yield traits were found higher, whereas, milk fat, lactose, SNF and TS per cent were found higher during late stage of lactation. All the milk constituent traits were higher in buffaloes those had calved at an early ages whereas buffaloes calved in older age had higher yield traits. Present study suggests that the milk quality of Murrah buffaloes could be improved by minimizing the significant impact of environmental factors on milk composition.

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