International Journal of Bio-resource and Stress Management

https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM July 2026, 17(7): 01-08

Article AR7084

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.7084

Seasonal and Inter-seasonal Variation for Milk Components in Marathwadi Buffaloes

A. K. Wankar and P. M. Kekan

Dept. of Veterinary Physiology, College of Veterinary and Animal Sciences, Parbhani, Maharashtra Animal & Fishery Sciences University, Nagpur, Maharashtra (431 402), India

Open Access

Corresponding wankaralok@gmail.com

0000-0002-0213-0306

ABSTRACT

The research was undertaken during November, 2019–November, 2020 (one year) at Livestock Farming Complex, College of Veterinary and Animal Sciences [MAFSU], Parbhani, Maharashtra, India to investigate the impact of seasons and the inter-seasonal period on milk components in indigenous Marathwadi buffalo (MB). For the study, six MB aged 5–8 years were randomly selected from the institution's livestock farming complex and reared on a semi-intensive management system (daily grazing, 0900–1300 hrs). All animals were maintained as per ICAR feeding standards and had free access to water throughout the experiment. Milk collection was done fortnightly and later analysed for milk fat, lactose, SNF, protein, salt and lactometer reading. While environmental variables like dry bulb temperature (DB), wet bulb temperature (WB), wind speed (WS), temperature humidity index (THI) and solar intensity were recorded weekly, during winter, transition 1, summer, monsoon and transition 2 periods, respectively. No significant difference was observed for any milk component at any treatment, nor was any notable correlation found between environmental variables and milk components. Our results reflected the superior acclimatisation and adaptability of MB over a wide range of stressful environmental conditions, which was confirmed by the lack of variation for milk components during seasons and inter-seasonal periods. Our study concluded that the MB breed was well-suited for sustainable milk production and could provide economic support for organised dairy units and marginal farmers alike.

KEYWORDS: Transition period, milk components, marathwadi buffalo, heat stress

Citation* (VANCOUVER)*: Wankar and Kekan, Seasonal and Inter-seasonal Variation for Milk Components in Marathwadi Buffaloes. *International Journal of Bio-resource and Stress Management,* 2026; 17(7), 01-08. HTTPS://DOI.ORG/10.23910/1.2026.7084.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 25th March 2026 RECEIVED in revised form on 19th June 2026 ACCEPTED in final form on 02nd July 2026 PUBLISHED on 09th July 2026

1. INTRODUCTION

The demand for milk and dairy products is constantly escalating as milk is considered a complete food, providing essential nutrients like protein, sugars, fats, vitamins and minerals and has a global acceptance. The buffalo milk is rich in all the nutrients and is made into popular products like mozzarella cheese and paneer, etc. (Zicarelli, 2020). Currently, Aisa has the largest buffalo population of 205.71 million heads, followed by America, Africa and the European Union (EU), respectively. Asia ranks first in buffalo milk production, with current estimates of 151.00 mt annually, followed by Africa, the Americas and the EU (Anonymous, 2026a). However, sustained milk production, in the global warming era, is becoming increasingly challenging, as the livestock are negatively affected by high environmental temperatures, humidity, high temperature humidity index values, droughts, and food scarcity (Wankar et al., 2024). Despite the harsh environment, poor housing and feed, the tropical and sub-tropical breeds are better adapted and more resilient as compared to exotic pure or crossbred animals (Saizi et al., 2019). And India has the largest buffalo population, closely followed by Pakistan and China, respectively (Anonymous, 2026a). India possesses 22 recognised buffalo breeds, and some of them are global leaders in milk production, for example, the *Murrah* and the *Nili Ravi* (Anonymous, 2026b). These buffalo are well adapted to the Indian climatic conditions and are equal contributors (50%) of total milk production, here (Bharali et al., 2025). Also, as compared to cow milk, the buffaloes milk contains more total solids, protein and SNF, and hence its cost is nearly double that of cow milk (Catillo et al., 2002; Abd El-Salam and El-Shibiny, 2011). As it's an economically important animal, contributing significantly to livestock GDP and an income source for the small and marginal farmers (Anonymous, 2019b), many research works have studied the impact of climatic variables on total milk yield and milk components in buffaloes (Kuralkar and Kuralkar, 2022). The majority of workers have reported variation, especially during the summer season, which is considered to be the most stressful season (Yadav et al., 2013; Kalyan et al., 2022; Bharali et al., 2025; Kumar et al., 2025). Primary reason for buffaloes poor heat tolerance can be attributed to, its black skin, sparse hair coat, less sweat gland, making it gain excess heat more quickly, as compared to cattle. But in-depth studies spanning all the major seasons and inter-seasonal periods on the buffaloes acclimatization against heat stress, are scarce. The seasonal transition period, especially the pre-monsoon season, is also equally stressful on the buffaloes, due to the high THI. The higher levels of THI, make evaporative cooling very difficult, and hence the animals are subjected to moderate levels of stress, which affect the production adversely. Hence, this study planned to study the seasonal and inter-seasonal impact on Marathwadi Buffaloes milk components. The Marathwadi buffalo is an important native buffalo breed from marathwada region of Maharashtra. The animals are mainly reared for their milk and draughtability and provide important economic support to the small and marginal farmers. As milk provides economic sustainability to the farmers, the observations from present study might reflect some major adaptation characteristics in the MB breed during different seasons, as well as inter-seasonal periods, helping the farmers adopt proper ameliorative measures when essential. The key findings would also, highlight the better adaptability of the breed and further promote government policies and plans for the MB breeds conservation and conservation, in future.

2. MATERIALS AND METHODS

2.1. *Experimental design and animals*

The research was undertaken during November 2019–November, 2020 (one year) at Livestock Farming Complex, College of Veterinary and Animal Sciences [MAFSU], Parbhani. For the present study, 6 *Marathwadi* (MB) lactating buffaloes (5–8 yrs) were randomly selected. All the animals were housed in a semi-intensive management system, and the daily grazing period was from 0900 to 1400 hrs, after which the animals were stall fed in the evening. Animals had free access to drinking water all the time and were fed concentrates as per the ICAR standards. The experiment spanned for an entire year, divided into three seasons and two transition periods viz., winter (mid-November, 2019–January, 2020), transition 1 [T_1] (February, 2020), summer (March–June, 2020), monsoon (mid-June–August, 2020) and transition 2 [T_2] (mid-September – early-November, 2020), respectively.

2.2. *Milk sampling and meteorological recordings*

Milk samples (40 ml) were collected from all the animals every 15th day and were analysed for normal milk components, within 2 hrs of collection, on an automatic milk analyser. While the weather parameters were recorded by using digital meteorological instruments at a weekly interval, at 1400 hrs near the animal shed.

2.3. *Milk analysis*

The milk components like fat (%), solid not fat (SNF, %), corrected lactometer reading (CLR), protein (%), lactose (%) and salt (%), were analysed on an automatic milk analyser, in the samples. Before analysis, the analyser was calibrated as per the protocol for the respective species. All the meteorological variables were directly recorded, while THI was calculated by using the standard formula given by Anonymous (1971) as below,

THI=[DB+WB]x 0.72+40.6 where,

DB=Dry bulb temperature, ˚F

WB=Wet bulb temperature, ˚F

2.4. Statistical analysis

Data for milk components was analysed in two ways by GLM (Anonymous, 1997) and indicated by their p values. Effect of independent variables i.e. seasons and days, and dependent variables and their interaction was analysed. The model used was $Y_{ij}=\mu+A_i+B_j+e_{ij}$, where Y_{ij} was the dependent variable, μ was the least square mean, A_i was the effect of season, B_j was the effect of days, and eij was the residual error. Correlation between environmental variables and milk components were estimated by Pearson's correlation and indicated by the *r* value. All data were presented as means±SE and the level of significance was fixed at $p<0.05$. Differences among treatments were determined by Tukey's b test (Anonymous, 1997) and indicated by superscripts a, b, c.

3. RESULTS AND DISCUSSION

3.1. About the marathwadi buffalo breed

The Marathwadi buffalo breed was an ancient buffalo breed that originated in southern India [India_Buffalo_1100_Marathwadi_01009, Anonymous, 2026b]. It breeding tract spreads across Aurangabad and Latur divisions, and it was distributed throughout Beed, Parbhani, Jalna, Aurangabad, Latur, Osmanabad, Nanded and Hingoli, districts of Maharashtra state (Anonymous, 2019a; Anonymous, 2023). The breed was mainly concentrated in Latur and Aurangabad divisions of Maharashtra, and presently, the pure graded recorded males were 9686 heads^{-1}, and females are 217554 heads^{-1}. The division-wise distribution of the MB was shown in Figures 1 and 2, while the region-wise distribution for females and there milking status were presented in Table 1, respectively. We could see from the above data that the breeding herd population was quite small as compared to cattle or other buffalo breeds, and the need for active conservation was even greater for the MB breed (Table 1).

The animals were of medium build, and mostly reared for milk, transport and as drought animals. These animals were reared on semi-intensive systems and thrive mostly on crop leftovers and roughages only. Average milk yield from the buffaloes ranges from 1000 to nearly 1200 l lactation^{-1} (Anonymous, 2026b). As compared to cattle, buffalo milk was denser in nutrients like proteins, lactose, total solids and fat, especially fat and total solids were more abundant (Abd El-Salam and El-Shibiny, 2011). Also, the MB milk was an A_2 variant, naturally providing health benefits and acting as an immunostimulant and was also proved to improve gut flora and protect intestinal epithelium, thus acting as a gut promoter compound (Misra et al., 2008; de Oliveira et al., 2021; Park and Haenlein, 2021; Hou et al., 2022).

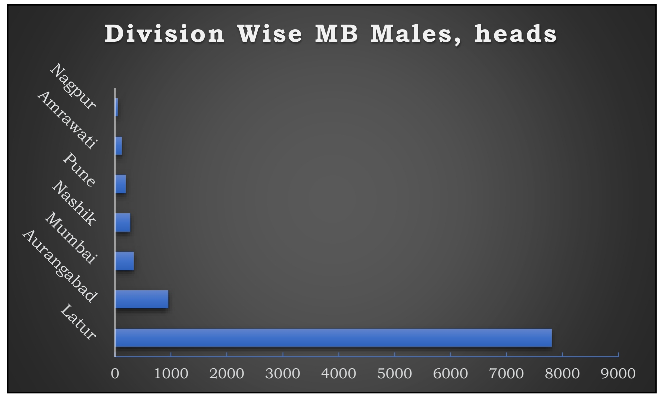

Figure 1: Division wise distribution of Marathwadi Male Buffalo (below 2 yrs)

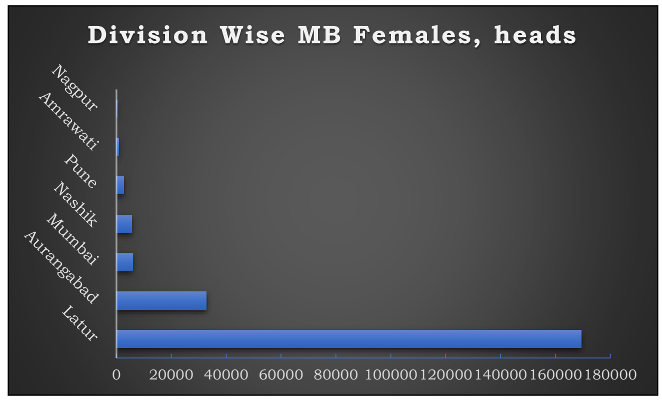

Figure 2: Division wise distribution of Marathwadi Female Buffalo (over 3 yrs)

Table 1: Region wise Marathwadi Buffaloes females' distribution and there milking status in Maharashtra (heads)

Region	Under 1 year	1–3 years	Milking	Dry
Aurangabad division				
Beed	5233	4883	7339	2909
Parbhani	1752	919	2472	1101
Jalna	489	388	995	482
Aurangabad	469	386	966	392
Latur division				
Latur	26572	14545	43035	15286
Osmanabad	8489	4924	15706	4488
Nanded	6053	3465	9016	2423
Hingoli	1149	631	1754	692

Therefore, as it contained more nutrients like total solids, fats and protein with its beneficial A_2 properties, the buffalo milk has more market value, making buffaloes profitable dairy livestock for both large organised dairies and also to the medium and small marginal farmers.

The breed was well adapted to the local climate, and the summers were prolonged (late February–early June), and the temperatures ranged upto 45–48°C. Droughts and scanty rainfall were also common features of the region. Although native breeds were well adapted, and have natural high resiliency to extreme environmental conditions, sustained multi-stressors negatively affect the thermoregulation and production drops gradually (Collier et al., 2019; Wankar et al., 2021). More future research on the MB breed was pertinent for its conservation as one of the most resilient and profitable buffalo breeds of Maharashtra and southern India. With this background, the present study was planned to observe the effect of different seasons and inter-seasonal periods on the normal milk constituents in lactating Marathwadi buffaloes. Another objective of the study was to confirm the economic suitability and sustainability of the breed, based on variation in marketable milk components, under different climatic conditions.

In the present research, the results for seasonal variation in milk components was presented in Table 2. Milk fat % did not vary significantly (p>0.05) during different seasons or the two transition periods, but higher levels of milk fat were seen at T_1, summer and monsoon periods, respectively. Fat was one of the most variable components of milk and represented the nutritional status and reserves of the animal. Other workers have also confirmed that maximum variation is seen for milk fat, as compared to other milk components (Misra et al., 2008; Yadav et al., 2013). Kumar et al. (2025), has also reported higher levels of milk fat in the summer season in Murrah buffaloes, while Bharali et al. (2025), reported no variation in milk fat in the same breed, corroborating our results. Contrastingly, other researchers have observed lower fat levels in buffaloes, attributed to summer stress (Lindmark-Mansson et al., 2003; Ozrenk and Sebnem, 2008; Das et al., 2014).

Similar to fat %, no difference was seen for SNF at any season, but SNF levels were numerically higher at summer, as compared to monsoon and winter seasons (Table 2). Similar results were also obtained in our previous study in MB, and in murrah buffaloes, where the SNF levels were not significantly higher in summer than winter periods (Bharali et al., 2025). While, Kalyan et al. (2022) and others have reported a significant decline in SNF during summer in buffaloes (Bhattarai et al., 2020; Kalyan et al., 2022; Kuralkar and Kuralkar, 2022).

The CLR, which was an estimate of the milk solids density, determining the specific gravity of milk, didn't vary significantly at any season, but was numerically highest in the winter season. Similarly, Bharali and co-workers (2025) have reported no notable variation in milk density, with average ranges of 29.7% in Murrah buffaloes (Bharali et al., 2025). Also, Viana et al. (2025) have reported buffalo milk, relative density at 15°C, within the ranges 1.028–1.034, which were comparable to the present results of CLR (Viana et al., 2025).

The non-significant seasonal variation in milk protein and marginally higher values during summer and monsoon, than the winter period, reflect optimum protein anabolism, utilisation, and secretion in the buffaloes. Khosroshahi et al. (2011) and Nateghi et al. (2014) also reported a non-significant seasonal effect on milk protein metabolism in buffaloes. Contrastingly, higher protein values during hot and humid seasons have been reported in buffaloes (Sikka et al., 2004; Kumar et al., 2025). While Bharali et al. (2025) observed higher protein levels in Murrah buffaloes during winter months as compared to summer (Kalyan et al., 2022). Ozrenk and Sebnem (2008) attributed the high THI to low protein in lactating buffaloes (Ozrenk and Sebnem, 2008).

Milk lactose didn't vary during seasons, and our results were corroborated by Bharali et al. (2025), and Kalyan et al. (2022) who also reported no changes for lactose levels during different seasons in Murrah and Marathwadi buffaloes. Lactose seemed to be a stable component of milk, and not much variation was seen during different seasons, as recorded by many workers previously (Dubey et al., 1997; Bhonsle et al., 2003; Khosroshahi et al., 2011; Kuralkar and Kuralkar, 2022). Like all the other milk components, we didn't recorded any change (p>0.05) for salt during any

Table 2: Effect of different seasons on milk components in Marathwadi Buffaloes

PERIOD	Fat	SNF	CLR	Protein	Lactose	Salt
Winter	5.712±0.438	9.270±0.338	31.330±1.255	3.350±0.124	5.055±0.183	0.705±0.026
T_1	6.445±0.419	9.186±0.131	30.425±0.543	3.325±0.052	5.025±0.070	0.700±0.018
Summer	6.494±0.231	9.279±0.093	30.723±0.370	3.352±0.034	5.052±0.052	0.709±0.009
Monsoon	6.706±0.248	8.988±0.110	29.465±0.391	3.253±0.037	4.903±0.062	0.703±0.010
T_2	5.962±0.345	9.147±0.104	30.678±0.513	3.326±0.036	5.000±0.053	0.700±0.010
p value	0.156	0.742	0.355	0.784	0.769	0.994

Means bearing different superscripts a,b,c within a column differed significantly at (p<0.05); SNF: solid not fat; CLR: Corrected lactometer reading; T_1: Transition period 1; T_2: Transition period 2 season or the inter-seasonal period. Similar, non-significant variation for salt % has also been reported earlier, which confirmed present findings (Kalyan et al., 2022).

The changes in the meteorological variables were shown in Table 3. The dry bulb temperature was highest in the summer, monsoon and T_2 than in T_1 and the winter period (p> 0.05), whereas the wet bulb temperature was lowest in the winter period than all other seasons (Table 3). Temperature humidity index levels were highest during the monsoon, T_2, followed by winter, summer and T_1 period respectively (p>0.05). Wind speed was significantly highest at winter season (p<0.05), as compared to the monsoon and T_2; however, no significant difference was seen at T_2 and the summer seasons. The recorded dry bulb temperature, wet bulb temperature, calculated THI, and all other variables in the present study fall within the established range as per the location in Maharashtra, India (Anonymous, 2020).

The Marathwada region was well known for its harsh summer temperatures and high THI, which continued till the mid of the monsoon season. The Marathwadi buffaloes displayed a superior acclimatisation to multi-stressors like high temperatures, THI, solar intensity, during different seasons and inter- seasonal periods. These temperature and THI ranges (temperatures of 88–91°F and THI of 81–83) were extremely stressful to other dairy breeds and predispose them to heat stress, reducing the production subsequently (Nonaka et al., 2008; Zimbelman et al., 2009). Lack of variation of any of the milk components, including fat, confirmed the natural adaptability of the Marathwadi buffalo to the climatic conditions and to produce sustainably. Our previous research on the breed also confirmed the superior resiliency to environmental conditions, without

Table 3: Meteorological variables during experimental period

PERIOD	DB	WB	THI	WS	LUX
Winter	84.533±6.275	67.577±5.644	81.031±0.473	2.988±0.719^{b}	49317.777±2578.193
T_1	86.075±1.087	70.900±1.090	78.087±0.325	1.500±0.081^{ab}	63865.000±3376.009
Summer	91.290±6.018	69.160±4.188	79.488±4.006	1.460±0.243^{ab}	61555.000±7485.158
Monsoon	89.116±1.707	80.058±0.763	83.006±0.969	1.091±0.230^{a}	48648.833±7654.388
T_2	88.811±1.804	76.355±1.940	81.390±1.212	0.566±0.153^{a}	54903.333±6801.694
p value	0.837	0.052	0.656	0.001	0.487

Means bearing different superscripts a,b,c within a column differ significantly at (p<0.05); DB: Dry bulb temperature; WB: Wet bulb temperature ; WS: Wind speed; THI: Temperature humidity index; LUX: Solar intensity; T_1: Transition period 1; T_2: Transition period 2

Table 4: Correlations between meteorological variables and milk components in Marathwadi Buffaloes

Parameter	DB	WB	WS	LUX	THI	Fat	SNF	CLR	Protein	Lactose	Salt
DB	1	.798**	-.313*	.231	.685**	-.016	-.008	-.003	-.015	-.009	-.008
WB	.798**	1	-.489**	-.039	.611**	.163	.036	-.015	.038	.040	.041
WS	-.313*	-.489**	1	.072	-.138	-.319*	-.117	-.025	-.124	-.122	-.080
LUX	.231	-.039	.072	1	.007	-.021	-.087	-.087	-.084	-.083	-.082
THI	.685**	.611**	-.138	.007	1	-.053	-.005	.013	-.013	-.001	.006
Fat	-.016	.163	-.319*	-.021	-.053	1	.262*	-.109	.253*	.267**	.215*
SNF	-.008	.036	-.117	-.087	-.005	.262*	1	.927**	.986**	.993**	.898**
CLR	-.003	-.015	-.025	-.087	.013	-.109	.927**	1	.924**	.925**	.853**
Protein	-.015	.038	-.124	-.084	-.013	.253*	.986**	.924**	1	.984**	.901**
Lactose	-.009	.040	-.122	-.083	-.001	.267**	.993**	.925**	.984**	1	.901**
Salt	-.008	.041	-.080	-.082	.006	.215*	.898**	.853**	.901**	.901**	1

**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level; SNF: Solid not fat; CLR: Corrected lactometer reading; DB: Dry bulb temperature; WB: Wet bulb temperature; WS: Wind speed; THI: Temperature humidity index; LUX: Solar intensity a serious decline in milk production and its components.

The correlations for the environmental parameters and milk components were presented in Table 4. The meteorological variables were weakly correlated with the milk components, except for WS, which negatively affected the fat % [r =-.319*, p<0.05]. However, strong positive associations were seen between milk SNF: CLR, protein, lactose, and salt [r=0.927**, 0.986**, 0.993** and 0.898**, p<0.0001, respectively]; CLR: protein, lactose, and salt [r=0.924**, 0.925**, 0.853**, p<0.0001, respectively] and salt: protein, lactose [r=0.901**, 0.901**, p<0.0001], respectively. While the interaction effect of days and seasons on any of the milk components was not significant, no variation was seen (Table 4). Earlier research has proved that an increase in THI leads to a decrease in milk yield and also its components (Rodriguez et al., 1985; Ozrenk and Sebnem, 2008; Upadhyay et al., 2008; Pawar et al., 2013). In the present study, no such significant correlation was found between the environmental variables and milk components. The same could be confirmed from, Table 5, where no effect was noted for season or specific day on milk components, respectively.

Table 5: Interaction effect of seasons×days on normal milk components in Marathwadi Buffaloes

Seasons×days	Marathwadi buffaloes
	p
Fat	0.172
SNF	0.828
CLR	0.443
Protein	0.828
Lactose	0.819
Salt	0.991

SNF: Solid not fat; CLR: Corrected lactometer reading

4. CONCLUSION

The *Marathwadi Buffalo* breed remained quite comfortable, over a range of seasons and climatic conditions, as there were no significant changes or reduction in any milk components. Our native animals were more resilient and well-adapted to harsh tropical climates, manifested as high temperatures and THI. This resiliency provided an edge over the crossbreeds or exotic dairy breeds and the indigenous Marathwadi buffalo breed be conserved and propagated, in the era of global warming and climate change, for sustainable milk production.

5. ACKNOWLEDGEMENT

The authors sincerely acknowledge the Livestock Farming Complex and the Associate Dean, College of Veterinary and Animal Sciences, Parbhani for providing the necessary facilities and funding for the research.

6. REFERENCES

Abd El-Salam, M.H., El-Shibiny, S., 2011. A comprehensive review on the composition and properties of buffalo milk. Dairy Science Technology 91, 663–699. Available from: https://hal.science/hal-00930589v1/document.

Anonymous, 2019b. Government of India, 20th Livestock Census-2019. Ministry of Fisheries, Animal Husbandry & Dairying; Department of animal husbandry and dairying, Krishi Bhawan, New Delhi. Available from: https://dahd.gov.in/schemes/programmes/animal_husbandry_statistics. Accessed on: March, 2026.

Anonymous, 2020. Indian meteorological department. Available from: https://mausam.imd.gov.in. Accessed on: April, 2020.

Anonymous, 1971. A guide to environmental research on animals. Washington (DC): National Academy of Science 13, 8, p196. Available from: DOI: https://doi.org/10.17226/20608. Accessed on: February 2026

Anonymous, 1997. Statistical package for social sciences for windows @ 1993. Chicago (IL): SPSS Inc. Version 26.0. Available from: https://www.scirp.org/reference/referencespapers?referenceid=1336213. . Accessed on: March 2026.

Anonymous, 2019a. Breeding report of livestock and poultry. Commissionerate of Animal Husbandry, Maharashtra State. Available from: https://cdnbbsr.s3waas.gov.in/s369dafe8b58066478aea48f3d0f384820/uploads/2024/02/2024021317378l9886.pdf . Accessed on: March, 2026.

Anonymous, 2023. Animal husbandry statistics. Available from: https://dahd.gov.in/schemes/programmes/animal_husbandry_statistics. Accessed on: March, 20226.

Anonymous, 2026a. Agricultural production database. Food and Agricultural Organization. Available from: https://www.fao.org/faostat/en/#home. Accessed on: February, 2026.

Anonymous, 2026b. ICAR-national Bureau of animal genetic resources (NBAGR), Karnal, Haryana., 2026. Available from: https://nbagr.res.in/. Accessed on: March, 2026.

Bharali, D., Bhattacharyya, H.K., Boro, P., Sonowal, M., Das, G., Choudhury, D., Kalita, M.C., Thakuria, J., 2025. Milk composition of Murrah buffalo cows reared under agro-climatic condition of Assam. International Journal of Advanced Biochemistry Research 9(2), 436–438. Available from: https://www.biochemjournal.com/archives/2025/vol9issue2/PartF/9-2-77-374.pdf.

Bhattarai, N., 2020. Seasonal variation in milk yield, fat and SNF content of murrah crossbred buffalo in midwestern Terai region of Nepal. Journal of Agriculture and Forestry University 4, 279–284. Available from: https://www.nepjol.info/index.php/jafu/article/view/47099.

Bhonsle, D., Chourasia, S.K., Singh, M., Jain, R.K., 2003. Factors influencing major milk constituents in Murrah buffaloes. Indian Journal of Animal Sciences 73(1), 107–109. Available from: https://epubs.icar.org.in/index.php/IJAnS/article/view/42526.

Catillo, G., Macciotta, N.P.P., Carretta, A., Cappio-Borlino, A., 2002. Effects of age and calving season on lactation curves of milk production traits in Italian water buffaloes. Journal of Dairy Science 85(5), 1298–1306. DOI: https://doi.org/10.3168/jds.S0022-0302(02)74194-5.

Collier, R.J., Baumgard, L.H., Zimbelman, R.B., Xiao, Y., 2019. Heat stress: Physiology of acclimation and adaptation. Animal Frontiers 9(1), 12–19. Available from: https://academic.oup.com/af/article/9/1/12/5146549.

Das, K.S., Singh, J., Singh, G., Upadhyay, R., Malik, R., Oberoi, P., 2014. Heat stress alleviation in lactating buffaloes: Effect on physiological response, metabolic hormone, milk production and composition. Indian Journal of Animal Science 84(3), 275–280. Available from: https://epubs.icar.org.in/index.php/IJAnS/article/view/38707.

de Oliveira, L.S.M., Alves, J.S., Bastos, M.S., da Cruz, V.A.R., Pinto, L.F.B., Tonhati, H., Costa, R.B., de Camargo, G.M.F., 2021. Water buffaloes (*Bubalus bubalis*) only have A_2A_2 genotype for beta-casein. Tropical Animal Health and Production 53, 145. DOI: https://doi.org/10 .1007/s11250-021-02591-9.

Dubey, P.C., Suman, C.L., Sanyal, M.K., Pandey, H.S., Saxena, M.M., Yadav, P.L., 1997. Factors affecting the composition of milk of buffaloes. Indian Journal of Animal Sciences 67, 802–804. Available from: https://epubs.icar.org.in/index.php/IJAnS/article/view/35004.

Hou, K., Wu, Z.X., Chen, X.Y., Wang, J.Q., Zhang, D., Xiao, C., Zhu, D., Koya, J. B., Wei, L., Li, J., Chen, Z.S., 2022. Microbiota in health and diseases. Signal Transduction and Targeted Therapy 7, 135. DOI: https://doi.org/10.1038/s41392-022-00974-4.

Kalyan, U.P.V., Vasantha, S.K.I., Nikhil Kumar Tej, J., 2022. Effect of seasonal variation in temperature humidity index on milk production and its composition in Murrah buffaloes. Journal of Veterinary and Animal Sciences 53(1), 89–93. DOI: https://doi.org/10.51966/jvas.2022.53.1.89-93.

Khosroshahi, Z.T., Rafat, S.A., Shoja, D., 2011. Effects of non-genetic factors in milk production and composition in East Azarbaijan native buffaloes of Iran. Buffalo Bulletin 30(3), 202–209. Available from: https://www.researchgate.net/publication/259997382_Effects_of_non-genetic_factors_in_milk_production_and_composition_in_east_azarbaijan_native_buffaloes_of_Iran.

Kumar, S., Upadhyay, P.K., Gupta, R., Yadav, M.P., Singh, D., Kumar, N., Shanker, H., Kumar, S., 2025. To study about of various milk compositions in buffalo in different seasons of the year and various categories of farmers. International Journal of Veterinary Sciences and Animal Husbandry 10(4), 248–254. Available from: https://www.veterinarypaper.com/pdf/2025/vol10issue4/PartD/10-4-30-616.pdf.

Kuralkar, P., Kuralkar, S., 2022. Effect of season and stage of lactation on milk components in Purnathadi buffaloes. Buffalo Bulletin 41(3), 511–519. Available from: https://kuojs.lib.ku.ac.th/index.php/BufBu/article/view/3165.

Lindmark-Mansson, H., Fonden, R., Pettersson, H.E., 2003. Composition of swedish dairy milk. International Dairy Journal 13(6), 409–425. DOI: https://doi.org/10.1016/S0958-6946(03)00032-3.

Misra, S.S., Sharma, A., Bhattacharya, T.K., Kumar, P., Saha, R.S., 2008. Association of breed and polymorphism of α-s1and α-s2casein genes with milk quality and daily milk and constituent yield traits of buffaloes (*Bubalus bubalis*). Buffalo Bulletin 27(4), 294–301. Available from: https://www.researchgate.net/publication/287422753_Association_of_breed_and_polymorphism_of_a-and_a-casein_genes_with_milk_quality_and_daily_milk_and_constituent_yield_traits_of_buffaloes_bubalus_bubalis.

Nateghi, L., Yousef, M., Zamani, E., Gholamian, M., Mohammadzadeh, M., 2014. The effect of different seasons on the milk quality. European Journal of Experimental Biology 4(1), 550–552. Available from: https://www.researchgate.net/publication/379874469_The_effect_of_different_seasons_on_the_milk_quality.

Nonaka, I., Takusari, N., Tajima, K., Suzuki, Higuchi, T., Kurihara, K.M., 2008. Effects of high environmental temperatures on physiological and nutritional status of prepubertal *Holstein heifers*. Livestock Science 113(1), 14–23. DOI: 10.1016/j.livsci.2007.02.010.

Ozrenk, E., Sebnem, S., 2008. The effect of seasonal variation on the composition of cow milk in van province. Pakistan Journal of Nutrition 7(1), 161–164. DOI: 10.3923/pjn.2008.161.164.

Park, Y.W., Haenlein, G.F.W., 2021. A2 bovine milk and caprine milk as a means of remedy for milk protein allergy. Dairy (Basel) 2, 191–201. DOI: https://doi.org/10.3390/dairy2020017.

Pawar H.N., Ravi Kumar, G.V.P.P.S., Narang, R., 2013. Effect of heat stress on milk production and composition in murrah buffaloes. Journal of Buffalo Science 2(2), 98–102. Available from: https://lifescienceglobal.com/pms/index.php/JBS/article/view/1198.

Rodriguez, L.W., Mekonnen, G., Wilcox, C.J., Martin, F.G., Krienk, W.A., 1985. Effects of relative humidity, maximum and minimum temperature, pregnancy and stage of lactation on milk composition and yield. Journal of Dairy Science 68, 973–978. DOI: http://dx.doi.org/10.3168/jds.S0022-0302(85)80917-6.

Saizi, T., Mpayipheli, M., Idowu, P.A., 2019. Heat tolerance level in dairy herds: a review on coping strategies to heat stress and ways of measuring heat tolerance. Journal of Animal Behaviour and Biometeorology 7, 39–51. Available from: https://malque.pub/ojs/index.php/jabb/article/view/934.

Sikka, P., Tomar, A.K.S., Sethi, R.K., 2004. Factors affecting milk protein in buffaloes. Indian Journal of Animal Sciences 74(6), 676–677. Available from: https://www.researchgate.net/publication/288765587_Factors_affecting_milk_protein_in_buffaloes.

Upadhyay, R.C., Singh, S.V., Ashutosh, A., 2008. Impact of climate change on livestock. In: Indian Dairyman, XXXVI Dairy Industry Conference BHU, Varanasi 60(3), 68–73. Available from: https://www.cabidigitallibrary.org/doi/full/10.5555/20083084640.

Viana, C.F., 2025. Buffalo milk quality: A study of seasonal influence on composition and somatic cell count. Journal of Dairy Science 108(3), 2215–2226. DOI: https://doi.org/10.3168/jds.2024-25534.

Wankar, A.K., Bhangale, G.N., Rindhe, S.N., Kumawat, B.L., Shafi, T.A., 2024. Heat stress in beef cattle: climate change and the global scenario–a review. Annals of Animal Science 24(4), 1093–1105. DOI: 10.2478/aoas-2024-0026.

Wankar, A.K., Rindhe, S.N., Doijad, N.S., 2021. Heat stress in dairy animals and current milk production trends, economics, and future perspectives: the global scenario. Tropical Animal Health and Production 53(1), 70. DOI: 10.1007/s11250-020-02541-x.

Yadav, S.P., Sikka, P., Kumar, D., Sarkar, S., Pandey, A.K., Adav, P.S., 2013. Variation in milk constituents during different parity and seasons in Murrah buffaloes. Indian Journal of Animal Sciences 83(7), 747–751. Available from: https://epubs.icar.org.in/index.php/IJAnS/article/view/31355.

Zicarelli, L., 2020. Current trends in buffalo milk production. Journal of Buffalo Science 9, 121–132. DOI: https://doi.org/10.6000/1927-520X.2020.09.14.

Zimbelman, R.B., Rhoads, R.P., Rhoads, M.L., Duff, G.C., Baumgard, L.H., Collier, R.J., 2009. A re-evaluation of the impact of temperature humidity index (THI) and black globe humidity index (BGHI) on milk production in high producing dairy cows. In: Collier, R.J. (Ed.), Proceedings of the Southwest Nutrition Conference, 158–169. Available from: https://wdmc.org/2011/A%20Re-Evaluation%20of%20the%20Impact%20of%20Temperature%20Humidity%20Index%20%28THI%29%20and%20Black%20Globe%20Humidity%20Index%20%28BG-HI%29%20on%20Milk%20Production%20in%20High%20Producing%20Dairy%20Cows%20pg%20113-126.pdf. Accessed on: February 2, 2009.