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Productive performance and serum cortisol level of Sahiwal cows under different housing systems during Winter season

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During winter season, when the environmental temperature goes below the thermoneutral zone, it affects the performance of dairy cows. The objective of current study was to evaluate the influence of various types of housing systems on productive and physiological performance of Sahiwal cows in winter season. For this purpose, Twelve Sahiwal cows almost same weight (363±5kg), milk yield (6±0.5Lday^{-1}) and 2nd parity (mid-lactation) were assigned to three experimental groups with four cows in each group. These groups are specified as; conventional barn (CB), open shed+curtain (O+C) and open shed (O) reared cows. Temperature-humidity index values were 63.8, 61.1 and 57.9 in CB, O+C and O groups respectively. Results showed that various types of housing systems had a significant effect on the performance of Sahiwal cows. The intake of dry matter was significantly higher in O reared cows (11.2 kg day^{-1}) followed by the O+C (10.3 kg day^{-1}) and CB reared cows (10.2 kg day^{-1}). The intake of water was maximum in CB reared cows (17.7 L day^{-1}) and was minimum in open shed reared O reared cows (14.4 L day^{-1}) cows. Similarly, milk yield was maximum in CB readed cows (7.8 L day^{-1}) and was minimum in O reared cows (5.2 L day^{-1}) cows. No differences were observed in the composition of milk in CB, O+C and O reared cows. The rectal temperature (101.6 °F) was significantly lower in O reared cows followed by O+C and CB reared cows. Similarly, respiration rate was also lower (17.06 breaths min^{-1}) in O reared cows followed by O+C and CB reared cows. Serum cortisol levels were significantly higher (21.1 ng/ml) in O reared cows as compared to-other dietary treatments. It was concluded that production performance and physiological norms of indigenous Sahiwal cows can be improved by keeping them in conventional closed barn during the winter season.

Keywords: Housing, cold stress, physiological norms, Sahiwal cows.

INTRODUCTION

It is acknowledged worldwide that livestock farming is playing a very vital role in poverty alleviation and food security for developing countries. In Pakistan, livestock play an important role in the agriculture based economy of the country by contributing 60.5% share in agriculture, and 11.2% in national GDP (Saleem and Shrestha, 2019). In terms of both management and genetic capital, the livestock sector is changing rapidly from conventional farming to progressive and modern farming (Annonymous, 2020-21). Most of the human and domestic animal populations in the world are situated in regions where adverse weather conditions affect productivity of animals (Collier *et al.*, 2006; Su *et al.*, 2013). When environmental temperature goes above or below the thermo-neutral zone (TNZ) of various species, they will experience stress (Kino *et al.*, 2019). During winter when animals are exposed to cold conditions, heat production requires additional energy to maintain homeostasis. This physiological response to cold stress triggers energy shortages as well as nutrient absorption. Temperature exposure also stimulates the sympathetic nervous system in bovine animals. Activation of the sympathetic nervous system and subsequent release of stress hormones, affect the immune system (Nakajima *et al.*, 2019). Different breeds and species have different TNZ of temperature tolerance according to their physiological states (Aziz ur Rahman *et al.*, 2017; Aziz ur Rahman *et al.*, 2019). Away from these limits, animals need more energy for thermoregulation. Consequently, there would not be sufficient energy available for growth and productive functions (Kumar *et al.*, 2012). At the start of lactation, low ambient temperatures in lactating cows minimize milk production more markedly as compared to the later stage of the lactation period (Young, 1981). Housing is needed for the

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protection of animals from adverse environmental conditions and provides comfort to the animals (Kumar *et al.*, 2018). During extreme weather conditions, it is necessary to provide shelter to minimize the chances of illness and loss of productivity (Mirza and Ali, 1988). Environmental stresses, including wind speed, humidity and temperature, can affect nutritional use and the output of animals. Identification of environmental and managemental stressors of domestic animals is a key step to handling and reducing stress-producing factors in livestock (Etim and Oguike, 2014). Cold stress is not a major problem for exotic dairy cows if feeding is balanced and animals are well managed because these animals can adapt well up to 5˚C. But in indigenous Sahiwal dairy cows, cold stress can cause heavy production losses by the increasing their feed intake and reducing the production efficiency because the TNZ for indigenous dairy cows is 15˚C to 27˚C. In Punjab, environmental temperature goes below 15˚C during winter months. Therefore, the current study was designed to find the effect of cold temperatures and winter conditions on the performance of Sahiwal cows under different housing systems in a subtropical environment of Punjab.

MATERIALS AND METHODS

***Arrangement of animals and experimental design*:** Twelve Sahiwal (all multiparous) cows of almost same weight (363±5kg), milk yield (6±0.5Lday^{-1}) and 2nd parity (mid-lactation) were selected from the herd maintained at Livestock Experiment Station, University of Agriculture Faisalabad. The experiment duration lasted for two months (January and February) including ten days as adaptation period. The experimental animals were randomly divided into three experimental groups with four animals in each group. These groups are specified as; conventional barn (CB), open shed+curtain (O+C) and open shed (O) reared cows.

***Description of the experimental treatments and animal management*:** In CB rearing, cows were kept in the conventional closed barn which was completely covered with roof and the side windows were closed with curtains, a clean housing environment was maintained to avoid dampness or cold stress in addition to wheat straw bedding and provided with daily access to open yard for sunbathing. In O+C cows, animals were kept under open shed plus curtains and in O rearing cows were maintained under the open shed of Zinc metal sheet.

Basal ration of berseem+ mustard+oat 80% and wheat straw 20% on DM basis was used in all treatment groups. For individual feeding and watering, all the animals were housed individually in separate tie stalls under natural ventilation (Chen *et al.*, 2020; Chen *et al.*, 2021). Feeding and watering of animals in all treatments were done *ad-libitum* twice daily at morning and evening (7:00 am and 3:00 pm). The concentrate feed was offered to all treatment animal groups at the time of milking (morning 5:00 am and evening 5:00 pm) @1.0 kg for each 2.5 kg of milk produced.

***Data collection*:** Fodder samples were collected from the offered and refused fodder to calculate daily dry matter intake (DMI). However, concentrate dry matter was determined on weekly basis. Daily water intake of the individual animal was measured by subtracting the refusal from the offered quantity of water as described in recent studies (Rehman *et al.*, 2019; Hussain *et al.*, 2020).

$$W1 \text{ (Water offered)} - W2 \text{ (refusal)} = WI \text{ (Water intake)}$$

Daily milk production of each cow was measured using Excel (TCS Electronic Price Platform Scale) maximum capacity 99kg and minimum 100g weighing balance in the parlour. Weekly composite milk samples were collected from individual animal and were analyzed for fat, protein, specific gravity, solids not fat and total solids. Daily morning 6:00 am and evening 6:00 pm ambient temperature and relative humidity in all treatment groups were measured by the use of Digital Thermo humidity meter (Power supply: 1.5V×1, Temperature: 0°C–50°C, Relative humidity: 30–90%, Bestone industrial limited, Guangdong China) HTC-1. Temperature humidity index (THI) was calculated by the use of the formula described by Mader *et al.* (2006).

$$THI = (0.8\times Tdb) + [(RH/100) \times (Tdb - 14.4)] + 46.4$$

Where, Tdb = Dry bulb temperature; RH = Relative humidity

***Respiration rate (RR) and rectal temperature (RT)*:** The RR (breaths min^{-1}) was recorded daily at 6-8 am throughout the study in all treatment groups. The RR of each cow was determined by observing the number of movements of flank inward and outward in a condition of rest. Whereas, the RT was recorded on daily basis after evening milking using a clinical thermometer by inserting it 2-2.5 inches deep per rectum (Wankar *et al.*, 2014). Rectal temperature value was recorded once it became stable on a digital display and washed the thermometer for further use.

***Blood collection and analysis*:** Blood samples were taken from the jugular vein using disposable syringes on a fortnightly basis. A sample of 5 ml was collected and immediately 3 ml were transferred to a gel vacutainer having gel for serum separation. After that, vacutainer was allowed to stay for 3 to 4 hours at room temperature. Then serum was collected in Eppendorf tubes with labels and immediately frozen at 0˚F for subsequent analysis. Cortisol (A.M) was performed on fully automated instrument Access 2 employing CLIA method. A commercially available Cortisol Access 2 Beckman Coulter ELISA KIT (Catalog no. K050202) was used to perform analysis according to manufacturer's instructions.

***Statistical analysis*:** For the analysis of data, Completely Randomized design was used by applying analysis of variance (ANOVA) technique of Minitab Statistical Software

18 and Tukey's test was used for the comparison of treatment means (Steel, 1997).

RESULTS

***Metrological data*:** During the study period, the ambient temperatures (°C) of the CB, O+C and O sheds were 18.4, 16.7 and 14.4, respectively. Relative humidity of the CB, O+C and O sheds were 67.3, 67.5 and 65.5 %, respectively. Whereas, THI was calculated as 63.8, 61.1 and 57.9, in CB, O+C and O sheds were respectively (Table 1).

***Dry matter intake, water intake, milk production and composition*:** Dry matter intake was significantly (P<0.05) higher in O reared cows (11.2 kg day^{-1}) as compared to the cows reared in O+C (10.3 kg day^{-1}) and CB (10.2 kg day^{-1}) (Table 2).

The intake of water was also significantly (P = 0.006) affected by different housing managements. Water intake was maximum in CB reared cows and the lowest in O reared cows (P<0.05) (Table 2).

Daily milk production was also affected (P<0.05) by different housing conditions. The highest milk production was observed in cows kept under CB and the lowest production was found in cows kept in O, results are shown in (Table 2).

The composition of milk was not affected (P>0.05) in all of the experimental animals reared in the different ambient management conditions (Table 2).

***Rectal temperature and respiration rate*:** The data on RT of cows kept under different housing conditions are given in (Fig. 1). The results revealed that various housing conditions i.e., CB, O+C and O during winter season affected (P<0.05) the overall mean RT of the cows.

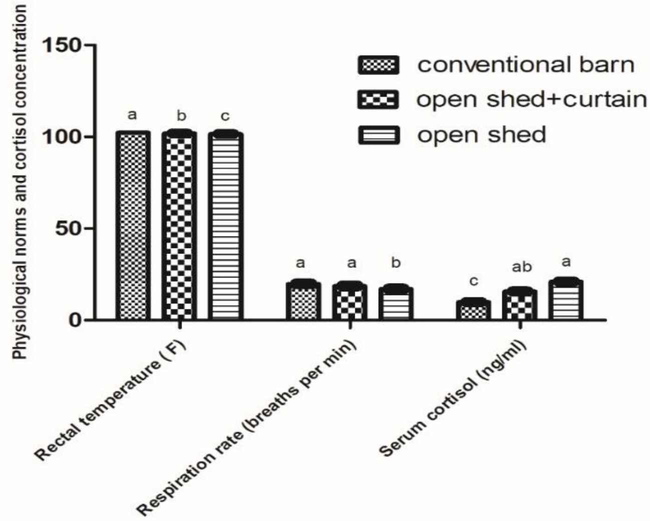

Figure 1. Physiological norms and serum cortisol concentration of Sahiwal cows under different housing systems

Respiration rate (RR) breaths min^{-1} varied significantly (P<0.05) in all the experimental cows managed under CB, O+C and O (Fig. 1). The results of RR showed that with a change in ambient temperature or THI, there was a significant (P<0.05) change in RR.

Table 1. Mean values of environmental factors under different treatments

Parameters	Treatments			SEM	*P*-value
	[1]CB	[2]O+C	[3]O		
Average ambient temperature (°C)	18.4^{a}	16.7^{b}	14.4^{b}	0.49	0.001
Relative humidity (%)	67.3^{b}	67.5^{a}	65.5^{c}	0.29	0.002
THI	63.8^{a}	61.1^{b}	57.9^{c}	0.72	0.001

[1]CB- conventional barn; [2]O+C- open shed+curtain; [3]O- open shed; $^{a-b}$ Means having different superscripts are statistically significant (*P* < 0.05)

Table 2. Effect of housing systems on productive performance and milk composition of Sahiwal cows

Parameters	Treatments			SEM	*P*-value
	[1]CB	[2]O+C	[3]O		
Green fodder intake (kg day^{-1})	30.8^{b}	32.5^{b}	35.9^{a}	0.53	0.000
DMI (kg day^{-1})	10.2^{b}	10.3^{ab}	11.2^{a}	0.26	0.038
Water intake (L day^{-1})	17.7^{a}	15.1^{b}	14.4^{b}	0.55	0.005
Milk production (L day^{-1})	7.8^{a}	6.6^{ab}	5.2^{b}	0.55	0.030
Fat (%)	4.0	4.1	4.2	0.05	0.180
Protein (%)	3.2	3.2	3.3	0.03	0.740
Total solids (%)	11.8	11.9	11.8	0.04	0.640
Solids not fat (%)	7.9	7.9	7.8	0.02	0.060
Specific gravity	1.03	1.03	1.03	0.00	0.940

[1]CB- conventional barn; [2]O+C- open shed+curtain; [3]O- open shed; $^{a-b}$ Means having different superscripts are statistically significant (*P* < 0.05)

***Serum cortisol*:** The results of changes in serum cortisol level of cows are presented in (Fig. 1). Significant (P<0.05) differences were observed in the level of serum cortisol in cows CB, O+C and O.

DISCUSSION

In this study, the effect of cold shock (winter season) was evaluated on dry matter intake, water intake, milk production and composition, respiration rate and serum cortisol concentrations in Sahiwal cows reared under different housing systems. The findings of our study showed that the O reared cows exhibited an improved DMI compared to the cows reared in the CB or O+C.

These findings are in line with the study Brouk (2000) who observed a higher feed intake following the lower temperature below the TNZ of the animal. It depicts that the rearing of the cows under the open barns provides more comfort to the animals which makes them less stressful while providing them convenient environmental conditions (i.e., decreased temperature under their TNZ) which has promoted their feed intake (Chen *et al.,* 2019). Thus, the increase in dry matter intake showed the necessity of the animal to produce more energy for heat production (Christopherson and Kennedy, 1983; Lee *et al*., 1993). It is also evidenced that the cold animals spend more energy for maintenance of their body temperature during the winter season (Haberman, 2015). Moreover, it has also been reported that the increase in ambient temperature or THI had a negative effect on dry matter intake of dairy cows (West *et al*., 2003).

The intake of water was also affected by different housing managements. The findings of the current study showed the highest water intake in the cows reared under CB.

These results are linked with the study of Cardot *et al.* (2008) who reported that various factors affect the intake of water in animals. These factors include DMI, milk yield, feed composition, and climatic situations. Whereas, in current study, the highest water intake in conventional barns reared cows is due to their decreased feed intake (i.e., less DMI).

Daily milk production was also affected by different housing conditions i.e., CB, O+C and O. In present study, when THI was below 60, milk yield was reduced significantly. Moreover, milk production increased in cows that were housed under CB. These results are in line with the study of the Aggarwal and Singh (2005) who reported that the provision of appropriate housing with comfortable bedding during winter seaosn can improve milk production in cows. Hence, it has reflected that the housing of cows under the closed barns could be improve the production of milk. It has also been reported that any abrupt change in ambient temperature has produced a negative effect on milk production (Upadhyay *et al.,* 2007). Thus, these findings indicate that the housing of animals plays a key role in their productivity.

The findings of the current study showed that the composition of milk was not affected by different housing conditions i.e., CB, O+C and O. These results are supported by the study of Haque *et al.* (2018) who reported that differences in the composition of milk are mainly governed by the nutrition. Whereas, the cold stress conditions do not affect the composition of milk.

***Rectal temperature and respiration rate*:** The results revealed that various housing conditions i.e., CB, O+C and O during winter season affected the RT of the cows. These results are well-supported by recent findings of Ahmad *et al.* (2018) who reported that Sahiwal cows kept under roof shade along with fans and sprinklers showed expressively lower RT (101.0 ± 0.04˚F) than those in fans along with roof shade and roof shade only. Furthermore, Butler *et al.* (2006) reported that cold stress decreases the RT of calves born in winter season. It might be due to the slower metabolism of the animals during the colder season.

The results of the current study showed that the RR breaths min^{-1} varied in all the experimental cows managed under i.e., CB, O+C and O. These results summarized that the rate of respiration is affected by the environmental stress. These results are in agreement with the study of Singh *et al.* (2014) found that RR (breaths min^{-1}) was lower in buffaloes which were kept under cool environmental conditions as compared to those kept under natural environmental conditions.

***Serum cortisol*:** The findings of the current study showed a considerable difference in the level of serum cortisol in cows managed under i.e., CB, O+C and O. The results of the present study are supported by the findings of Titto *et al.* (2013) who reported that serum cortisol level was increased significantly during the winter season in Holstein dairy cows. Increased cortisol content in the current study is also in line with Kumar *et al.* (2017) who concluded that cortisol showed significant (p < 0.05) differences in Hariana and Sahiwal cows during summer and winter season.

The differences in the level of serum cortisol might be due to different level of environmental stress of winter days. When ruminants faced a stressful condition, it resulted in increased adrenal gland activity with increased concentrations of cortisol in the blood (Jacor *et al.*, 2001). Increase in the concentration of cortisol in the blood is an indicator of stress (Odore *et al.*, 2011).

***Conclusion*:** Dairy housing systems had a significant effect on production and physiological norms of indigenous Sahiwal cows under subtropical conditions. Housing management through the provision of proper shelter during cooler months of the year can help to improve the status of cortisol in the blood which in turn would lead to improved production.

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Author's contribution**:** All the authors worked in a coordinated way. Ghayyoor Ahmad has done the experiment. Muhammad Iqbal Mustafa and Muhammad Qamar Bilal: data analysis, and manuscript drafting. Muhammad Aziz ur Rahman and Muhammad Riaz: Conceived experiment, manuscript preparation. Sibtain Ahmad and Muhammad Farhan Ayaz Chishti: Data analysis and data collection. Muhammad Jahanzaib Khalid and Shehryaar Shahid: Manuscript finalization

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REFERENCES

Aggarwal, A. and M. Singh. 2005. Impact of microclimatic modification on milk production, composition and physiological responses in Murrah buffaloes during winter. Journal of Dairy Science. 58:269-274.

Aggarwal, A. and M. Singh. 2009. Effect of in-house shelter during winter on plasma hormones in cows and buffaloes. Journal of Dairy Science. 62:35-38.

Ahmad, M., J.A. Bhatti, M. Abdullah, K. Javed, M. Ali, G. Rashid, R. Uddin, A.H. Badini and M. Jehan. 2018. Effect of ambient management interventions on the production and physiological performance of lactating Sahiwal cattle during hot dry summer. Tropical Animal Health and Production. 50:1249-1254.

Aziz ur Rahman, M., X. Chuanqi, S. Huawei and C. Binghai. 2017. Effects of hay grass level and its physical form (full length vs. chopped) on standing time, drinking time, and social behavior of calves. Journal of Veterinary Behavior 21: 7-12.

Aziz ur Rahman, M., C. Xia, L. Ji, B. Cao and H. Su. 2019. Nutrient intake, feeding patterns, and abnormal behavior of growing bulls fed different concentrate levels and a single fiber source (corn stover silage). Journal of Veterinary Behavior. 33:46-53.

Annonymous. 2020-21. Economic Survey of Pakistan, Ministry of Finance, Government of Pakistan Islamabad Pakistan.

Brouk, M. J. 2000. Environmental factors affecting feed intake of cows. In: Tri-State Dairy Nutrition Conference. pp. 61.

Butler, L., R. Daly and C. Wright. 2006. Cold stress and newborn calves. Extension Extra. Paper. 73.

Cardot, V., Y. Le Roux and S. Jurjanz. 2008. Drinking behavior of lactating dairy cows and prediction of their water intake. Journal of Dairy Science. 91:2257-2264.

Collier, R.J., G. Dahl and M. Van Baale. 2006. Major advances associated with environmental effects on dairy cattle. Journal of Dairy Science. 89:1244-1253.

Chen, D., Y. Chen, H. Zhen, K. Xiao, J. Tang, Q. Tang and A.U.R. Muhammad. 2019. Effects of replacing whole-plant corn silage with whole-plant rice silage and rice straw on growth performance, apparent digestibility and plasma parameters in growing angus cross bred beef cattle. International Journal of Agriculture and Biology 22: 1116-1122.

Chen, D., J. Yan, W. Shen, Y. Song, X. Lan, K. Yi and A.U.R. Muhammad. 2020. Effect of inclusion of HMBi in the ration of goats on feed intake, nutrient digestibility, rumen bacteria community and blood serum parameters. Journal of Animal Physiology and Animal Nutrition 104: 987-997. doi:10.1111/jpn.13270

Chen, D., G. Zhong, H. Su, M.A. Ur Rahman, K. Chen, J. Tang and F. Li. 2021. Physiological variation in ruminal microbiota under altered energy levels in starter ration of suckling angus calves. Pakistan Veterinary Journal 41: 409-413.

Christopherson, R.J. and Kennedy, P.M. 1983. Effect of the thermal environment on digestion in ruminants. Canadian Journal of Animal Science. 63:477-496.

Etim, N.N. and M.A. Oguike. 2014. Environmental and management stressors: Implications for reproductive and productive performances of farm animals in the tropics. J. Sustain. Agric. 5:153-170.

Haberman, J. A. 2015. Biological effects of hutch covers in reducing heat and cold stress in individually housed dairy calves. Office of Graduate and Professional Studies of Texas A&M University.

Haque, N., M. Singh and S. Hossain. 2018. Improved milk production through PG–PL system by provision of in-house shelter management in lactating Murrah buffaloes during winter season. Journal of Animal Physiology and Animal Nutrition. 102:166-174.

Hussain, M., A. Mahmud, J. Hussain, S.N. Qaisrani, S. Mehmood, S. Ahmad and A.U. Rehman. 2020. Effect of dietary amino acid regimens on growth performance and body conformation and immune responses in Aseel chicken. Indian Journal of Animal Research. 54:53-58.

Jacor, S., V. Ramnath, P. Philomina, K. Rahun and Hanan and A. Kannan. 2001. Assessment of physiological stress in periparturient cows and neonatal calves. Indian Journal of Physiology and Pharmacology. 45:233-238.

Kino, E., M. Uematsu, G. Kitahara, T. Osawa and Y. Sasaki. 2019. Quantitative relationship between climatic conditions and the conception rate of Japanese Black cattle in commercial cow–calf operations. Livestock Science. 228:170-176.

Kumar, A., M. Kamboj, S. Chandra and P. Bharti. 2018. Effect of modified housing system on physiological parameters of Murrah buffaloes during autumn and winter season. Indian Journal of Animal Research. 52:829-833.

Kumar, B., A. Manuja and P. Aich. 2012. Stress and its impact on farm animals. Frontier in Bioscience (Elite Ed). 4:1759-1767.

Kumar, M., H. Kaur, V. Mani, R. S. Deka, A. K. Tyagi, G. Chandra, A. K. Dang and R. Kushwaha. 2017. Supplemental chromium in cold-stressed buffalo calves (Bubalus bubalis): effects on growth performance, nutrient utilization and cell mediated and humoral immune response. Veterinarski arhiv. 87:441-456.

Lee, C.N., 1993. Environmental stress effects on bovine reproduction. Veterinary Clinics of North America: Food Animal Practice. 9:263-273.

Mader, T. L., M. Davis and T. Brown-Brandl. 2006. Environmental factors influencing heat stress in feedlot cattle. Journal of Animal Science. 84:712-719.

Mirza, I. and A. Ali. 1988. Effect of cold stress on cattle and buffalo cows kept under and without shelter. Journal of Animal Health and Production (Pakistan). 8:72-79.

Nakajima, N., K. Doi, S. Tamiya and M. Yayota. 2019. Effects of direct exposure to cold weather under grazing in winter on the physiological, immunological, and behavioral conditions of Japanese Black beef cattle in central Japan. Journal of Animal Science. 90:1033-1041.

Odore, R., P. Badino, G. Re, R. Barbero, B. Cuniberti, A. D'Angelo, C. Girardi, E. Fraccaro and M. Tarantola. 2011. Effects of housing and short-term transportation on hormone and lymphocyte receptor concentrations in beef cattle. Research in Veterinary Science. 90:341-345.

Saleem, T. and R.B. Shrestha. 2019. Agricultural Research and Development: Policy and Program Priorities in Pakistan. Agricultural Policy and Program Framework: Priority Areas for Research & Development in South Asia, p.151.

Singh, S., O. Hooda, B. Narwade, B. Baliyan and R. Upadhyay. 2014. Effect of cooling system on feed and water intake, body weight gain and physiological responses of Murrah buffaloes during summer conditions. Journal of Dairy Science. 67:426-431.

Steel, R. G. 1997. Pinciples and Procedures of Statistics. A biometrical approach, McGraw Hill Book Co., New York.

Su, H., Y. Wang, Q. Zhang, F. Wang, Z. Cao, M.A. Rahman, B. Cao and S. Li. 2013. Responses of energy balance, physiology, and production for transition dairy cows fed with a low-energy prepartum diet during hot season. Tropical Animal Health and Production 45: 1495-1503.

Titto, C. G., J. A. Negrão, E. A. L. Titto, T. de Souza Canaes, R. M. Titto and A. M. F. Pereira. 2013. Effects of an evaporative cooling system on plasma cortisol, IGF-I, and milk production in dairy cows in a tropical environment. International Journal of Biometeorology. 57:299-306.

Upadhyay, R., S. Singh, A. Kumar, S. Gupta and Ashutosh. 2007. Impact of climate change on milk production of Murrah buffaloes. Italian Journal of Animal Science. 6:1329-1332.

Wankar, A. K., G. Singh and B. Yadav. 2014. Thermoregulatory and adaptive responses of adult buffaloes (Bubalus bubalis) during hyperthermia: physiological, behavioral, and metabolic approach. Veterinary World. 7:825-830.

West, J.W., Mullinix, B.G. and Bernard, J.K. 2003. Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. Journal of Dairy Science. 86:232-242.

Young, B. 1981. Cold stress as it affects animal production. Journal of Animal Science. 52:154-163.