Indian Journal of Animal Sciences **93** (12): 1199–1204, December 2023/Article
https://doi.org/10.56093/ijans.v93i12.138031

Strategic supplementation of novel feed supplement improved the lactation and reproductive performance in post-partum dairy cows

SANDEEP K CHAUDHARY[1]✉, NARAYAN DUTTA[2], SUNIL E JADHAV[2], SANJAY K SINGH[2], GYANENDRA SINGH[2] and DHARMESH TEWARI[3]

ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh 243 122 India

Received: 20 June 2023; Accepted: 3 October 2023

ABSTRACT

The present experiment aimed to establish the efficacy of dietary inclusion of a novel feed supplement on plane of nutrition, milk yield, and its characteristics, reproductive events and circulating concentrations of reproductive hormones in dairy cows during early lactation. Twelve post-partum crossbred lactating cows were equally and randomly assigned to two dietary treatments for 90 days. The cows in CON (control) group were fed on green fodder and wheat straw-based diet with concentrate mixture, whereas, cows in NFS (Novel Feed Supplement) group were fed according to CON group with additional novel feed supplement @0.25% of BW. A comparative study of plane of nutrition revealed that both DCP and TDN were deficient in CON by 12.0 and 18.99%, respectively, however, it was sufficient in NFS group. The daily and total milk yield (kg), 4% FCM, ECM, fat and protein yields (g/d) were improved in NFS than CON group. The average composition of milk showed no significant difference throughout the study. The supplement fed cows had an evident early return of heat (26.20 d in NFS v/s 42.60 d in CON) with enhanced conception rate (66.7% in NFS v/s 50% in CON). The estradiol concentration (pg/ml) was reduced and progesterone concentration (ng/ml) was enhanced in NFS fed cows. In conclusion, incorporation of the novel feed supplement @0.25% of BW significantly improved the plane of nutrition, milk production and reproduction in lactating crossbred cows during the early post-partum period.

Keywords: Cows, Estrogen, Milk yield, Novel feed supplement, Progesterone, Reproduction

Indian livestock production is a predominantly small-holder enterprise that accounts for most of the rural economy. The socio-economic development of the rural population is largely influenced by livestock production. Livestock production is most prevalent among marginal and smallholder farmers in India, and more than 62% of them are directly associated with this sector (Das *et al.* 2020). Therefore, the challenges of maintaining the productivity of dairy farming need to be addressed and resolved with the current perspective.

The complementary action of livestock rearing and green fodder production is creating many challenges for livestock enterprises. These challenges mainly include scarcity of palatable quality fodder, deficiency of specific nutrients along with scarce and unbalanced nutritional practices. According to IGFRI Vision 2030, India will face an overall deficit of 65.45% and 24.90% green fodder and dry crop residues, respectively by the year 2030 (IGFRI 2011). In the concurrent scenario, the researchers are mainly focusing on fodder-based economical feeding approaches so as to economize the cost of final livestock products disposal with sustainable production. With an increasing population size and decreasing cultivatable land for fodder production, this enterprise is suffering from tremendous pressure to produce optimally. Consequently, the animals are forced to feed on low-quality crop residue based rations, agro-industrial by products or locally accessible green fodders lacking balanced supply of fermentable energy, degradable protein and minerals to the rumen. Hence, it is reducing the ruminal fermentation and microbial biomass leading to compromised production and reproduction in animals (Uddin *et al.* 2015). Critical supplementation of limiting nutrients to poor quality roughages can efficiently modulate the activity of rumen microbial consortium through a positive associative effect on intake, digestibility and utilization (Yulistiani *et al.* 2015, Wang *et al.* 2019). Significant effect of dietary regime during the transition period on reproductive events in dairy cows through the somatotrophic axis has been noticed (Santos *et al.* 2011).

Keeping in view, a novel feed supplement was formulated which is rich in easily fermentable carbohydrates, degradable protein as well as macro and trace minerals. Hence, the present study investigated the effect of strategic supplementation of a novel feed supplement on the productive and reproductive performance of lactating

Present address: [1]FVAS, RGSC, BHU, Barkachha, Mirzapur. [2]ICAR-IVRI, Izatnagar, Uttar Pradesh. [3]ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh. ✉Corresponding author email: sandy6050@gmail.com

crossbred cows. Further, we hypothesized that novel feed supplement would prevent and alleviate the specific nutrient paucities and production losses in cows, frequently exhibited by lactating animals under common dairy practices.

MATERIALS AND METHODS

Animals, treatments and management: All procedures regarding animal handling and treatments were approved (25/17/2019-CPCSEA-DADF) by the Institutional Animal Ethics Committee and Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA) in India.

The experiment was undertaken at Farm unit of Livestock Production Management (LPM) Section, ICAR-Indian Veterinary Research Institute, Izatnagar, India. Twelve crossbred (*Bos taurus* × *Bos indicus*) lactating cows (60 days post-partum; 314.29±11.12 kg mean BW; 8.36±0.33 kg milk yield/d) were randomly assigned to CON (control) and NFS (Novel Feed Supplement) groups consisting of six cows in each. The experimental cows in CON group were fed on green oats, berseem and wheat straw-based diet with concentrate mixture (maize: 35; deoiled soybean meal: 15; wheat bran: 50%) as per dairy practices, whereas, cows in NFS group were fed according to CON with additional novel feed supplement (patent application no. 202211032024; dated 03.05.2022) @0.25% of BW. All the cows were offered two equal portions of daily allowance of respective supplements by separate mangers at the time of milking (morning and evening). Green fodder (green oats and berseem) and wheat straw were offered *ab lib*.

The animals were housed in hygienic well-ventilated, roofed and cement-floored sheds with facilities for proper feeding and watering (clean tap water, free choice twice daily). Standard prophylactic measures including de-worming for endo and ecto-parasites was followed before the start of experimentation. The ration schedule was adjusted every fortnight after recording the milk yield and body weight of each cow. The feeding trials were continued from 60 day post-partum to 150 day lactation period (total experimental period was 90 days). The feed samples were analysed for proximate principles by the methods of AOAC (2012), and fibre fractions were analysed as per Van Soest *et al.* (1991). The chemical composition of feeds offered to the cows is presented in Table 1.

Milk yield and characteristics: Cows were milked twice daily (07:00 and 16:00 hrs) in hygienic manner to arrive milk yield per day. About 100 ml thoroughly mixed milk samples from individual animals were transferred to a screw capped sample bottle with rounded corners (to avoid lodging of the milk solids) at fortnightly intervals. Properly labelled sample bottles were dispatched to laboratory at the earliest and processed immediately. Thoroughly mixed milk samples were analysed for milk fat, SNF, lactose, protein and ash contents using Ultrasonic milk analyzer (Master Classic milk analyser, LM-2). The total solid in the samples were determined by adding SNF and fat content of the milk. 4% FCM and ECM in the milk was calculated as per Gains (1928) and Tyrrell and Reid (1965), respectively.

Reproductive performance: Oestrus detection of all lactating cows was done twice daily during the entire experimental trial period with the help of a trained teaser bull. The post-partum cows in both the groups exhibiting oestrus were inseminated artificially with frozen semen. All the non-return cows were diagnosed for pregnancy by transrectal palpation at 60 d post-insemination. Post-partum reproductive variables such as onset of oestrus, services per conception and conception rate were recorded. The cows were also closely monitored for any post-partum disease/disorders.

Reproductive hormones: The quantitative determination of reproductive hormones, viz. estradiol and progesterone in the serum samples collected at 0, 45 and 90 days of experimental feeding were performed via estradiol (DEH3355) and progesterone (DE1561) ELISA kits (Demeditec Diagnostics GmbH, Germany) as per manufacturer instructions using Microplate spectrophotometer.

Statistical analysis: The data produced in the present experiment was subjected to statistical analysis as per Snedecor and Cochran (2004) using IBM, SPSS (20.0) and means were categorized using Tukey's test. The parameters containing periodic collections were scrutinized by implementing repeated measures protocol via GLM of SPSS; which encompassed between-subjects principal effect of treatments, within-subjects principal effect of period and interaction amid the treatment and

Table 1. Chemical composition of feeds offered (% DM basis)

Attribute	Concentrate mixtures		Wheat straw	Green oats	Berseem
	CON	NFS			
DM	90.19	90.35	92.35	18.85	13.44
OM	94.77	93.06	94.96	89.70	90.40
CP	19.01	25.35	4.33	8.57	17.55
EE	2.05	3.03	1.04	2.89	3.20
TA	5.23	6.94	5.04	10.30	9.60
NDF	40.38	44.54	82.04	65.61	47.29
ADF	11.53	13.07	54.65	42.35	39.62

Abbreviations: CON, Control; NFS, Novel feed supplement; DM, Dry matter; OM, Organic matter; CP, Crude protein; EE, Ether extract; TA, Total ash; NDF, Neutral detergent fibre; ADF, Acid detergent fibre.

period. Independent samples t-test was performed for the parameters not involving any periodic collections. P<0.05 was used to declare the means to be significant unless otherwise stated.

RESULTS AND DISCUSSION

Plane of nutrition: The comparative study of plane of nutrition with Kearl (1982) feeding standard revealed that both DCP (12.0%) and TDN (18.99%) were deficit in CON, however, it was sufficient in NFS group (Fig. 1). The plane of nutrition is largely influenced by the composition of diet. Several researchers have been reported an improved intake of CP and TDN with increasing levels of concentrate mixtures in lactating goats, crossbred heifers and beef cattle (Pereira *et al.* 2007, de Souza Duarte *et al.* 2011, Sultana *et al.* 2012, Mahfuz *et al.* 2018).

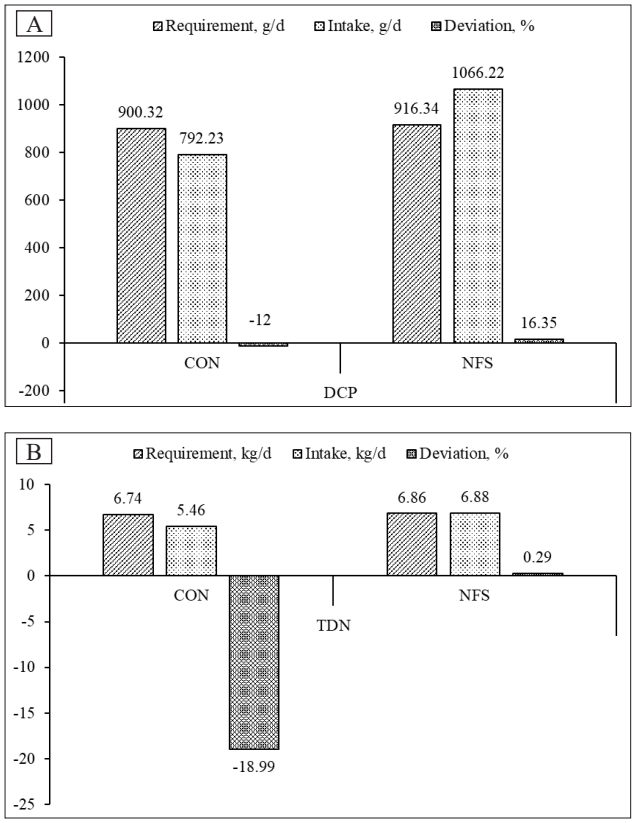

Fig. 1. Comparative plane of nutrition with Kearl (1982) feeding standard of lactating cows supplemented with novel feed supplement (A) DCP, Digestible crude protein and (B) TDN, total digestible nutrient.

Milk yield and characteristics: The daily milk yield (kg) was significantly (P<0.001) higher in NFS than CON group. The total milk production (kg), 4% FCM, ECM, fat and protein yields (g/d) were also followed the similar trend and was higher (P<0.001) in NFS group than CON. The composition of milk such as fat, SNF, total solid, protein, lactose and ash showed no significant difference (P>*0.*05) between the groups (Table 2). It has been well established that the dietary energy and proteins are the most critical nutrients for optimum lactation performance

Table 2. Effect of novel feed supplement on lactation performance of dairy cows

Attribute	Dietary treatments		P-value
	CON	NFS	
Milk yield			
Daily milk yield, kg/d	8.02±0.20[b]	9.19±0.16[a]	0.000
Total milk yield, kg	721.99±28.39[b]	827.14±24.09[a]	0.000
4 % FCM, kg/d	9.07±0.23[b]	11.00±0.19[a]	0.000
ECM, kg/d	9.38±0.24[b]	11.31±0.20[a]	0.000
Fat yield, g/d	390.68±9.90[b]	488.01±8.57[a]	0.000
Protein yield, g/d	235.85±5.98[b]	275.71±4.84[a]	0.000
Milk composition, %			
Fat	4.87±0.23	5.31±0.24	0.223
SNF	8.13±0.08	8.29±0.06	0.121
Total solid	13.06±0.26	13.54±0.34	0.227
Protein	2.94±0.02	3.00±0.02	0.160
Lactose	4.39±0.13	4.52±0.09	0.115
Ash	0.63±0.01	0.63±0.01	0.810

Abbreviations: CON, basal diet (green fodder and wheat straw-based diet with concentrate mixture); NFS, CON + novel feed supplement @ 0.25% of BW; FCM, Fat Corrected Milk; ECM, Energy Corrected Milk; SNF, Solid Not Fat. [a,b]Means in the same row with different superscript differ significantly (P<0.001).

of dairy animals (Wang *et al.* 2014). In agreement with the present results, several researchers have been reported an increased milk yield in dairy cows and goats fed different levels of concentrate mixture (Muñoz *et al.* 2015, Obese *et al.* 2018, Adjorlolo *et al.* 2019). McKay *et al.* (2019) reported significantly higher milk yield, 4% FCM, ECM, fat and protein yields from dairy cows fed barley or maize based concentrate diet as compared to pasture diet alone. Grala *et al.* (2011) also reported an increased milk production, fat, protein, 4% FCM and ECM yields in dairy cows fed concentrate mixture. Zhou *et al.* (2015) reported that daily milk production, 4% FCM, ECM, fat and protein yields were significantly higher for cows fed high energy diet than those fed on low energy diet. Feeding of high energy corn silage increased the ruminal concentration of fermentable carbohydrates and made energy available for milk production (Zhou *et al.* 2015). The improved lactation performance of dairy cows is reported to be closely associated with the continuous supply of rumen fermentable carbohydrates, easily degradable protein and microbial protein to rumen (Wang *et al.* 2014, Zhou *et al.* 2015). Accordingly, the improved lactation performance of crossbred dairy cows fed novel feed supplement may also be due to the increased supply of easily fermentable energy and protein (Chaudhary *et al.* 2021).

Reproductive performance: Data on the reproductive performance of cattle are presented in Table 3. The conception rate in NFS (66.67%) group was considerably improved as compared to CON (50%). The cows fed NFS came into heat (oestrus) following 26.20 d, however, cows in CON group become oestrus after 42.60 d and were inseminated. Following insemination, 33.33 and 16.67% of total animals from CON and NFS groups, respectively were

Table 3. Effect of novel feed supplement on reproductive performance of lactating cows

Attribute	Dietary treatments		P-value
	CON	NFS	
Total no. of animals selected	6	6	-
Total no. of animals confirmed pregnant	3	4	-
No. of animals conceived at first insemination	1 (16.67%)	3 (50%)	-
No. of animals conceived at subsequent insemination	2 (33.33%)	1 (16.67%)	-
No. of animals remained non-responsive	1 (16.67%)	1 (16.67%)	-
First oestrus after start of feeding (days)	42.60±3.83[a]	26.20±2.29[b]	0.006
No. of inseminations per conception	1.67±0.33	1.25±0.25	0.352

Abbreviation: CON, basal diet (green fodder and wheat straw-based diet with concentrate mixture); NFS, CON + novel feed supplement @0.25% of BW. [a,b]Means in the same row with different superscript differ significantly (P<0.01).

returned to heat again and become pregnant in subsequent inseminations. A total of 16.67% of the animals were non-responsive and did not show any sign of oestrus in both the group. The number of inseminations per conception were 1.67 and 1.25 in CON and NFS, respectively and were comparable (P>*0*.05) between them. Nutrition also plays an important role in regulating the reproductive performance like postpartum oestrus expression and ovarian functions in animals (Maurya *et al.,* 2010). Good nutrition directly influences the fertility in cattle through supply of essential nutrients needed for gametogenesis and synthesis of blood metabolites related to ovulation and pregnancy (Robinson *et al.* 2006, Konigsson *et al.* 2008, Samadi *et al.* 2013). Dairy animals with inadequate nutrition and poor BCS during early post-partum period predisposes to Negative Energy Balance (NEB). This NEB severely affects both productive and reproductive performance by reducing the plasma glucose, insulin and IGF-1 concentrations and increasing the NEFA concentrations (Kawashima *et al.* 2012). NEB delays the involution of uterus, increases the incidences of anoestrus, days open, delays or inhibit the ovulation rate by inhibiting LH surge, reduces ovulatory ovarian follicular functions, increases calving interval as well as the number of services per conception (Robinson *et al.* 2006, Peter *et al.* 2009, Kafi and Mirzaei 2010, Drackley and Cardoso 2014). The inhibition of LH pulse and decreased blood concentrations of glucose, insulin and IGF-1 results in low oestradiol concentration which is essential for initiation of gonadotrophin surge and successive ovulation (Wathes *et al.* 2007, Walsh *et al.* 2011, Soca *et al.* 2014). In accordance with the present results, Adjorlolo *et al.* (2019) reported that cows supplemented with 2.5 kg of concentrate per day had significantly less proportion of non-cyclic animals (20%) than non-supplemented group (55%). They proposed that higher plasma protein concentrations in supplemented group indicated improved nutritional status, therefore, increased conception rate in cattle (Robinson *et al.* 2006, Almeida 2017). Tewari *et al.* (2014) also reported that onset of estrus and conception rate were significantly higher following strategic nutrient supplementation to heifers and lactating cows under field condition. The role of minerals to maximise the reproductive efficiency of dairy animals has already been established by several workers (Chester-Jones *et al.* 2013, Ghosh *et al.* 2016). In agreement with our results, several workers have reported a significant reduction in first oestrus post-feeding (days) and number of services per conception following supplementation of mineral mixture in problematic dairy animals (Mohapatra *et al.* 2012, Agrawalla *et al.* 2017).

Reproductive hormones: The estradiol concentration (pg/ml) of cattle was significantly (P<0.05) lower and progesterone concentration (ng/ml) was significantly (P<0.05) higher in NFS relative to CON group (Table 4). Progesterone plays an important role in the reproductive events related to establishment and maintenance of pregnancy (Lonergan *et al.* 2016, Lonergan and Sánchez 2020). A reduced circulating progesterone concentration during growth of the ovulatory follicle decreases fertility, however, reduced circulating progesterone concentration after ovulation have been implicated as a causative factor for decreased conceptus growth, decreased production of interferon-τ and lower pregnancy rates in high-yielding dairy cows (Lonergan and Sánchez 2020). It has been reported that NEB reduces serum progesterone concentration and hence, fertility in dairy animals (Butler 2005). The concentration of serum progesterone and estrogen can be altered due to deficiency of micro-nutrients. Trace minerals such as copper and zinc are linked to reproductive hormones, viz. progesterone and estradiol (Prasad *et al.* 1989) and are

Table 4. Effect of novel feed supplement on reproductive hormones in lactating cows

Hormone	Dietary treatments		SEM	P-value[†]		
	CON	NFS		T	P	TxP
Estradiol, pg/ml	951.10[a]	616.31[b]	59.03	0.001	0.023	0.159
Progesterone, ng/ml	2.93[b]	7.14[a]	1.00	0.008	0.001	0.128

Abbreviation: CON, basal diet (green fodder and wheat straw-based diet with concentrate mixture); NFS, CON + novel feed supplement @0.25% of BW; SEM, Standard error of means.[†]Significant effects of the dietary treatments (T), period (P) and their interactions (T×P). [a,b]Means in the same row with different superscript differ significantly (P<0.05).

the activators of specific enzyme systems that support in maintaining the activity of these hormones in the blood (Georgievskii 1982). Hence, deficiency of trace minerals adversely affects the reproductive performance of the farm animals (Bearden *et al.* 2004). Godara *et al.* (2016) and Joshi *et al.* (2019) observed significantly higher circulating concentration of progesterone in mineral supplemented problematic crossbred cattle and buffaloes than their non-supplemented counterparts, however, no significant change was observed in plasma estrogen level. Rajala-Schultz and Saville (2003) reported improved serum concentration of progesterone in cows following supplementation of high energy diet as compared to cows fed low energy diet. Khan *et al.* (2018) reported significantly higher progesterone concentration in early lactating cows fed high energy diet. The reason behind the lower plasma progesterone concentration in non-supplemented cattle may be due to the lower steroidogenesis associated with altered enzymatic activity because of lower plasma trace mineral concentrations (Godara *et al.* 2016). The higher concentration of serum progesterone hormone in novel feed supplement fed cows is attributed to the higher conception rate in these groups as evident from the study. This also reflects the re-establishment of normal cyclicity and luteal phase in animals following supplementation (Joshi *et al.* 2019).

Based on the results, it can be concluded that dietary supplementation of novel feed supplement @0.25% of body weight significantly improved the plane of nutrition, daily and total milk production, 4% FCM, ECM, fat, and protein yields as well as overall reproductive performance of lactating crossbred cattle during early lactation.

ACKNOWLEDGEMENT

This study was financially supported by funds provided by the Indian Council of Agricultural Research, New Delhi, India.

REFERENCES

Adjorlolo L, Obese F Y and Tecku P. 2019. Blood metabolite concentration, milk yield, resumption of ovarian activity and conception in grazing dual purpose cows supplemented with concentrate during the post-partum period. *Veterinary Medicine and Science* **5**: 103–11.

Agrawalla J, Sethy K, Behera K, Swain R K, Mishra S K, Sahoo N, Mohapatra M R and Khadenga S. 2017. Improved reproductive performance of crossbred cattle in Puri district of Odisha following supplementation of area specific mineral mixture. *Indian Journal of Animal Reproduction* **38**: 43–45.

Almeida D M 2017. 'Effects of supplementation levels on performance and metabolic and nutritional characteristics of cows, suckling female calves and heifers on grazing.' D.Sc. Thesis. Department of Animal Science, Universidade Federal de Vicosa, Brazil.

AOAC. 2012. *Official Methods of Analysis*, 19th edn. Association of Official Analytical Chemists, Washington, DC.

Bearden H J, Fuquay J W and Willard S T. 2004. *Applied Animal Reproduction*, 6th edn. Pearson Prentice Hall, Upper Saddle River, New Jersey, NY, U.S.A.

Butler W R. 2005. Nutrition, negative energy balance and fertility in the postpartum dairy cow. *Cattle Practice* **13**: 13–18.

Chaudhary S K, Dutta N, Jadhav S E and Pattanaik A K. 2021. Influence of customized supplement on voluntary feed intake and nutrient metabolism in crossbred calves. *Indian Journal of Animal Research* **55**: 174–79.

Chester-Jones H, Vermeire D, Brommelsiek W, Brokken K, Marx G and Linn J G. 2013. Effect of trace mineral source on reproduction and milk production in Holstein cows. *The Professional Animal Scientist* **29**: 289–97.

Das A, Raju R and Patnaik N M. 2020. Present scenario and role of livestock sector in rural economy of India: A review. *International Journal of Livestock Research* **10**(11): 23–30.

de Souza Duarte M, Paulino P V R, de Campos Valadares Filho S, Paulino M F, Detmann E, Zervoudakis J T, dos Santos Monnerat J P I, da Silva Viana G, Silva L H P and Serão N V L. 2011. Performance and meat quality traits of beef heifers fed with two levels of concentrate and ruminally undegradable protein. *Tropical Animal Health and Production* **43**(4): 877–86.

Drackley J K and Cardoso F C. 2014. Prepartum and postpartum nutritional management to optimize fertility in high-yielding dairy cows in confined TMR systems. *Animal* **8**: 5–14.

Gaines W L. 1928. *The energy basis of measuring milk yield in dairy cows*. Bulletin, University of Illinois, Urbana-Champaign campus. Agricultural Experiment Station, no. 308.

Georgievskii V I. 1982. *Mineral Composition of Bodies and Tissue of Animals: Mineral Nutrition of Animals*. (Eds) Georgievskii V I, Annenkov B N and Samokhin V T. Butterworths, London, England.

Ghosh M K, Mondal M, Verma R K and Muwel N. 2016. Use of area specific mineral mixture to ameliorate region specific reproductive problems in ruminants. *Research and Reviews: Journal of Dairy Science and Technology* **5**: 1–4.

Godara R S, Naskar S, Das A K, Godara A S, Kankar S K, Patel M and Bhat S A. 2016. Effect of area specific mineral supplementation on growth and reproductive performance of female Black Bengal goats. *Journal of Animal Research* **6**: 335–40.

Grala T M, Lucy M C, Phyn C V C, Sheahan A J, Lee J M and Roche J R. 2011. Somatotropic axis and concentrate supplementation in grazing dairy cows of genetically diverse origin. *Journal of Dairy Science* **94**: 303–15.

IGFRI. 2011. *Vision 2030*. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India.

Joshi P M, Patel D C and Patel P D. 2019. Effect of chelated mineral mixture on blood biochemistry, hormone and mineral status in repeat breeder buffaloes in tribal areas of Dahod district in Gujarat, India. *Indian Journal of Veterinary Sciences and Biotechnology* **15**: 40–44.

Kafi M and Mirzaei A. 2010. Effects of first postpartum progesterone rise, metabolites, milk yield and body condition score on the subsequent ovarian activity and fertility in lactating Holstein dairy cows. *Tropical Animal Health and Production* **42**: 761–67.

Kawashima C, Matsui M, Shimizu T, Kida K and Miyamoto A. 2012. Nutritional factors that regulate ovulation of the dominant follicle during the first follicular wave postpartum in high-producing dairy cows. *Journal of Reproduction and Development* **58**: 10–16.

Kearl L C. 1982. *Nutrient Requirements of Ruminants in Developing Countries*. Utah Agricultural Experimental Station, Utah State University, International Foodstuffs

Institute, Logan, USA. Pp. 71-87.

Khan N S S, Shah S, Ali J and Khan S M. 2018. Effect of variable dietary energy levels on reproductive hormonal profile, body condition score, body weight and blood metabolites concentration of early lactating cows. *Journal of Entomology and Zoology Studies* **6**: 1172–76.

Konigsson K, Savoini G, Govoni N, Invernizzi G, Prandi A, Kindahl H and Veronesi M C. 2008. Energy balance, leptin, NEFA and IGF-I plasma concentrations and resumption of postpartum ovarian activity in Swedish red and white breed cows. *Acta Veterinaria Scandinavica* **50**: 1–7.

Lonergan P and Sánchez J M. 2020. Symposium review: Progesterone effects on early embryo development in cattle. *Journal of Dairy Science* **103**: 8698–707.

Lonergan P, Forde N and Spencer T. 2016. Role of progesterone in embryo development in cattle. *Reproduction, Fertility and Development* **28**: 66–74.

Mahfuz S U, Islam M S D, Chowdhury M R, Islam S, Hasan M K and Uddin M N. 2018. Influence of concentrate supplementation on production and reproduction performance of female Black Bengal goat. *Indian Journal of Animal Research* **52**(5): 735–39.

Maurya V P, Sejian V, Kumar D and Naqvi S M K. 2010. Effect of induced body condition score differences on sexual behaviour, scrotal measurements, semen attributes, and endocrine responses in Malpura rams under hot semi-arid environment. *Journal of Animal Physiology and Animal Nutrition* **94**: 308–17.

McKay Z C, Lynch M B, Mulligan F J, Rajauria G, Miller C and Pierce K M. 2019. The effect of concentrate supplementation type on milk production, dry matter intake, rumen fermentation, and nitrogen excretion in late-lactation, spring-calving grazing dairy cows. *Journal of Dairy Science* **102**: 5042–53.

Mohapatra P, Swain R K, Mishra S K, Sahoo G and Rout K K. 2012. Effect of supplementation of area specific mineral mixture on reproductive performance of the cows. *Journal of Animal Science* **82**: 1558–63.

Muñoz C, Hube S, Morales J M, Yan T and Ungerfeld E M. 2015. Effects of concentrate supplementation on enteric methane emissions and milk production of grazing dairy cows. *Livestock Science* **175**: 37–46.

Obese F Y, Dwumah K, Adjorlolo L K and Ayizanga R A. 2018. Effects of feed supplementation on growth, blood parameters and reproductive performance in Sanga and Friesian-Sanga cows grazing natural pasture. *Tropical Animal Health and Production* **50**: 1739–46.

Pereira D H, Pereira O G, da Silva B C, Leão M.I, de Campos Valadares Filho S, Chizzotti F H M and Garcia R. 2007. Intake and total and partial digestibility of nutrients, ruminal pH and ammonia concentration and microbial efficiency in beef cattle fed with diets containing sorghum (*Sorghum bicolor* (L.) Moench) silage and concentrate in different ratios. *Livestock Science* **107**(1): 53–61.

Peter A T, Vos P L A M and Ambrose D J. 2009. Postpartum anoestrus in dairy cattle. *Theriogenology* **71**: 1333–42.

Prasad C S, Sharma P V, Obireddy A and Chinnaiya G P. 1989. Trace elements and ovarian hormonal levels during different reproductive conditions in crossbred cattle. *Indian Journal of Dairy Sciences* **42**: 489–92.

Rajala-Schultz P J and Saville W J A. 2003. Sources of variation in milk urea nitrogen in Ohio dairy herds. *Journal of Dairy Science* **86**(5): 1653–61.

Robinson J J, Ashworth C J, Rooke J A, Mitchell L M and McEvoy T G. 2006. Nutrition and fertility in ruminant livestock. *Animal Feed Science and Technology* **126**: 259–76.

Samadi F, Phillips N J, Blache D, Martin G B and D'Occhio M J. 2013. Interrelationships of nutrition, metabolic hormones and resumption of ovulation in multiparous suckled beef cows on subtropical pastures. *Animal Reproduction Science* **137**: 137–44.

Santos J E P, Bisinotto R S, Ribeiro E S, Lima F S, Greco L F, Staples C R and Thatcher W W. 2011. Applying nutrition and physiology to improve reproduction in dairy cattle. *Society of Reproduction and Fertility Supplement* **67**: 387–403.

Snedecor G W and Cochran W G. 2004. *Statistical Methods*, 9th edn. The Iowa State University Press, Ames, Iowa, USA.

Soca P, Carriquiry M, Claramunt M, Ruprechter G and Meikle A. 2014. Metabolic and endocrine profiles of primiparous beef cows grazing native grassland. 2. Effects of body condition score at calving, type of suckling restriction and flushing on plasmatic and productive parameters. *Animal Production Science* **54**: 862–68.

Sultana S, Khan M J, Hassan M R and Khondoker M A M Y. 2012. Effects of concentrate supplementation on growth, reproduction and milk yield of Black Bengal goats (*Capra hircus*). *Bangladesh Veterinarian* **29**(1): 7–16.

Tewari D, Jain R K and Mudgal V. 2014. Effect of strategic nutrient supplementation on the reproductive performance of anoestrus crossbred cattle in Malwa region of Madhya Pradesh. *Indian Journal of Animal Research* **48**: 580–84.

Tyrrell H F and Reid J T. 1965. Prediction of the energy value of cow's milk. *Journal of Dairy Science* **48**: 1215–23.

Uddin M J, Haque K Z, Khan M J and Khan M M H. 2015. Dynamics of microbial protein synthesis in the rumen – A review. *Annals of Veterinary and Animal Science* **2**: 116–131.

Van Soest P J, Robertson J B and Lewis B A. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* **74**: 3583–97.

Walsh S W, Williams E J and Evans A C O. 2011. A review of the causes of poor fertility in high milk producing dairy cows. *Animal Reproduction Science* **123**: 127–38.

Wang B, Mao S Y, Yang H J, Wu Y M, Wang J K, Li S L, Shen Z M and Liu J X. 2014. Effects of alfalfa and cereal straw as a forage source on nutrient digestibility and lactation performance in lactating dairy cows. *Journal of Dairy Science* **97**: 7706–15.

Wang C, Zhao Y, Aubry A, Arnott G, Hou F and Yan T. 2019. Effects of concentrate input on nutrient utilization and methane emissions of two breeds of ewe lambs fed fresh ryegrass. *Translational Animal Science* **3**: 485–92.

Wathes D C, Fenwick M, Cheng Z, Bourne N, Llewellyn S, Morris D G, Kenny D, Murphy J and Fitzpatrick R. 2007. Influence of negative energy balance on cyclicity and fertility in the high producing dairy cow. *Theriogenology* **68**: S232–S241.

Yulistiani D, Jelan Z A, Liang J B, Yaakub H and Abdullah N. 2015. Effects of supplementation of mulberry (*Morus alba*) foliage and urea-rice bran as fermentable energy and protein sources in sheep fed urea-treated rice straw based diet. *Asian-Australasian Journal of Animal Sciences* **28**: 494–501.

Zhou X Q, Zhang Y D, Zhao M, Zhang T, Zhu D, Bu D P and Wang J Q. 2015. Effect of dietary energy source and level on nutrient digestibility, rumen microbial protein synthesis, and milk performance in lactating dairy cows. *Journal of Dairy Science* **98**: 7209–17.