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**Amit Kumar Singh, Champak Bhakat,
D. K. Mandal, A. Mandal, S. Rai,
A. Chatterjee & M. K. Ghosh**

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Effect of reducing energy intake during the dry period on milk production, udder health, and body condition score of Jersey crossbred cows in the tropical lower Gangetic region

Amit Kumar Singh¹ · Champak Bhakat¹ · D. K. Mandal¹ · A. Mandal² · S. Rai¹ · A. Chatterjee³ · M. K. Ghosh³

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Abstract

To find out the effect of reducing energy intake during dry period on milk production, udder health, and body condition, the experiment was conducted on 14 Jersey crossbred cows during whole dry period and continued up to 120 days of lactation. Reduction in energy intake was done during far-off period for each dry cow of treatment group as compared to control group. Statistically analyzed data revealed that overall significantly ($P < 0.01$) lower DMI and WI were recorded in control than treatment group. Overall significantly ($P < 0.01$) higher total milk production was found in treatment than control group. Overall significantly ($P < 0.01$) lower milk SCC, MCMT, pH, and EC were found in treatment than control group. Nonsignificant difference in milk fat, SNF, total solid, total protein, and fat:protein ratio was found. Overall significantly ($P < 0.01$) better quality milk (MBRT) was found in treatment than control groups. BCS during dry period and at calving was significantly ($P < 0.01$) different between groups. Significantly ($P < 0.01$) higher plasma NEFA concentration was estimated in control than treatment groups in all stages. No significant difference was found for plasma concentrations of glucose, urea, and total protein. The coefficients of correlation indicated significant ($P < 0.01$) correlation among BCS, milk production, milk SCC, MCMT, pH, and EC. It can be concluded that reducing energy intake during far-off dry period can lead to achieve optimum BCS at calving. Suitable BCS at calving was beneficial to get higher milk production with improved quality, better maintenance of udder health and body condition of Jersey crossbred cows at tropical lower Gangetic region.

Keywords Tropical lower Gangetic region · Jersey crossbred · Energy intake · Milk production · Udder health · BCS

Abbreviations

DMI Dry matter intake
WI Water intake

SCC Somatic cell count
MCMT Modified California mastitis test
EC Electrical conductivity
BCS Body condition score
NEFA Non-esterified fatty acids
MBRT Methylene blue reduction test

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✉ Champak Bhakat
bhakat56@gmail.com

¹ LPM Section, ICAR, National Dairy Research Institute (NDRI), Eastern Regional Station (ERS), Kalyani, Nadia, WB Kalyani-741235, India

² Animal Breeding section, ICAR, National Dairy Research Institute (NDRI), Eastern Regional Station (ERS), Kalyani, Nadia, WB Kalyani-741235, India

³ Animal Nutrition Section, ICAR- National Dairy Research Institute (NDRI), Eastern Regional Station (ERS), Kalyani, Nadia, WB Kalyani-741235, India

Introduction

Maintenance of proper milk production with better udder health is a challenge for dairy farmers at tropical lower Gangetic region. High-producing Jersey crossbred cows of this region are susceptible to subclinical mastitis (SCM) which may hamper milk quantity, quality, and overall body condition of those cows. Obtaining an optimum body condition score (BCS) during dry period and at calving may be beneficial in optimizing milk yield and udder health (Beever 2006; Klocke et al. 2007). Berry et al. (2007) reported that BCS was very helpful tool to increase

profitability of farm by aiding to early detection of possible health problems, improving feeding management practices, altogether helping to optimize herd health, production, and reproduction. Proper feeding management strategies for obtaining optimum BCS during prepartum period, at calving, as well as postpartum period are highly advisable (Drackley and Cardoso 2014). The change in energy intake during far-off and closeup dry period was found to cause significant difference in calving BCS, affecting postpartum metabolic status (Roche et al. 2013). BCS monitoring is helpful and easy tool in improving nutritional programs, udder health and milk yield. Change in energy status of animal body, in different stages of life, causes variation in body condition, production, and health (Singh et al. 2015).

Dry period feed intake has been found highly associated with BCS of animal during dry period as well as postpartum period (Gumen et al. 2011; Smith et al. 2017). The cows which were overfed and over-conditioned were more on the risk of mastitis (Butler 2009) and other ailments. It had been noted that over-fattened cow at calving losses more body weight postpartum (Paul et al. 2019). Among several ailments during transition period, SCM has been found to be associated with BCS during transition period (Alhussien and Dang 2018). Achieving proper BCS during prepartum period leads to decreased body condition loss during post-calving, decreased incidence of udder health problems and increased milk production (Reis et al. 2012). It has been suggested that feeding management of cows should be done in such a way that it can suffice the cow's proper body condition during dry period for better postpartum performance when there are greater chances of mastitis infection. Focus needs to be directed toward far-off period to improve cow health, performance, and fertility (Drackley et al. 2005). Furthermore, it was also suggested to avoid over-consumption of energy in far-off period (Beever 2006) as higher BCS cows near to calving were corroborated with higher rates of udder infections at herd level (Valde et al. 2007). For dry period, Overton and Waldron (2004) suggested strategy to reduce energy supply during early dry period and increased energy supply during late dry period to optimize health and production of dairy cows.

There are very less researches done on management strategies of far-off and closeup dry period on production and health of Jersey crossbred cows, and there is no confirming study done to establish that reduction in energy intake during far-off period than closeup dry period leads to improve production and health performance. Therefore, present study was aimed to investigate the effect of reducing energy intake during dry period on milk production, udder health, and body condition of Jersey crossbred cows at tropical lower Gangetic region.

Materials and methods

This study was carried out at organized dairy farm at Eastern Regional Station, ICAR-National Dairy Research Institute

(ERS-NDRI), cattle yard located in Kalyani, WB (lower Gangetic region of tropics). The latitude and longitude position being 22°56'30"N and 88°32'04"E, respectively.

Experimental animals

This experimentation was conducted during the year 2018 to 2019 on fourteen healthy Jersey crossbred cow having almost similar age groups, body weight, BCS, and parity which were divided into 2 comparable groups, i.e., group-1 as treatment and group-2 as control. After an adaptation period the final observations were taken during whole dry period (60 days pre-calving), which were continued during calving and postpartum (period) up to 120 days of lactation. Housing and other management practices were similar to both groups. All animals of both groups were individually stall fed in individual manger of the cage.

Feeding alteration during dry period

Each dry cow of treatment group was provided with 33% less amount of concentrates (2 kg/day/animal) during far-off period (1 to 45 days) as compared to each dry cow of control group which received 3 kg/day/animal of concentrates during same period. Both groups during closeup (to calving) period (46 to 60 days) and postpartum period received same amount of concentrates as per the standard farm management practices. Ad libitum green and dry fodders (70:30) were provided to both groups during dry period as well as postpartum period as per the standard farm management practices (NRC standards). Thus, cows of treatment group consumed high fiber and low energy diet than control group cows during far-off dry period. The DCP and TDN contents were 14% and 68%, respectively. Same concentrate mixture as per the Bureau of Indian Standards type II concentrate mixture (BIS 2052:2009) for feeding cattle was included in diet of each group cows (Table 1).

Dry matter intake

Each and every animal was stall-fed in individual manger with separate watering provision. During dry period, animal's feed intake (individual feeding) of concentrate mixture and fodder (green and dry) was measured every day with the help of an electronic weighing balance with least count 50 g. DMI through concentrate and fodder (green + dry) was estimated daily during dry period. Dry matter through fodder was determined by taking a composite mixture of fodder and drying it into a hot air oven at 38 °C for 48 h. This dry matter was then added to the DM of concentrate mixture to obtain total dry matter intake through concentrate and fodder.

Table 1 Nutrient content of concentrate mixture

S.N.	Nutrients Present	% DM	S.N.	Nutrients present	% DM
1.	Moisture	11	7.	Salt as NaCl	1
2.	CP	20	8.	Calcium	0.5
3.	CF	7	9.	Available Phosphorus	0.5
4.	EE	3	10.	Vit. A	5000 IU/kg
5.	AIA	3	11.	Vit. D ₃	1200 IU/kg
6.	U	1	12.	Vit. E	30 IU/kg

Note: *SN* serial number; *CP* crude protein (min.); *CF* crude fiber (max.); *EE* ether extract (min.); *AIA* acid insoluble ash (max.); *U* urea (max.); *Vit. A* vitamin A (min.); *Vit.D₃* vitamin D₃ (min.); *Vit.E* Vitamin E (min); *DM* dry matter

Water intake

Water having hardness between 200 and 220 mg/l of CaCO₃, which is acceptable to cattle (Adams and Sharpe 1995), along with pH range from 7.30 to 7.71 with water temperature 23.1 to 26.3 °C, was offered to the cows during their 60 days dry period with the help 15 l capacity of aluminum buckets. Cows were offered ad libitum water and left untouched for about 30 min each time to every cow to have as much water as they want to drink thrice a day during 8–9 AM, 1–2 PM, and 7–9 PM, daily. However, water was measured every time using an electronic weighing balance, with least count 50 g, before and after offering to cows to determine the actual amount of water intake by experimental animals.

Milk production

Every day, milk productions were recorded at cattle yard, organized farm at ERS (Eastern regional station) – NDRI. Milk recording continued for 4 months (daily morning, evening) for all experimental animals.

Analysis of milk samples

From every animal, about 70 ml of milk samples were collected from whole milk bucket after complete milking of individual animals in sterilized glass bottles at fortnight intervals. Udder health status (subclinical mastitis) was detected by SCC in milk sample, MCMT, EC, and pH of milk samples. The MCMT was conducted as per procedure described by Pranay et al. (2015a). To check the quality aspect of milk samples through MBRT was conducted. Milk composition parameters were analyzed by estimating fat, protein, SNF, total solid, fat-protein ratio in morning and evening milk samples daily by using automatic milk analyzer (MILKOSCAN) and also cross-checked manually.

Somatic cell count in milk

This was carried out by an automatic machine of DeLaval cell counter DCC. For cross-checking of SCC, the microscopic

procedure (Bhakat et al. 2017a) was also adapted in which modified Newman's Lampert stain was used, and smears were examined under oil immersion lens (100×). Thirty different fields per smear were observed, and average number of cells per field was then multiplied by microscopic factor to obtain number of somatic cells per ml of milk.

Milk quality

For testing milk quality, the methylene blue reduction test (MBRT) was carried out.

Blood collection

Under aseptic conditions, blood samples were collected by venipuncturing jugular vein of individual cows into a 10-mL blood collection tube at 60 days pre-calving, 30 days pre-calving, at calving, and post-calving period at 30 days, 60 days, and 90 days. Some relevant blood metabolites were analyzed using spectrophotometer for non-esterified fatty acid (NEFA), total protein, urea, and glucose.

Body condition score (BCS)

BCS of animals was assigned using visual plus palpation technique. This method grades the status of cow's body condition on a six-point scale (1–6). The score 1 reflects very thin and 6 reflects very fat condition of cow. For assessing the body condition of animals, anatomical regions (critical points) were taken into account meticulously as standardized (ultrasonography method) by Paul et al. (2019) for Jersey crossbred dairy cows of tropical lower Gangetic region.

Statistical analysis

All data were meticulously analyzed by IBM SPSS statistics 21 software for statistical analysis. Each and every parameters were analyzed by using the univariate general linear model (GLM) method for analysis of variance. The correlation coefficients were determined as per Pearson correlation. The

logarithms of somatic cell count (SCC) numbers were used to normalize wide variation of data distribution. Turkey's HSD test was performed to test the significance among the means. The significant differences were set at $P < 0.05$ and $P < 0.01$.

Results and discussion

Dry matter intake and water intake

Statistically analyzed data (Table 2) revealed that significantly ($P < 0.01$) lower DMI through fodder in control than treatment group in 2nd month onward and overall of dry period. This may be due to higher amount of concentrate mixture (3 kg/day/cow) consumed by control group, whereas treatment group consumed lesser amount (2 kg/day/cow) of concentrate. Consumption of higher amount of concentrate might have satisfied the appetite of animals of control group on the other hand lesser amount of concentrate had led to more fodder (green + dry) intake by animals of treatment group. Significantly ($P < 0.01$) lower DMI through fodder and concentrate mixture was recorded in control than treatment group in 2nd month onward and overall of dry period. The reason may be due to lesser consumption of fodder (green + dry) by cows of control than treatment group. Consumption of higher amount of concentrate may lead to reduction of ruminal pH which may ultimately reduce dry matter intake (Nocek, 1997). However, Maekawa et al. (2002) suggested that comparatively lower concentrate and higher fodder intake may decrease the case of much lower ruminal pH and may prevent loss in dry matter intake. Ryan et al. (2003) found numerically higher

Table 2 LSQ mean $\pm$ S.E of DMI and WI in Jersey crossbred cows during dry period

Month of dry period	Treatment group	Control group
<u>¹DMI through fodder (green + dry)</u>		
1.	1.74	1.67
2.	1.86 ^a	1.64 ^b
Overall	1.80 ^a	1.65 ^b
<u>¹Total DMI through fodder and concentrate</u>		
1.	2.38	2.29
2.	2.49 ^a	2.25 ^b
Overall	2.44 ^a	2.27 ^b
<u>WI (kg/day/animal)</u>		
1.	24.41 $\pm$ 0.13	24.38 $\pm$ 0.28
2.	34.91 ^a $\pm$ 0.17	33.44 ^b $\pm$ 0.21
Overall	29.66 ^a $\pm$ 0.15	28.91 ^b $\pm$ 0.25

Means with different superscripts differ significantly ($P < 0.01$) from each other row wise

Note: DMI dry matter intake; Total DMI total dry matter intake; WI water intake ¹- % of body weight

total dry matter intake in cows fed on higher fiber diet as compared to low fiber diet. Beever (2006) also had suggested for provision of high fiber and low energy diet to cows during dry period for better performance of cows post-partum.

Statistically analyzed data (Table 2) for daily water intake revealed significantly ($P < 0.01$) higher water intake was recorded in treatment than control group in 2nd month onward and overall of dry period. This may be due to higher total DMI by cows of treatment than control group. WI by cows of each groups of this study was in range (Holter and Urban 1992; Kume et al. 2010) during dry period. The coefficients of correlation indicated a positive and significant ($P < 0.05$) correlation (+0.317) between total DMI and WI of this present study. However, Appuhamy et al. (2016) suggested a model, without DMI measurement, for estimating water intake due to absence or inconsistent accuracy of DMI measurement.

Milk production and milk composition

Statistically analyzed data (Table 3) revealed that morning (M), evening (E), and total milk production per day per cow were significantly ($P < 0.01$) higher in treatment than control group during all 4 months and overall milk production. The reason of significantly ($P < 0.01$) higher milk production in all cases (M, E, total) in treatment group might be due to higher DMI and WI by treatment than control group. Moreover, during dry period, consumption of less concentrate mixture and

Table 3 LSQ mean $\pm$ S.E. of milk production of Jersey crossbred cows at tropical lower Gangetic region

Lactation months	Treatment group	Control group
<u>Morning milk production (kg/cow/day)</u>		
1	9.89 ^a $\pm$ 0.21	8.07 ^b $\pm$ 0.18
2	9.58 ^a $\pm$ 0.24	8.12 ^b $\pm$ 0.19
3	8.17 ^a $\pm$ 0.22	7.47 ^b $\pm$ 0.20
4	6.83 ^a $\pm$ 0.19	6.08 ^b $\pm$ 0.21
Overall	8.62 ^a $\pm$ 0.22	7.44 ^b $\pm$ 0.20
<u>Evening milk production (kg/cow/day)</u>		
1	4.87 ^a $\pm$ 0.08	4.17 ^b $\pm$ 0.09
2	4.59 ^a $\pm$ 0.09	4.08 ^b $\pm$ 0.11
3	3.70 ^a $\pm$ 0.06	3.56 ^a $\pm$ 0.10
4	3.17 ^a $\pm$ 0.10	2.92 ^a $\pm$ 0.08
Overall	4.08 ^a $\pm$ 0.08	3.68 ^b $\pm$ 0.10
<u>Total milk production (kg/cow/day)</u>		
1	14.76 ^a $\pm$ 0.31	12.24 ^b $\pm$ 0.26
2	14.18 ^a $\pm$ 0.26	12.19 ^b $\pm$ 0.26
3	11.87 ^a $\pm$ 0.26	11.02 ^b $\pm$ 0.29
4	10.01 ^a $\pm$ 0.28	9.00 ^b $\pm$ 0.31
Overall	12.70 ^a $\pm$ 0.28	11.11 ^b $\pm$ 0.28

Means with different superscripts differ significantly ($P < 0.01$) from each other row wise

more fodder (green + dry) by cows of treatment group than cows of control group might had helped to achieve optimum BCS (around 4 in 1 to 6 scale) as suggested by Paul et al. (2018b) at calving in treatment than control group which in turn was reflected in better milk yield in treatment group cows. Statistically analyzed data (Table 5) revealed nonsignificant difference in percent of fat, total SNF, total solid, total protein of control, and treatment group milk samples. Milk samples of both groups contained normal and standard amount of percent of fat, total SNF, total solid, and total protein. However, comparatively higher fat:protein ratio was found in control than treatment group. The fat:protein ratio 1.5 or higher was found to be representing energy deficiency (Duffield et al. 2009), and those cows having postpartum fat:protein ratio 1.5 or higher were more prone for ketosis, SCM, and mastitis. Garai et al. (2017) reported that Jersey crossbred cow of this region can produce average milk 9.60 ± 0.56 kg/day/cow. Ryan et al. (2003) found that the cows with proper BCS produced significantly ($P < 0.05$) more milk as compared to those in under BCS. Increased milk production in this study is in line with findings and suggestion by Mohammed et al. (2015) and Beever (2006) and Overton and Waldron 2004. However, some earlier researches suggest that BCS at calving had non-significant effect on milk yield and milk composition (Busato et al. 2002; Lake et al. 2006).

Milk quality

Statistically analyzed data (Table 6) revealed significantly ($P < 0.01$) lower MBRT values in control than treatment groups during overall 4 months of lactation period. It is based on fact that color imparted to milk by addition of a dye such as methylene blue disappears more or less quickly. The agencies responsible for oxygen consumption were bacteria. Thus, time of reduction was taken as a measure of the number of organisms in the milk according to Wathore and Bhakat (2016). Kumari et al. (2019) found that supplementation of trisodium citrate was an effective, easy, and cost-effective management practices to increase milk quality and quantity. Bhakat et al. (2017b) reported that the intra-mammary infections (IMI) lead to changes in glandular tissue of the udder. So it is essential to monitor IMI in dairy cows in order to maintain milk quality and udder health.

Udder health status

The occurrence of SCM can adversely affect udder health status and finally lead to lower milk production. Statistically analyzed data (Table 4) revealed that Log_{10} Somatic cell count was found significantly ($P < 0.01$) lower SCC (cells/ml of milk) in treatment than control group in all 4 months and overall values. Retransformation of Log_{10} SCC indicated that milk samples of cows of treatment group had normal somatic

Table 4 Milk testing parameters for udder health/subclinical mastitis in Jersey crossbred cows

Months	Treatment group	Control group
<u>Log₁₀SCC(cells / ml)</u>		
1	5.18 ^a ± 0.05	5.51 ^b ± 0.06
2	5.05 ^a ± 0.04	5.64 ^b ± 0.07
3	5.10 ^a ± 0.06	5.70 ^b ± 0.04
4	5.09 ^a ± 0.05	5.72 ^b ± 0.08
Overall	5.11 ^a ± 0.05	5.64 ^b ± 0.06
<u>(MCMT)</u>		
1	1.43 ^a ± 0.14	2.36 ^b ± 0.20
2	2.00 ^a ± 0.16	2.86 ^b ± 0.22
3	2.07 ^a ± 0.09	2.93 ^b ± 0.21
4	1.64 ^a ± 0.11	3.21 ^b ± 0.26
Overall	1.70 ^a ± 0.13	2.84 ^b ± 0.22
<u>pH</u>		
1	6.58 ^a ± 0.02	6.73 ^a ± 0.03
2	6.62 ^a ± 0.03	6.80 ^b ± 0.03
3	6.57 ^a ± 0.02	6.83 ^b ± 0.02
4	6.58 ^a ± 0.02	6.89 ^b ± 0.04
Overall	6.59 ^a ± 0.02	6.81 ^b ± 0.03
<u>EC (mS/cm)</u>		
1	4.18 ^a ± 0.05	4.58 ^b ± 0.06
2	4.29 ^a ± 0.04	4.82 ^b ± 0.06
3	4.48 ^a ± 0.04	5.12 ^b ± 0.04
4	4.47 ^a ± 0.06	5.19 ^b ± 0.03
Overall	4.36 ^a ± 0.05	4.94 ^b ± 0.05

Means with different superscripts differ significantly ($P < 0.01$) from each other row wise

Note: MCMT modified California mastitis test; $\text{Log}_{10}\text{SCC}$ - Log_{10} Somatic cell count; EC electrical conductivity

cell count which is usually required for udder self-defense mechanism, whereas milk samples of cows of control group had more than 200,000 somatic cell count which indicated the occurrence of subclinical mastitis where no visible health symptoms were found but milk production became gradually lesser and lesser as lactation period progressed. Since cows of control group could not achieve optimum BCS at calving, so during post-calving period, higher negative energy balance was found which might had led to impaired immune function and increased risk of IMI which ultimately resulted in higher somatic cell count in control group. Findings of other workers (Lacetera et al. 2005; Klocke et al. 2007; Butler 2009) support the results of present study which indicates that udder health problems were encountered in high BCS cows as compared to optimum BCS cows. Proper BCS cows showed significantly lower SCC. Kumari et al. (2018) reported that milk SCC, MCMT, and SFMT were suitable diagnostic tests for SCM diagnosis in dairy cows. Paul and Bhakat (2018a) found that under BCS and over BCS at calving significantly ($P < 0.05$)

Table 5 Milk composition of Jersey crossbred cows at tropical lower Gangetic region

Parameters	Treatment group	Control group
¹ Total fat	5.27 ± 0.09	5.34 ± 0.06
¹ Total SNF	8.99 ± 0.03	8.87 ± 0.05
¹ Total solids	14.26 ± 0.10	14.21 ± 0.09
¹ Total protein	3.68 ± 0.04	3.60 ± 0.04
Fat:protein	1.44 ± 0.03	1.50 ± 0.02

¹ (%/day/animal); Total SNF total solid not fat

increased SCC in milk. Pranay et al. (2015b) reported that delay in post-milking feeding time leads to IMI and SCM in Jersey crossbred cows. Pranay et al. (2017) reported that rate of incidence of SCM was higher in cows where less green fodder was available. Bhakat et al. (2016) found that the Log₁₀ SCC (cells/ml) were significantly ($P < 0.01$) higher in IMI cows (6.55 ± 0.05) as compared to non-IMI Jersey crossbred cows (4.05 ± 0.04).

MCMT of milk samples indicated higher-grade value in control group than treatment group cows. Statistically analyzed data (Table 4) revealed that there was overall significantly ($P < 0.01$) higher MCMT value in control than treatment group milk samples. The coefficients of correlation (-0.358) indicated a negative and significant ($P < 0.01$) correlation between MCMT and milk yield of this study. Bhakat et al. (2017b) reported that MCMT grade can be reduced in machine milking practices in Jersey crossbred cows at lower Gangetic region of tropic. Statistically analyzed data (Table 4) revealed that overall significantly ($P < 0.01$) lesser pH was recorded for treatment than control group milk samples. Treatment group milk samples had normal milk pH, and on the other hand, control group milk sample had higher pH. As per the findings of Batavani et al. (2007), pH 6.69 or more was associated with subclinical mastitis milk. This might be due to presence of higher Na⁺, K⁺ ion, and somatic cell count in milk sample of animals of control than treatment group. Bhakat et al. (2017c) found higher milk pH of cows maintained on poor hygiene status which was one of the vulnerable factors for IMI in Jersey crossbred cows.

Table 6 LSQ mean ± S.E. of MBRT (minutes) for milk quality test at tropical lower Gangetic region

Months	Treatment group	Control group
1	282.86 ^a ± 13.42	180.00 ^b ± 19.11
2	256.07 ^a ± 19.41	166.07 ^b ± 25.45
3	218.57 ^a ± 20.32	170.36 ^b ± 23.92
4	192.86 ^a ± 21.26	136.07 ^b ± 25.34
Overall	237.59 ^a ± 18.60	163.13 ^b ± 23.45

Means with different superscripts differ significantly ($P < 0.01$) from each other row wise

Statistically analyzed data (Table 4) revealed that overall significantly ($P < 0.01$) has lesser EC for treatment than control group milk samples. However, in other study, both group milk samples showed normal values of EC (Norberg et al. 2004). Furthermore, critical analysis of coefficients of correlation among all diagnostic tests for subclinical mastitis indicated positive and significant ($P < 0.01$) correlation between SCC and MCMT (+0.520), SCC and pH (+0.769), SCC and EC (+0.725), MCMT and EC (+0.574), pH and EC (+0.665), and significant ($p < 0.05$) correlation in between MCMT and pH (+0.304) of this study. Therefore, it clearly indicated confirmation of diagnostic tests for subclinical mastitis which finally revealed poor udder health status of cows in control group. All four tests of milk samples clearly indicated that cows of control group developed SCM as lactation progressed with no clinical symptoms.

Body condition score

Statistically analyzed data (Table 7) and close scrutiny of Fig 1 revealed that initial BCS of both groups were similar. As dry period progressed, overall BCS was significantly ($P < 0.01$)

Table 7 LSQ mean ± S.E of BCS, blood metabolites in Jersey crossbred cows at tropical lower Gangetic region

Months (M)	Treatment group	Control group
BCS		
Initial	3.79 ± 0.11	3.85 ± 0.09
DP Overall	3.79 ^a ± 0.08	4.13 ^b ± 0.06
At calving	4.07 ^a ± 0.07	4.93 ^b ± 0.08
LP overall	3.89 ± 0.05	4.00 ± 0.06
¹NEFA (mmol/l)		
DP overall	0.08 ^a ± 0.004	0.11 ^b ± 0.002
At calving	0.14 ^a ± 0.007	0.19 ^b ± 0.004
Overall 3 M LP	0.09 ^a ± 0.006	0.17 ^b ± 0.004
¹Glucose (mmol/l)		
DP overall	3.12 ± 0.07	3.17 ± 0.06
At calving	3.28 ± 0.10	3.37 ± 0.09
Overall 3 M LP	3.35 ± 0.05	3.44 ± 0.06
¹Urea (mmol/l)		
DP Overall	4.77 ± 0.14	5.11 ± 0.11
At calving	4.59 ± 0.18	4.76 ± 0.14
Overall 3 M LP	5.04 ± 0.09	5.24 ± 0.08
¹Total protein (g/l)		
DP overall	67.92 ± 0.39	66.98 ± 0.49
At calving	67.47 ± 0.26	66.83 ± 0.30
Overall 3 M LP	67.82 ± 0.42	67.65 ± 0.52

Means with different superscripts differ significantly ($P < 0.01$) from each other row wise

Note: DP dry period; LP lactation period; BCS body condition score; NEFA non-esterified fatty acid ¹⁻ in blood plasma

Fig. 1 Changes in body condition score (BCS) in different months in Jersey crossbred cows

differed between treatment and control group's cows. At the time of calving, BCS was significantly ($P < 0.01$) higher in control group as compared to treatment group. However, overall difference in BCS during lactation period was nonsignificant between two groups. During dry period, BCS followed more increasing trend in control group than treatment groups due to higher consumption of concentrate mixture. This had led to over conditioning of control group's cows at calving, whereas treatment group's cows achieved optimum BCS at calving. Over conditioned cows of control group suffered rapidly reduced BCS during post-calving lactation period which resulted in negative energy balance (NEB) evidenced from higher NEFA in blood plasma (Table 7). On the other hand, treatment group's cow consumed proper nutrition during dry period which might be reason for achieving optimum BCS at calving. It might had led to gradual (normal) reduction BCS during post-calving lactation period with minimum NEB. Washburn et al. (2002) states that early postpartum stressors like NEB and periparturient diseases can potentially hamper the fertility of dairy cows too. Results of this study are in

corroboration with findings and suggestions of Ryan et al. (2003) who found increased BCS at calving in cows fed on high-energy diet. Similar findings of Roche et al. (2013) stated that far-off treatment diet was found to cause significant difference in calving BCS, which affected DMI and metabolic status of dairy animals postpartum.

Blood metabolites

Statistically analyzed data (Table 7) revealed significantly ($P < 0.01$) higher NEFA concentration in cows of control than treatment groups in all stages (dry period overall, at calving time and lactation period overall). The close scrutiny of Fig. 2 indicated that initially NEFA concentration was found to be statistically similar in both groups, but after calving, it increased more in control than treatment group during lactation period and remained higher in control than treatment group. Over-feeding of dairy cows, during dry period, leads to over-conditioning at calving and depression of appetite during calving and after calving.

Fig. 2 Blood plasma non-esterified fatty acid (NEFA) variation (month wise) in Jersey crossbred cows

During early lactation, DMI by cows of control group was low, whereas nutrient demand was high, which lead to cows in NEB. The energy deficiency experienced by most cows usually starts few days before calving and continues for several weeks after parturition. The concentrations of NEFA in plasma increased as cows mobilized greater amounts of body fat, as a consequence of which over-conditioned cows, at calving, went into more severe NEB postpartum than cows that had a normal appetite. Reduction in energy intake during dry period was found to reduce plasma NEFA (Douglas et al. 2006), and also, restricted feeding shown reduced NEFA concentration (Busato et al. 2002). Furthermore, there are many other studies which also suggested that lower DMI during dry period reflected elevated NEFA prepartum (Murondoti et al. 2004; Dann et al. 2006; Roche 2007). But some studies suggested that there was no effect of energy intake during prepartum on NEFA and during dry period (Holtenius et al. 2003; Guo et al. 2007).

Statistically analyzed data (Table 7) revealed that there was no significant difference between groups for the concentrations of plasma glucose, urea, and total protein during all stages (overall dry period, at calving, overall lactation). However, numerically higher values of plasma total protein, glucose, and urea were investigated in the herd of high-energy diets as compared to that of lower energy diets by Ryan et al. (2003). Investigation of coefficients of correlation indicated a positive and significant ($P < 0.01$) correlation among NEFA and SCC (+0.656), NEFA and MCMT (+0.558), NEFA and milk pH (+0.550), and NEFA and milk EC (+0.428).

Conclusions

This investigation revealed a newer aspect of proper feeding management strategies during dry period which may be adapted to prevent dairy cows from becoming excessively higher BCS during dry period, at calving and late lactation. It can be concluded that reducing energy intake during far-off dry period can lead to achieve optimum BCS (3.5 to 4.5) at calving. Excessively increased BCS at parturition has a negative impact on udder health and overall milk production. Suitable changes in BCS from dry period to calving are beneficial to get higher milk production, quality, and better maintenance of body condition and udder health of Jersey crossbred cows at tropical lower Gangetic region.

Recommendation Appropriate reduction in the level of concentrate mixture with ad libitum fodder should be done for feeding during far off period as compared to close up period of dry cow management to achieve proper body condition for getting higher milk production and better health performance of Jersey crossbred cows at tropical lower Gangetic region.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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