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Effect of Dietary Cation-Anion Difference on Milk Composition and Blood Mineral Status of Peripartum Buffaloes

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Authors' contribution

This work was carried out in collaboration among all authors. Authors RNP and PCL designed the study, performed the statistical analysis. Authors Vipin and PKS wrote the protocol and wrote the first draft of the manuscript. Authors KK and SB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to determine the effect of diet formulated to provide prepartum (DCAD= -749.16 mEq/head/day) and postpartum (DCAD = 1473.56 mEq/head/day) by feeding 90 g of an anionic and 120 g cationic salt respectively, on blood mineral concentration, health, postpartum milk production and composition in buffaloes. Twenty multiparous buffaloes were enrolled 21 days before expected calving date and divided into two groups. The treatment group with 10 cows received anionic rations for - 21 day to parturition and cationic ration from parturition to +21 days, while the control group was fed a usual ration. Postpartum incidences of milk fever, dystocia, retention of placenta, mastitis as well as weekly data of milk production, and milk composition were recorded. Plasma samples obtained at days -21, -10, -1, +1, +10 and +21 relative to calving were

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analyzed for calcium and magnesium. Magnesium concentration was increased with reduced prepartum Dietary Cation-Anion Difference (DCAD) in the diet value being 2.77±0.13 mg/dl and 3.15±0.12 mg/dl for the control and treatment group respectively, one day before calving. Calcium concentration was significantly higher (P<0.05) just one day before calving and it further higher (P<0.001) at 1, 10 and 21 days after calving in the treatment group as compared to the control group. Considerable reduction in per cent incidence of parturient paresis (10.0 vs. 20.0), and prolapse (0.0 vs. 10.0) was observed treatment group as compared to the control group. The DCAD concentration had no effect on milk yield, protein, lactose and fat corrected milk, but postpartum milk fat was significantly increased by the treatment. It may be concluded that by altering DCAD of the diet can increase postpartum milk fat with benefits in calcium status and reduced disease incidence without negatively affecting performance in periparturient buffaloes.

Keywords: Calcium; milkfat; milk fever; buffaloes.

1. INTRODUCTION

The transition period is marked by the highest risk for metabolic diseases and health complications greatly affecting the productive efficiency of dairy animals in the ensuing lactation [1]. Increased Ca demands 12 times above normal due to colostrum and increased milk production, paired with the delay in Ca absorption and bone mobilization 2 to 3 days around calving [2] leads to overwhelming of homeostatic mechanisms, resulting in insufficient availability of ionized Ca [3]. Resulting hypocalcemia can be a clinical disease in about 5% of the cows [4] or subclinical disease in around 50% in cows with more than 2 lactations [5]. Many reports have shown clinical hypocalcemia being closely related to periparturient disorders, such as dystocia, retained placenta, ketosis, and displaced abomasum [6] as well as hampered fertility, conception, and pregnancy rate [7]. Nutritional strategies like a low level of calcium diet during last few weeks of pregnancy or feeding a negative Dietary Cation-Anion Difference (DCAD) diet formulated through the inclusion of anionic salts induces a state of compensated metabolic acidosis, which enhances the capacity to mobilize Ca from bones while maintaining parathyroid hormone activity represent a relevant short-term strategy aimed at improving the health and welfare of the transitioning cow [8]. Although it is well described that acidogenic diets increase blood concentrations of total (Ca) and ionized Ca and prevent milk fever, it is less clear what effect these diets have on lactation performance and other diseases [9] also the optimum DCAD amount, kinds of anionic salts and interrelated dynamic metabolism of calcium with Phosphorous and Magnesium remains controversial [10,11,12]. An opportunity exists to explore a level of prepartum DCAD in congruence with available feeding practice which results in improved health and productivity of buffaloes in Indian conditions. The objectives of this study were to determine the effects of DCAD of the peripartum diet on aspects of mineral metabolism, and performance of periparturient buffaloes.

2. MATERIALS AND METHODS

2.1 Study Design and Feeding of Experimental Animals

This experiment was conducted at livestock Farm of Central Institute for Research on Buffaloes, Haryana, India with the approval by the Institutional Ethics Committee from December 2017 to February 2018 for 42 days. The farm is located 212 meters above mean sea level. The maximum daytime temperature during the summer varies between 40 and 46 ℃ (104 and 115 ℉). During winter, its ranges between 1.5℃ and 4℃. Relative humidity varies from 5 to 100%.20 multiparous buffaloes enrolled were divided into two groups of (ten each in each group) based on previous 305 days milk yield (2629.4± 154.43 vs. 2629.7±125.87 litres). The Standard milk yield of experimental buffaloes in both groups was (P>0.05) non-significant. One group was kept on farm feeding management (control group) and another group was kept on the supplementation of anion salt (-749.16 mEq/animal/day) with normal feeding 21 days before the expected date of calving to up to parturition and after calving started supplementing cation salt (+1473.56 mEq/animal/day) up to 21 days of calving. The exact weight of feeds offered and residual left was recorded.

2.2 Formulation of DCAD Based Diets Calculation of DCAD (Meq/ Kg DM) Diet

The per cent of various minerals (Na, K, Cl and S) were measured by atomic absorption spectrometer and ionometry IC Plus instruments while different feeds were analyzed by chemical methods and values were taken from various ICAR Publications. Analysis of ions (Cl and S) content of Feeds and fodders were done by ionometry (IC Plus). The mEq weights (mg x valency/ atomic weight) of different minerals (Na, K, Cl and S) with DCAD values of feeds and fodders, were calculated with the help of formula Goff et al. [13] and are presented in Table 1. Supplementation of 90 g anion salt mixture (-749.16 mEq) from -21 days up to calving and 125 g cation salt (Sodium bicarbonate, +1473.56 mEq) from calving to 21 days after calving was followed on experimental animals.

2.3 Chemical Analysis of Feed and Fodder

Chemical analysis of feed and fodder was done according to AOAC [14]. The chemical compositions of feeds almost being similar during experiment ingredients were adjusted to meet the requirements (Table 2).

2.4 Effect of Feeding Cation-Anion Diets on Various Parameters

2.4.1 Sampling and chemical composition of milk

Milk produced from each animal was recorded at the weekly interval after calving and samples of individual buffalo were analyzed for chemical composition (milk protein, lactose, milk fat and SNF) using pre-calibrated ultrasonic milk analyzer (LACTOSCAN LA, 8900 Zagora BULGARIA). Total Solid (TS) content was calculated by adding fat content with solid-not-fat (SNF). Fat corrected milk (FCM) of buffalo milk was calculated at 6.0% by using the formula of Rice et al. [15].

2.4.2 Estimation of Magnesium and Calcium content in plasma

Plasma magnesium was estimated by Atomic Absorption Spectrometer (AAS), using the instrument ICE 3300 Thermo fisher. Plasma calcium was estimated by calcium estimation kit (Coral Clinical Systems, India) by OCPC method in Automated Biochemistry Analyzer (Coralyzer200, Tulip Diagnostics, Pvt. Ltd, India).

2.4.3 Health status of buffaloes

The time of the expulsion of fetal membranes within 12 h after parturition was considered as cases of retained placenta (RP). Post parturition complications such as milk fever, metritis, acidosis, alkalosis, mastitis, and udder edema and abomasal displacement cases were recorded in the control as well as the treatment group and calculated the per cent incidence.

2.5 Statistical Analysis

Statistical analysis of experimental data was carried out through the SPSS 16.0 software package by analyzing the data through one way ANOVA. The effect of different factors, viz., treatment (groups), period and treatment x period interaction was determined by two way Analysis of variance (ANOVA).

3. RESULTS AND DISCUSSION

3.1 Milk Production and Composition

There was no significant (P>0.05; Table 3) effect on postpartum milk production between the groups but the overall mean value of milk yield was higher in the treatment group than the control. This might be due to generation of a slightly acidic environment in the rumen by lower DCAD diet [16] or genetic makeup [17] which is in line with findings of Martinez et al. [7]; Weich et al. [18] and Silva [19] and Balbir et al. [20] who reported that prepartum negative DCAD feeding did not affect post-parturient milk production. The treatment group had higher (P>0.05; Table 3) FCM, protein and lactose content with significantly (P<0.001; Table 3) higher overall mean of fat % as compared to control group. Similar results were reported by Delaquis and Block [21], Roche et al. [22], and Apper-Bossard et al. [23], who reported higher fat content in milk when cows were fed increasing DCAD. Similarly, Sanchez [24] reported FCM yield was maximized at +380 mEq/kg positive DCAD. This increased fat content of milk may be a response to the positive effect of DCAD on rumen pH after feeding [23], which may result in a more stable rumen microbial activity, especially of cellulolytic bacteria that present great growth at around neutral pH. Additionally, Roche et al. [22] reported that increasing DCAD might increase DMI as well as short-chain FA synthesis in the rumen, providing more substrate for de novo FA production, which may contribute to increasing the milk fat content. In our study, DMI was

Table 1. Ingredients composition of concentrate mixture given to buffaloes and its mEq status

S. No.	Ingredients	Before calving		After calving	
		Parts	DCAD (mEq)	Parts	DCAD (mEq)
1	Wheat	13	175.06	13	175.06
2	Barley	13	-1338.97	13	-1338.97
3	Maize	14	829.79	14	829.79
4	Mustard cake	35	3404.27	5	529.19
5	Cotton Seed Cake			30	3673.62
6	Wheat bran	22	705.73	22	705.73
7	Mineral mixture	2	-39.43	2	-39.43
8	Salt	1	2.43	1	2.43
9	Total	100	3738.88	100	4839.92
DCAD mEq/kg =37.39 DCAD (mEq) on DM basis 4142.80 mEq on DM basis 41.43 mEq/kg DM basis mEq supplementation by 90 g anion supplementation= -749.16 mEq/animal/day by supplementing 90.00 g of anion salt mixture				DCAD (mEq/Kg) = 48.40 DCAD (mEq) on DM basis 5362.79 mEq on DM basis 53.62mEq /kg DM basis mEq supplementation by 125 g of cations supplementation=1473.56 mEq/animal/day by supplementing 125 g of sodium bicarb.	

Table 2. Chemical composition of concentrate mixture

S. No.	Parameters	Concentrate mixture fed before calving	Concentrate mixture fed after calving
1	Dry matter (%)	90.74	90.25
2	Crude protein (%)	20.13	19.70
3	Crude fibre (%)	10.03	10.62
4	Ether extract (%)	4.35	4.51
5	Nitrogenfree extract (%)	56.23	55.42

Table 3. Effect of cation anion salt feeding on the production of buffaloes

Attributes	Control	Treatment	P
Milk yield (kg/week)	813.40±6.35	901.67±5.34	
FCM (kg/week)	122.10±0.87	145.46±0.83	
FCM(Kg/head/day)	12.26	14.56	
Protein (%)	4.23±0.04	4.27±0.03	
SNF (%)	9.09±0.08	9.06±0.05	
Lactose (%)	4.42±0.10	4.57±0.06	
Fat (%)	6.24±0.08^{a}	6.83±0.11^{b}	<0.001

Superscript bearing different letters in a row differs significantly

non-significantly higher in the treatment group from -7 d to +7 d and become significantly higher on 21 d after calving. Non-significant (P>0.05; Table 3) difference was observed in the overall mean of SNF content. Our result also lines with Lean et al. [25]; DeGroot et al. [26]; Moore et al. [12]; who reported intake of lower DCAD was not influenced milk protein. Milk protein percentage is most substantially influenced by rumen fermentable energy Intake [27] and lactose is less influenced by nutritional factors when compared with other milk components, such as fat and protein. However, Martins et al. [28] reported that DCAD in the diets from -71 to 290 mEq/kg of DM noticed fat-corrected milk, fat, lactose and total milk solids contents linearly improved by 13.52, 8.78, 2.5 and 2.6%, respectively. Santos et al. [9] noticed decreasing the DCAD in diets, improved milk yield, fat corrected milk, fat content and milk protein in parous animals but, not in nulliparous animals.

3.2 Plasma Mineral Profile

Calcium concentration initially being similar gradually increased in the treatment groups and became significant (P<0.05; Table 4) higher just one day before calving up to 21 d after calving.

Studies by Vagg and Payne [29]; Oetzel et al. [30] and Wang and Beede [31] proved that acidogenic salts improved animal's ability to maintain blood calcium level. Fredeen et al. [32] and Goff et al. [33] also reported that cows fed a diet containing DCAD value of -22.8, had significantly higher plasma calcium concentration than the cows fed the diet with DCAD value of 97.8 mEq/l00g DM. They hypothesized that feeding of anionic salts in the diet may increase the activity of the osteoclasts or stimulate the multiplication of new osteoclasts. Balbir et al. [20] reported that during the transition phase, blood calcium had increased linearly ($P<0.05$) with reducing the DCAD levels in Sahiwal cows, highest blood calcium content being noticed at more negative DCAD diets. Studies by Grunberg et al. [34]; Lopera et al. [35] and Martinez et al. [36] reported that feeding anionic salts in the diets can maintain calcium homeostasis as metabolic acidosis procured by feeding negative DCAD salts improve the calcium movement from bone but do not change serum calcium concentrations during the entire treatment period [9,25] and prepartum plasma calcium concentrations did not vary much in their study. The increased calcium mobilization is expected to increase calcium availability at calving [37], and this reduces the risk of subclinical mastitis. In our study, no significant ($P>0.05$; Table 4) difference was observed in magnesium content between both groups except one day before calving when the magnesium concentration was higher ($P<0.05$) in the treatment group than the control. This result showed that the effect of feeding anionic salt has a positive effect on plasma magnesium content while cationic salt not affect. Similarly, Goff et al. [33] also reported higher plasma magnesium content in the anionic group as compared to the cationic group of cows (-22.8 vs. 97.8 mEq /100g DM) also Oetzel et al. [30] reported that plasma magnesium content was significantly higher in the anionic feeding group of cows from -3 to -1 day before calving. The plasma concentration of Mg after calving was 2.22 mg/dl for anionic diet feeding group cows and 2.72 mg/dl for control group cows was reported [8].

3.3 Effect on Urine pH

Before starting the study, urine pH was higher in feeding group than control group animals but it was significantly lower ($P<0.05$ & $P<0.01$; Table 5) three day before calving to one day after calving due to anionic salt supplementation. The urine pH has increased in the treatment group after calving because of the feeding of sodium bicarbonate. Urine pH was not significantly affected by lowering DCAD concentration from -21 up to -7 day of calving but in -3,-1 and 1 day of calving, a decrease ($P<0.05$; Table 5) of urine pH was observed in the treatment group as compared to control group.

It is well documented that increased dietary cations increase urine pH [38]. Jackson et al. [39] noticed increased pH of urine pH (8.09) in dairy cattle fed a high DCAD level (200 mEq/kg) in the diet as compared that cows fed a low (0 mEq/ kg) DCAD level (6.80). Sarwar et al. [40] reported that lambs fed +110 and +220 mEq/ kg DCAD diet had a urine pH of 7.43 and 7.68, respectively. The alteration in urine pH in the positive DCAD fed groups reflects an alteration in blood pH and kidneys minimize this change by making the urine pH alkaline, by excreting more $HCO3^-$ and conserving H+ [41]. Increased urinary pH with increased DCAD level might be

Table 4. Effect of cation anion salt feeding on plasma Ca and Mg level (mg/dl) ±SE

Minerals	Days	Control	Treatment	P
Calcium	-21 days of Calving	8.49±0.19	8.49±0.22	
	-10 days of Calving	8.92±0.52	10.11±0.41	
	-1 day of Calving	8.74±0.25^{a}	9.71±0.35^{b}	<0.05
	1 day of calving	7.74±0.27^{a}	9.58±0.24^{b}	<0.001
	10 days of Calving	8.65±0.41^{a}	10.79±0.44^{b}	<0.001
	21 days of Calving	8.59±0.40^{a}	10.88±0.36^{b}	<0.001
Magnesium	-21 days of Calving	2.54±0.18	2.58±0.22	
	-10 days of Calving	2.72±0.14	2.59±0.17	
	-1 day of Calving	2.77±0.13^{a}	3.15±0.12^{b}	<0.05
	1 day of calving	2.63±0.21	3.06±0.15	
	10 days of Calving	2.86±0.18	2.54±0.23	
	21 days of Calving	2.73±0.14	2.91±0.25	

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Table 5. Effect of cation-anion feeding during transition feeding on urine pH (±SE)

Days	Control	Treatment	P
-21 days of Calving	7.99±0.06	8.06±0.06	
-14 days of Calving	8.00±0.06	7.83±0.12	
-7 day of Calving	7.92±0.07	7.76±0.10	
-3 day of calving	7.89±0.05[a]	7.72±0.04[b]	<0.05
-1 day of Calving	7.97±0.08[a]	7.61±0.02[b]	<0.001
1 day of Calving	7.93±0.04[a]	7.63±0.03[b]	<0.001
3 day of Calving	7.87±0.04	7.91±0.05	
7 day of Calving	7.99±0.06	8.01±0.05	
14 days of Calving	7.98±0.04	7.96±0.05	
21 days of Calving	7.96±0.06	8.00±0.07	

Superscript (a, b) bearing different letters in a row differ significantly

Table 6. Effect of cation-anion feeding on common metabolic disorder

Diseases	Control		Treatment	
	No. of cases	% incidence	No. of cases	% incidence
Prolapse	1/10	10	0/10	0
Metritis	0/10	0	0/10	0
Retained placenta	0/10	0	0/10	0
Mastitis	0/10	0	0/10	0
Milk Fever	2/10	20	1/10	10
Dystocia	0/10	0	0/10	0
Mortality	0/10	0	0/10	0

attributed to higher blood $HCO3^-$ and lower urine net acid excretion, implying that the acid load of the animals decreased rapidly as DCAD increased [42,43]. Our findings reflect that increase in urine pH in positive DCAD fed animals was because of the alkaline nature of the diet. Luebbe et al. [44] also reported that urinary pH increased as DCAD increased. These decrease in pH of urine noticed during the feeding period when fed total mix ration with a DCAD between −100 and −200 mEq/kg of DM [45,35,9]. Our findings reflect that increase or decrease in urine pH in DCAD fed animals was because of the alkaline or acidic nature of the diet respectively, which is the function of salts used for the respective mineral composition. So, it can be inferred from the present study that cationic diet being alkaline, increases the urine pH. All animals of the control and treatment group had shown a trace level of protein in their urine. Ketone body and glucose are negative in all animals of treatment and control throughout the experiment period.

3.4 Common Metabolic Disorder and Health Status

The overall incidence of milk fever and prolapse was 20% and 10% for control while the treatment group had 10% incidence for milk fever and no incidence of prolapse (Table 6). In both the groups, no incidences were found for another disease like metritis and retained placenta, mastitis dystocia. The negative DCAD diet considerably reduced the risk of postparturient problems supported by various researchers [46, 47,48]. The experiment also reported the incidence of postpartum metritis to be 71.43% in cationic with no incidence in anionic group animals [49]. Oetzel [50] and Goff [51] described that low concentration of calcium is directly related with the various health problems like dystocia, retained placenta and mastitis as Ca play a significant role in muscle contraction and immunity of the body [52]. However, results of the present study are inconsistent with the finding of Melendez et al. [53], Hu et al. [54], Gulay et al. [55] who reported that negative DCAD diet did not reduce the incidence of post parturient problems.

4. CONCLUSION

Results of this study indicate that feeding peripartum buffaloes with an anionic salt prior to calving and cationic salt after calving altered the dynamics of the mineral to boost the blood calcium concentration with decreased incidence of different diseases and it also increases the milk fat without significant effect on milk production.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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