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Lactation performance of dairy cows on feeding rumen-protected choline

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ABSTRACT

The experiment was designed to assess the effect of supplemental feeding of 40 g/day rumen-protected choline (33.5% w/w) in the total mixed ration of lactating cows on nutrient intake, lactation, reproduction, feed efficiency, and feed cost during 294 days of the lactation. The study was conducted at Livestock Research Station, Anand during 2018 to 2021. A total of sixteen cows were randomly distributed into two groups of eight each based on descending order of previous standard lactation yield and lactation numbers. An intake and milk yield were calculated for 1-21 biweekly periods. The milk composition was assessed four times during lactation. The body condition score (BCS) on a 1-5 point scale with an increment of 0.25 points was measured at -21, -14, -7, 0, 7, 14, 21, 35, 49, 63, 91, and 119 days of calving. The supplemental feeding of rumen-protected choline (RPC) in T2 group resulted in lower nutrient intake, lesser insemination to conceive, and service period with higher 4% fat corrected milk (FCM) yield in dairy cows. The body condition score and milk yield persistency were higher along with improved feed efficiency and feed economics in the T2 group as compared to the T1 group. The daily feeding of 40 g RPC during -21 to 120 days of calving resulted in significantly lower nutrient intake with improved 4% FCM yield, reproductive performance, feed efficiency, and feed economics in dairy cows.

Keywords: Cow, Feed efficiency, Intake, Milk yield, Reproduction, Rumen protected choline

Most high-yielder cows experience negative energy balance after calving as nutrient intake is insufficient to meet the increased energy demands of lactation (Grummer *et al.* 2004). To meet the energy demand, cow utilizes body fat reserve, which predisposes to hepatic lipidosis and ketosis. These hepatic lipidosis and ketosis compromise production, immune function, and fertility (Hayirli 2006). The body requires choline chloride for building and maintaining cell structures, fat metabolism of the liver, formation of acetylcholine, and as a methyl group donor. Choline as a lipotropic factor transports fat from the liver and improves production. The earliest investigations with unprotected choline, reveal a non-significant effect on milk yield and milk composition, due to rapid degradation in the rumen (Chaudhary *et al.* 2017). *In vitro* rumen degradation of choline was 80-90% for common feedstuffs and choline supplements (Sharma and Erdman 1989). Rumen-protected choline (RPC) chloride improves milk yield, fat, and reproductive parameters; reduces serum non-esterified fatty acids in transitional periods (Jayaprakash *et al.* 2016) and along with an improvement in milk yield, reproduction, and feed efficiency (Acharya *et al.* 2020, Amrutkar *et al.* 2015) in dairy cows. Research on supplementation/top dressing of RPC in dairy cows during variable peripartum periods improved production and reproduction (Arshad *et al.* 2019) while information recorded during the lactation period is meager. It was hypothesized that the supplementation of RPC positively affects dairy cow performance. The specific objective was to study the effect of supplementation of RPC on milk production, reproduction, feed efficiency, and feed economics in dairy cows.

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MATERIALS AND METHODS

Animals and design of experiment: All procedures and protocols used in this experiment were approved by Institutional Animal Ethics Committee, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand (272/LRS/2018). Cows (16) were randomly distributed into two groups of eight each. Each group had six multiparous cows [Five crossbred (50% HF and 50% Kankrej) and one Kankrej cow], and two primiparous crossbred cows (50% HF and 50% Kankrej). Criteria for allotment of cows were in descending order of previous lactation milk yield (kg/day) and lactation numbers. The primiparous cows were distributed based on the first lactation yield of the dam. Cows were housed in a well-ventilated barn with an individual feeding facility. All animals were dewormed before the initiation of the experiment. Animals were offered clean and fresh water at noon and in the evening at a tying place. Animals were let loose for exercise after morning milking (5:30 h to 9:30 h), during this time, they had free access to water. The water was also provided at the tying place.

Total mixed ration preparation and animal feeding: Total mixed ration (TMR) was prepared using 20% compounded concentrate mixture-1, 33% green fodder (sorghum/Hybrid Napier-Coimbatore-3), 25% wheat straw, 20% pulse straw (ground-nut/pigeon pea), 1% premix and 1% common salt on dry matter basis and fed to both groups of cows (ICAR 2013). Rumen-protected choline (33.5% w/w choline), @ 40 g/day was supplemented to cows of the T2 (RPC) group from 21 days prepartum to 120 days postpartum. Individual feeding of TMR was followed at tying place from 21-day pre-calving to 294 days post-calving two times in the morning (10:00 h) and afternoon (16:30 h). The leftover was measured the next day in the morning (5:00 h) to arrive at the daily feed intake. The cows required the concentrate at milking, were offered weighed quantity of pelleted concentrate mixture-2 and calculated in intake.

Data recording and statistics: Cows were milked two times a day in the morning (4:30 to 5:30 h) and evening (16:30 to 17:30 h). The daily milk yield was averaged at a bi-weekly period for 294 days (1-21 period). The milk yield during the 1-8th and 9-21st biweekly periods was considered as initial and residual milk yield, respectively. Four times milk samples were collected in the morning and evening in lactation and analyzed using Milkoscan (BIS 1981). FCM (4% fat corrected milk) was calculated using formula FCM = (0.4 × milk yield in kg) + (15 × milk fat in kg). The body condition score (BCS) from 1 to 5 point scale was recorded by three scientists individually with an increment of 0.25 points (Edmonson *et al.* 1989). BCS of cows was measured at 21, 14, and 7 days prepartum, at calving, and 7, 14, 21, 35, 49, 63, 91, and 119 days postpartum. Reproduction parameters viz. number of services required to conceive and service period were recorded. The feed efficiency was calculated based on dry matter and nutrients required to produce one kg of milk and 4% fat-corrected milk. The feed cost (₹) was calculated considering the price of milk, feeds, and fodders. The data were analyzed as per Snedecor and Cochran (2014) as one-way ANOVA using web-based agriculture statistic software WASP 2.0 (Jangam and Wadekar 2004). The difference between treatment means was considered significant at less than 5 % level.

RESULTS AND DISCUSSION

Feed and nutrient intake: The nutrient composition of TMR, feeds, and fodder is given in Table 1. The feeding TMR supplemented with 40g/day RPC (T2) resulted in a daily lower ($P<0.05$) intake of dry matter (DM; 2.44 kg), total digestible nutrients (TDN; 1.46 kg), crude protein (CP; 0.35 kg), and ether extract (0.07 kg) than the control group (Table 2). The periodical DMI of cows (Fig. 1) showed lower intake trend with milder fluctuation in T2 group than in T1 control group.

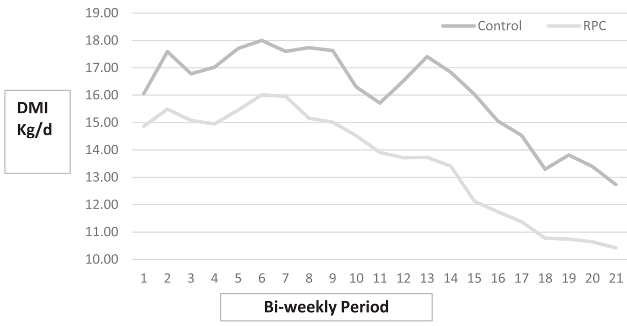

Fig. 1. Dry matter intake (DMI) of cows.

The cows of the RPC group had lower dry matter intake and a higher body condition score in the present experiment, this finding is in accordance with Hartwell *et al*. (2020) who reported significantly lower post-partum dry matter intake in high BCS cows compared to low BCS cows. Cooke *et al*. (2007) have also reported that supplementation of RPC in dairy cows improves liver function by reducing fatty liver during the peripartum period and it might be the reason for lower DMI. The RPC supplementation can reduce the fatty liver during the transition period and lead to increased gene expression related to VLDL mobilization (Abbasi *et al.* 2017). This mobilized fat can be utilized for milk synthesis and body energy requirements.

Contrary to the present study, a non-significant influence of feeding of rumen-protected choline on dry matter intake was reported (Elek *et al.* 2008, Potts *et al.* 2020, Hartwell *et al.* 2020) in dairy cows. The meta-analysis revealed that RPC did not impact DMI and appetite in dairy cows (Jayaprakash *et al.* 2016). While the study of Zom *et al*. (2011) and Arshad *et al*. (2019) reported higher dry

Table 1. Composition of TMR, feeds, and fodder (% on dry matter basis)

Composition parameter	DM	CP	EE	CF	NFE	TDN	Ash	Silica	Ca	P
TMR	86.19	11.04	2.81	26.02	47.85	54.40	10.26	4.22	096	063
Compounded concentrate mixture-1	90.05	27.13	4.91	13.11	46.84	80.00	8.01	2.59	2.56	1.54
Pelleted compounded concentrate mixture-2	90.20	19.66	3.41	13.39	49.45	75.00	14.09	4.16	2.25	1.23
Green sorghum	75.50	6.16	2.11	35.70	46.91	55.00	9.12	4.15	0.99	0.75
Green Hybrid Napier-CO3 (Coimbatore-3)	79.75	9.53	1.56	28.65	45.72	55.00	14.54	4.35	0.43	0.23
Wheat straw	90.00	4.02	1.94	30.18	54.24	45.00	9.62	6.25	0.23	0.21
Pigeon pea straw	90.02	9.01	3.27	27.34	46.71	45.00	13.58	5.45	069	0.34
Ground nut straw	90.22	11.23	4.14	25.05	49.69	45.00	9.89	1.90	1.00	0.72

TMR, Total mixed ration; DM, Dry matter; CP, Crude protein; EE, Ether extract; CF, Crude fibre; NFE, Nitrogen free extract; TDN, Total digestible nutrients; Ca, Calcium; P, Phosphorus.

Table 2. Nutrients intake, milk yield, and components yield of cows fed rumen-protected choline

Parameter	T1 (Control)	T2 (RPC)	P value
Nutrients intake (kg/day)			
DM	16.01±0.27	13.57±0.26	0.039
TDN	9.07±0.17	7.61±0.13	0.040
CP	1.91±0.04	1.56±0.03	0.034
EE	0.46±0.01	0.39±0.01	0.043
Milk yield			
Whole milk, kg/day (1-21 Biweekly period)	9.71±0.48	10.61±0.32	0.118
Initial whole milk yield, kg/day (1-8 Bi-week)	13.59±0.67	13.20±0.37	0.609
Residual whole milk yield, kg/day (9-21 Bi-week)	7.33±0.53	9.02±0.39	0.011
4% FCM yield, kg/day (1-21 biweekly period)	9.80±0.48	10.99±0.33	0.042
Initial 4% FCM yield, kg/day (1-8 Bi-week)	13.63±0.66	13.73±0.36	0.893
Residual 4% FCM yield, kg/day (9-21 Bi-week)	7.45±0.54	9.30±0.41	0.007
Milking days	273.25±14.39	282.13±11.31	0.635
Fat yield, kg/day	0.401±0.02	0.446±0.01	0.056
SNF yield, kg/day	0.853±0.04	0.953±0.03	0.048
TS yield, kg/day	1.254±0.06	1.399±0.04	0.049
Lactose yield, kg/day	0.472±0.02	0.520±0.02	0.080
Protein yield, kg/day	0.309±0.01	0.344±0.01	0.055
Milk components (%)			
Fat	4.28±0.27	4.25±0.17	0.911
SNF	8.88±0.14	9.02±0.11	0.461
TS	13.17±0.39	13.26±0.26	0.845
Lactose	4.91±0.06	4.93±0.05	0.895
Protein	3.23±0.05	3.26±0.04	0.650

RPC, Rumen protected choline; DM, Dry matter; TDN, Total digestible nutrients; CP, Crude protein; EE, Ether extract; FCM, Fat corrected milk; SNF, Solid not fat; TS, Total solid.

matter and net energy intake on choline supplementation. The present experiment was carried out for 294 days of lactation and most researchers did work for the RPC feeding period, so the further whole lactation study will be more interesting.

Milk and component yield: The effect of RPC supplementation on 4% FCM yield and milk yield during the 9-21 bi-week period was significantly higher but not during the overall 21 bi-week period (Table 2; Fig. 2). A significant ($P<0.05$) improvement was also noted in the yield of milk solids not fat and total solids. The milk fat, SNF, TS, lactose, and protein content (%) were not influenced ($P>0.05$) by supplemental feeding of RPC to dairy cows.

Similar results were reported by Acharya *et al.* (2020) in Karan Fries cows fed 55 g/d RPC from -30 days to + 60 days of calving. The milk yield improvement was also reported by Potts *et al*. (2020), Soltan *et al*. (2012), Mohsen *et al*. (2011), Xu *et al*. (2006), and Pinotti *et al*. (2004) on supplementation of rumen-protected choline in the diet of lactating cows. Meta-analysis of Arshad *et al*. (2019) also revealed similar findings from different research. The present improvements in yield were attributed to more milking days, and higher daily milk yield, which may be owing to higher TVFA, efficient nitrogen fermentation, nutrient digestibility, and lipid metabolism as reported by Mohsen *et al*. (2011). The RPC also spares methionine, which can be utilized for milk production in dairy cows (Acharya *et al.* 2020). Contrary to the present findings, Hartwell *et al*. (2020), Pawar *et al*. (2015) and Leiva *et al*. (2015) reported a non-significant effect on milk production.

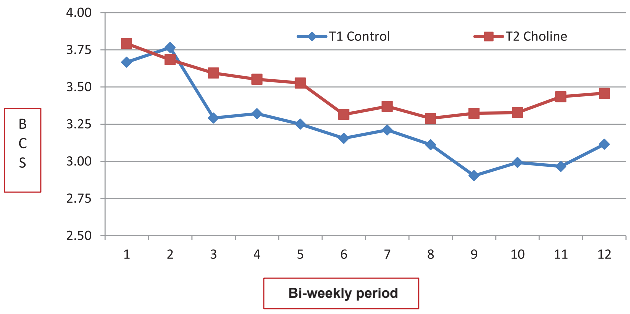

Fig. 2. Body condition score of cows.

Reproductive performance: The feeding of RPC to dairy cows resulted in a lesser ($P<0.05$) number of artificial inseminations to conceive and a reduction ($P<0.05$) in the service period compared to a control group of cows. The calf weight was only 1.321 kg lower in the rumen-protected choline group than in the control even though having a higher ratio of females to males in the RPC group (Table 3). Choline supports cows to minimize negative energy, improves follicular development and fertility (Pirestani and Aghakhani 2018), improves follicular stimulating hormone-FSH and luteinizing hormone-LH production (Evans *et al.* 2006) which improves

Table 3. Reproductive performance, feed efficiency and feeding economics of cows

Parameter	T1 (Control)	T2 (RPC)	P value
BCS	3.23±0.08	3.47±0.05	0.012
Reproduction			
AI/conception	2.286±0.18	1.857±0.14	0.008
Service period days	177.38±20.92	108.13±20.73	0.024
Calf weight (kg)	29.150±1.91	27.838±1.12	0.194
Female to male ratio	5:3	7:1	
Feed efficiency			
DM/kg milk	2.032±0.06	1.399±0.08	0.033
DM/kg FCM	1.921±0.03	1.345±0.08	0.014
TDN/kg milk	1.133±0.09	0.807±0.06	0.042
TDN/kg FCM	1.071±0.01	0.772±0.01	0.015
Feeding economics			
Feed cost (₹/kg milk)	25.228±0.699	17.867±0.258	0.002
Milk value (₹/cow/day)	293.13±51.23	321.88±36.47	0.650
Feed cost (₹/cow/day)	179.63±15.60	163.57±10.81	0.342
Return over feed cost (ROF) (₹/cow/day)	113.50±41.78	158.31±27.34	0.462
Feed cost to milk income ratio	1.00:1.63	1.00:1.97	
ROF over control (₹/cow/day)		+44.81	
% ROF over control		39.48	

RPC, Rumen protected choline; AI, Artificial insemination; ROF, Return over feed cost; DM, Dry matter; TDN, Total digestible nutrients; FCM, Fat corrected milk.

reproduction. Similarly, a reduction in the open days, service per conception in Holstein dairy cows was reported on daily feeding of 18 g (Ardalan *et al.* 2010) and 60 g (Pirestani and Aghakhani 2018) RPC during -4 to 20 and -1 to 4 weeks of calving, respectively.

Body conditions score (BCS) and milk yield: The post-partum decline in body condition score of cows (Fig. 2) fed RPC was gradual but in the control group, a sharp decline was observed up to 14 days post-partum. BCS of cows of the RPC-supplemented group remained on the higher side throughout the experiment. The milk yield curve (Fig. 3) of RPC group cows showed higher persistency compared to the cows of the control group.

The cows under RPC group experienced only mild decline in BCS and higher persistency of milk yield that

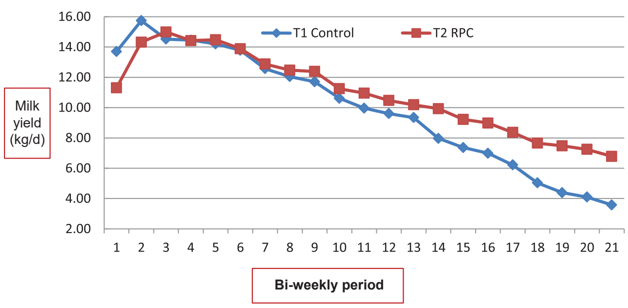

Fig. 3. Bi-weekly milk yield (kg/day) of cows

might have diverted more energy to improve reproductive performance. The loss of BCS has more consequences on reproduction than the absolute value. A loss of BCS under one point has a modest effect on reproduction while a loss above one point has a negative effect on production and reproduction (Souissi and Bouraoi 2019) in dairy cows. Similarly, a trend in milk yield and BCS was reported by Elek *et al*. (2008) in Holstein cows, fed 25 and 50 g/d RPC during pre- and post-partum periods, respectively. The meta-analysis of choline supplementation 0 to 12.9 g/d by Arshad *et al*. (2019) also revealed a positive and linear effect (P=0.008) on postpartum BCS in dairy cows.

Feed efficiency and feed economics: The feed conversion efficiency (Table 3) of cows fed RPC was improved significantly ($P<0.05$) compared to the control group. The cows consumed 0.633 and 0.576 kg less dry matter to produce a kg of whole and 4% fat-corrected milk, respectively. The requirement of total digestible nutrients was 0.326 and 0.299 kg less for the same. The daily feeding cost of cows fed supplemental RPC was ₹ 7.361 lower ($P<0.05$) to produce a kilogram of milk. The return over feed cost was ₹ 44.81/cow (39.48%) more in the RPC group. Similarly, improved feed utilization efficiency for milk yield was reported in Karan-Fries cows (Amrutkar *et al.* 2015) and in Holstein cows (Soltan *et al.* 2012). A meta-analysis by Arshad *et al*. (2019) also showed efficient feed utilization in dairy cows fed 12.9 g RPC daily. The lower intake of nutrients and better milk production in the current experiment may be due to improved feed utilization for milk production.

The supplementation of 40 g/day rumen-protected choline (35% w/w) from 21 days prepartum to 120 days postpartum in dairy cows resulted in significantly lower nutrient intake, improved 4% FCM yield, reproductive performance, body condition score, feed efficiency, and feed economics.

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