*Indian J. Anim. Nutr.* 2024. 41 (1): 126-133
doi:10.5958/2231-6744.2024.00022.7

Indian Journal of Animal Nutrition



# Body Weight and Feed Intake Dynamics in Early and Mid-lactation in Gir Cows Supplemented with Bypass Fat and Choline

V.V Gamit*, M.R. Gadariya, H.H. Savsani, M.D. Odedra, G.P. Sabapara, M.R. Chavda, P.M. Gamit and V.K. Karangiya

*Department of Livestock Production Management, College of Veterinary Science & Animal Husbandry, Kamdhenu University, Junagadh-362001, Gujarat, India

*Correspondence: vimmy.rouge@gmail.com

## ABSTRACT

A study was conducted with eighteen healthy Gir cows, which were selected and divided into three groups of six cows each on the basis of their previous 300-day milk yield, parity, and body weight. The cows were subjected to an adaptation period of 21 days (from -15 to +7 days peri-partum). The cows in the control group were fed only basal ration, while the cows under treatment 1 (T-1) were supplemented with bypass fat (BPF) at 10 g/kg of milk or cow in addition to basal ration, whereas treatment 2 (T-2) received a combination of BPF at 10 g/kg of milk/cow and bypass choline (BPC) at 45 g/day/cow in addition to basal ration for 168 days from the 7th to 175th days post-partum. During the early phase of lactation, body weight loss of the cows was minimum in the T-1 (-36.67 kg, 10.39%) group, whereas in the mid-phase, the regain in body weight was maximum in the T-2 group (+56.00 kg, 18.10%) as compared to the other two groups. The dry matter intake (DMI, kg/d) in the T-1 (9.10±0.07) and T-2 (9.01±0.04) groups was found to be significantly ($P<0.05$) higher than that in the control (8.83±0.05) group. Significantly ($P<0.05$) higher DMI was observed in T-1 and T-2 during the mid-phase of lactation from the 15th to 25th weeks of lactation. The additional energy intake from bypass fat and choline supplementation contributed towards the reduction of body weight loss in lactating Gir cows, whereas the intake of feed was positively influenced by the addition of bypass fat and bypass choline.

**KEYWORDS:** Bypass Choline, Bypass fat, Day matter intake, Early lactation, Mid-lactation

Article received: 31 May 2023; Article accepted: 30 October 2023

## INTRODUCTION

Gir cattle, an indigenous breed, make up 4.8% of the total indigenous cattle population and Gujarat is home to 25.6% of Gir cows (Anonymous, 2022). During the early and middle stages of lactation, the energy needed for maintaining body tissues and producing milk frequently surpasses the energy obtained from the diet, compelling the utilization of body fat reserves to meet these energy demands (Garg et al., 2012). Increased milk production results in elevated metabolic activity and stress. Nutrient deficiencies during lactation can impact metabolism (Reist, 2002). The high energy demand during the early lactation may not be met due to limited feed intake, impacting the cow's production capacity throughout lactation.(Sirohi et al., 2010). During the course of lactation, it is important to provide dairy cows with slightly above or optimal energy intake to support body reserve build up and maximise milk production (Mishra et al., 2016; Gowda et al., 2013). Supplementing the diet with fat is a viable approach to enhancing the energy density. Fat in the diet increases energy content, as fat contains 2.25 times more energy than carbohydrates. Choline is essential for liver metabolism of fatty acids and the synthesis of very low density lipoproteins, facilitating fat export from the liver (Acharya et al., 2019[b]).

The term bypass refers to feed sources that resist bio-hydrogenation by ruminal microbes. Adding unprotected fat is not recommended as it disrupts rumen fermentation, specifically by impeding fibre digestion. This can lead to reduced dry matter intake

and subsequently, lower milk production (Shankhpal et al., 2016). Feed and fodder do contain certain amounts of free choline and phosphatidylcholine; their levels in plants are limited and they undergo significant degradation in the rumen (Sharma and Erdman, 1989). Consequently, the intestinal supply of these compounds falls short of meeting the tissue requirements.

Choline is a biologically active micronutrient that acts as a precursor for a variety of molecules (Swartz et al., 2022). Choline is an essential nutrient that is required for all cells to function normally. Choline plays a vital role in maintaining cell structures, fat metabolism in the liver and the formation of acetylcholine (Pour et al., 2014). Choline is extensively degraded in the rumen; for this reason, dietary choline contributes insignificantly (Pinotti et al., 2005). Because rumen microbes rapidly degrade unprotected dietary choline extensively, the use of rumen-protected version of choline supplements containing choline chloride is required, allowing choline release and absorption in the small intestine (Elek et al., 2008; Garg et al., 2012). The rumen's microbial populations quickly break down dietary choline, emphasising the need to supply bypass choline to dairy cows as the most effective method (Atkins et al., 1988).

Therefore, the present study aimed to investigate the impact of providing bypass fat alone and along with bypass choline from the 2nd to 25th week of lactation on the body weight and dry matter intake in lactating Gir cows.

## MATERIALS AND METHODS

### Experimental animals

The research protocol was approved by the Animal Ethics Committee, vide protocol no. JAU-JVC-IAEC-LA-72-20, including the number of animals and various procedures involved. Eighteen lactating Gir cows based on their body weight (351.8±12.6 kg), parity (1.72±0.21) and milk yield of previous lactation (1633.6±190.6 L) were selected and divided into three groups (control, T-1 and T-2) consisting of 6 animals in each group. The cows in the control group were fed only a basal diet of 10 kg of seasonal green, 250 g of ground maize grain and dry fodder ad lib. Pelleted compound concentrate cattle feed and cotton seed cake were offered to meet the nutrient requirements of the cows as per the ICAR (2013) feeding standard. After the colostrum phase, which typically occurs during the first week after parturition, the period from the 2nd week of lactation to the 9th week is categorized as the "early phase of lactation." Following this, the period from the 10th week to the 25th week is referred to as the "mid lactation phase." The proximate composition of feeds and fodders offered to experimental cows is given in Table 1.

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

| Nutrients | Compound cattle feed | Cotton seed cake | Maize bhardo | Sorghum green | Dry mixed mature pasture grass |
|---|---|---|---|---|---|
| DM | 91.1 | 91.9 | 90.2 | 23.4 | 93.1 |
| OM | 86.7 | 92.8 | 97.1 | 90.1 | 92.6 |
| CP | 21.1 | 20.2 | 10.4 | 5.7 | 3.3 |
| EE | 3.71 | 8.15 | 3.21 | 3.0 | 1.2 |
| CF | 10.6 | 31.3 | 2.67 | 32.6 | 38.9 |
| NFE | 51.9 | 29.9 | 81.2 | 50.9 | 46.9 |
| Total Ash | 12.7 | 6.8 | 2.6 | 7.9 | 8.5 |

**Treatment**

The cows in the T-1 group were fed a basal diet supplemented with bypass fat at 10 g/kg of milk yield per day per cow, whereas in the T-2 group, bypass fat was at 10 g/kg of milk yield per cow, along with bypass choline at 45 g/day per cow with a basal diet. The rumen protected fat and rumen protected choline were purchased from Kemin Industries South Asia Pvt. Ltd., Chennai, India. Rumen protected fat (EnerFAT™) is a bypass fat that consist of saturated and unsaturated long chain fatty acids. EnerFAT™ contained added flavor and sweetener to enhance taste and increase feed intake. Rumen protected choline (CholiPEARL®) was an encapsulated source of rumen bypass and intestinally released choline for ruminant diets. It contained vegetable oil, choline chloride, silicon dioxide and water. Bypass fat and bypass choline were mixed with ground maize grain and fed once a day in the evening. The study was conducted for a period of 24 weeks (2nd to 25th weeks of lactation) after an adaptation period of 21 days (-15 to +7 days peri-partum). To determine the daily dry matter intake, the quantity of feed provided and the amount of leftover feed were recorded on a daily basis throughout the duration of the experiment. The body weight (kg) of each individual experimental cow was recorded at every 2-week interval in the morning before watering and feeding using an electronic platform balance for large animals.

**Statistical analysis**

The experimental data were analyzed using one-way ANOVA, as described by Snedecor and Cochran (1994). Pair-wise mean differences between groups were compared by the Duncan multiple range test for significance at $P<0.05$.

## RESULTS AND DISCUSSION

**Change in body weight**

The average 2-weekly body weight (kg) of lactating Gir cows in different treatment groups is given in Table 2. In each group, the cows exhibited weight loss as they advanced through the early phase of lactation. While there were differences in the amount of weight loss between the groups, these differences were statistically non-significant. It is important to note that the cows under control, T-1 and T-2 groups saw body weight losses of 41.34, 36.67 and 54.50 kg, respectively, with T-1 reflecting the lowest loss of 10.39%, followed by control (11.77%) and T-2 (15.51%). In the early phase of lactation, all of the experimental cows decreased body weight, which may be a result of the physiological process of lactation. The weight loss of lactating cows was caused by the mobilization of body reserves to support lactation.

During the initial week of mid-lactation, the body weights of Gir cows exhibited a continuous decrease. However, by the end of the experiment, the body weights in the control, T-1, and T-2 groups showed varying degrees of increase. During the mid-phase of lactation, the control, T-1, and T-2 groups exhibited body weight gains of 15.81%, 16.65%, and 18.90%, respectively. The T-2 group showed the highest weight gain, followed by T-1 and the control group. These findings indicate that supplementing with bypass fat and bypass choline, which provide additional energy, helped prevent abrupt and severe body weight losses among the experimental cows. The supplementation of the basal diet with bypass fat alone or in combination with choline did not have a significant impact on the body weight of lactating cows as compared to the control group. However, the control group experienced a higher body weight loss (3.70%) during the experiment, while the T-1 and T-2 groups showed better weight regain (2.55% and 0.28%, respectively). This indicated that the additional energy intake from bypass fat and choline supplementation contributed towards reduction of body weight loss in lactating Gir cows.

Table 2. Mean ± SE for body weight (kg) of experimental lactating Gir Cows during early and mid-phases of lactation

| Weeks of lactation | | Body weight (kg) | | |
|---|---|---|---|---|
| | | Control (n=6) | T-1 (n=6) | T-2 (n=6) |
| Early phase of lactation | 1 | 351 ± 8.57 | 353 ± 19.66 | 351 ± 16.56 |
| (2-9 weeks) | 3 | 337 ± 7.44 | 340 ± 19.26 | 330 ± 17.47 |
| | 5 | 324 ± 6.81 | 334 ± 14.83 | 319 ± 18.81 |
| | 7 | 316 ± 6.65 | 331 ± 17.21 | 306 ± 18.78 |
| | 9 | 309 ± 7.95 | 316 ± 12.53 | 296 ± 17.60 |
| | Overall | 327 ± 6.99 | 335 ± 16.38 | 320 ± 17.73 |
| Mid-phase of lactation | 11 | 292 ± 7.20 | 310 ± 17.94 | 296 ± 17.03 |
| (10-25 weeks) | 13 | 298 ± 7.50 | 316 ± 15.12 | 306 ± 13.04 |
| | 15 | 305 ± 8.38 | 326 ± 15.38 | 316 ± 13.19 |
| | 17 | 312 ± 8.01 | 334 ± 14.48 | 324 ± 13.74 |
| | 19 | 321 ± 8.23 | 340 ± 13.33 | 333 ± 13.49 |
| | 21 | 325 ± 7.32 | 345 ± 13.83 | 339 ± 12.29 |
| | 23 | 328 ± 8.63 | 355 ± 12.16 | 345 ± 12.64 |
| | 25 | 338 ± 7.73 | 362 ± 12.27 | 352 ± 12.38 |
| | Overall | 315 ± 7.59 | 336 ± 14.09 | 326 ± 13.41 |
| $2^{nd}$ to $25^{th}$ week | Total | 320 ± 6.93 | 335 ± 14.85 | 324 ± 14.96 |

T-1 Bypass fat: T-2 Bypass fat along with bypass choline

During the early phase of lactation, cows commonly experience weight loss due to lipid mobilization from adipose tissue to compensate for the negative energy balance (Contreras et al., 2020). At the end of the experiment, there were no significant differences ($P > 0.05$) in the mean body weight (kg) between the control group and both treatment groups. Throughout the experiment, all groups showed similar weight loss during the early phase of lactation and comparable weight gain during the middle phase. The findings indicated a slightly higher weight gain in both treatment groups by the end of the experiment. These results are in consonance with the findings of previous studies by Sirohi et al. (2010), Wadhwa et al. (2012), Singh et al. (2014), Mobeen et al. (2017), Ranaweera et al. (2020) and Roskopf et al. (2023), which also reported non-significant changes in body weight in the bypass fat supplemented group. Likewise, no significant weight gain in the bypass choline supplemented group was found by other researchers (Amrutkar et al., 2015; Pineda and Cardoso, 2015; Leiva et al., 2015; Acharya et al., 2019[a]; Bakr and Mohamed, 2020; Bollatti et al., 2020)."

The current findings partially accord with the study conducted by Chavda et al. (2023), which reported a significantly higher body weight gain in the bypass fat supplemented group. However, when combined with choline, no significant change in body weight was observed during early lactation. Therefore, the results of the present experiment suggested that cows fed diets supplemented with bypass fat alone or in combination with choline mobilized body reserves, resulting in minimal weight loss during the early phase of lactation and a steady increase in body weight during the mid-phase of lactation.

**Change in dry matter intake**

Average dry matter intake (DMI) of Gir cows in the early phase of lactationwas 8.32 ± 0.05, 8.42 ± 0.07 and 8.37 ± 0.05 kg/day (Figure 1) in the control, T-1 and T-2 groups, which was numerically higher by 1.20% in T-1 and 0.60% in T-2 than that of the control group. The DMI was not affected by the supplementation of bypass fat alone or in combination during the early phase of lactation. During the mid-phase of lactation, average DMI (kg/d) was significantly ($P<0.05$) higher in T-1 (9.44±0.08) by 3.06% and 2.75% in T-2 (9.33±0.05) group in comparison to the control (9.08 ± 0.06) group. DMI in both supplemented groups was significantly higher from the 8th fortnight (15th week) until the end of the experiment. The experimental cows from the T-1 and T-2 groups consumed, on average, 270 g and 180 g more DMI, respectively, than the control group of cows during the experimental period. The average daily DMI was significantly ($P<0.05$) higher by 3.96% and 2.04% in the T-1 and T-2 groups, respectively.

The present study's findings align with those of Tyagi et al. (2009) who observed increased DMI in the group supplemented with bypass fat at 2.5% of total DMI from 40 days pre-partum to 90 days postpartum ($P<0.05$). Similarly, Ardalan et al. (2010) reported the significant impact of 60 g/day of RPC supplementation 14 weeks post-partum on average DMI ($P<0.05$). Singh et al. (2014) reported a higher DMI in cows supplemented with 75 g/day/animal of bypass fat during mid-lactation ($P<0.05$). Additionally, Chavda et al. (2022) found higher DMI in Gir cows supplemented with RPC at 45 g/day and RPF at 80 g/day during a specific period ($P<0.01$). These findings suggested that the palatability and intake of feed were positively influenced by the addition of bypass fat and bypass choline.

Contrary to the present study, Acharya et al. (2019) reported no significant difference in dry matter intake between cows supplemented with RPC and the control group. Sihag et al. (2020) observed reduced DMI in crossbred cows supplemented with bypass fat. Lunagariya et al. (2022) found a significant decrease in dry matter intake with RPC supplementation. Similar findings were observed in other studies (Sirohi et al., 2010; Mudgal et al., 2012; Patel et al., 2013; Pineda and Cardoso, 2015; Shankhpal et al., 2016; Kumari et al., 2018; Ranaweera et al., 2020; Butt et al., 2020), suggesting that supplementation with bypass fat and choline can lead to lower dry matter intake, possibly due to an undesirable smell affecting feed palatability during the early stages of the experiment.

## CONCLUSION

During the early phase of lactation, cows fed only bypass fat experience minimal body weight loss, while in the mid-phase, cows supplemented with both bypass fat and bypass choline show the highest body weight regain. Supplementing lactating cows with bypass fat alone and bypass fat along with bypass choline resulted in increase in total DMI during the early and mid-lactation phase.

## ANIMAL WELFARE STATEMENT

## ACKNOWLEDGEMENT

The authors express their gratitude to the Principal, College of Veterinary Science & Animal Husbandry, Kamdhenu University (KU), Junagadh, and the Research Scientist, Cattle Breeding Farm, KU, Junagadh for their support and provision of facilities during the study.

## REFERENCE

Acharya, P., Lathwal, S.S., Moharana, B., Patnaik, N.M. and Thul, M., 2019[a]. Analysing the effect of supplementing rumen protected choline with green tea extract in transition Karan Fries cows. International Journal of Current Microbiology and Applied Sciences. 8. 2432-2440.

Acharya, P., Lathwal, S.S., Patnaik, N.M. and Moharana, B., 2019[b]. Rumen protected choline along with green tea extract maintain glucose homeostasis in transition Karan Fries cows. Indian Journal of Animal Nutrition. 36:276-280.

Amrutkar, S.A., Pawar, S.P., Thakur, S.S., Kewalramani, N.J. and Mahesh, M.S. 2015. Dietary supplementation of rumen-protected methionine, lysine and choline improves lactation performance and blood metabolic profile of Karan-Fries cows. Agricultural Research. 4:396-404.

Anonymous. 2022. Breed-wise report of livestock and poultry based on 20th livestock census. Department of animal husbandry, dairying and fisheries, Ministry of Fisheries, Animal husbandry and Dairying, Government of India. KrishiBhavan, New Delhi.

Ardalan, M., Rezayazdi, K. and Dehghan-Banadaky, M., 2009. Investigation on the effect of supplementing rumen-protected forms of methionine and choline on health situation and reproductive performance of Holstein dairy cows. Pakistan Journal of Biological Sciences. 12 (1): 69-73.

Atkins, K.B., Erdman, R.A. and Vandersall, J.H., 1988. Dietary choline effects on milk yield and duodenal choline flow in dairy cattle. Journal of Dairy Science. 71(1):109-116.

Bakr, M. and Mohamed, S.H., 2020. Effect of rumen-protected choline supplementation on productive performance of lactating dairy cows. Egyptian Journal of Animal Production. 57.113-120.

Bollatti, J.M., Zenobi, M.G., Artusso, N.A., Alfaro, G.F., Lopez, A.M., Barton, B.A., Nelson, C.D., Staples, C.R. and Santos, J.E.P., 2020. Timing of initiation and duration of feeding rumen-protected choline affects performance of lactating Holstein cows. Journal of dairy science. 103(5):4174-4191.

Butt, J.H., Konwar, D., Brahma, B., Khan, A. and Sharma, R., 2020. Effect of bypass fat supplementation on performances in crossbred cattle during winter season. Indian Journal of Animal Health. 59 (1): 78–84.

Chavda, M.R., Savsani, H.H., Chavda, J.A., Karangiya, V.K., Vaghamsi, D.G., Kansagara, B.K. and Makwana, K.R., 2021. Effect of feeding rumen protected choline and rumen protected fat on dry matter intake and nutrient digestibility in periparturient Gir cows. Indian Journal of Animal Nutrition. 38(4):366-373.

Chavda, M.R., Savsani, H.H., Gamit, V.V., Gadariya, M.R., Sabapara, G.P., Garg, D.D., Karangiya, V.K., Kansagara, Y.G. and Makwana, R.B., 2023. Effect of supplementing rumen protected choline and fat during transition period on body parameters of periparturient Gir cows. Indian Journal of Animal Nutrition. 40(1): 9-15.

Contreras, G.A. and Sordillo, L.M., 2011. Lipid mobilization and inflammatory responses during the transition period of dairy cows. Comparative Immunology, Microbiology and Infectious Diseases. 34(3): 281-289.

Elek, P., Newbold, J.R., Gaal, T., Wagner, L. and Husveth, F., 2008. Effects of rumen-protected choline supplementation on milk production and choline supply of periparturient dairy cows. Animal. 2(11), pp.1595-1601.

Garg, M.R., Bhanderi, B.M. and Sherasia, P.L., 2012. Effect of supplementing bypass fat with rat with rumen protected choline chloride on milk yield, milk composition and metabolic profile in crossbred cows. Indian Journal of Dairy Science. 65(4).

Gowda, N.K.S., Manegar, A., Raghavendra, A., Verma, S., Maya,G., Pal, D.T., Suresh, K.P. and Sampath, K.T. 2013. Effect of protected fat supplementation to high yielding dairy cows in field condition. Animal Nutrition and Feed Technology. 13 : 125-130.

ICAR. 2013. Nutrients Requirements of Cattle and Buffalo. 3rd Edn. Indian Council of Agricultural Research, New Delhi

Kumari, S., Kumar, D., Mandal, S.K. and Sahu, R., 2018. Effect of feeding bypass fat on milk yield, composition, efficiency of nutrients and economics in cross bred cow: A field trial. International Journal of Current Microbiology and Applied Sciences. 7: 3095-3102.

Leiva, T., Cooke, R.F., Brandao, A.P., Marques, R.S. and Vasconcelos, J.L.M., 2015. Effects of rumen-protected choline supplementation on metabolic and performance responses of transition dairy cows. Journal of animal science. 93(4): 1896-1904.

Lunagariya, P. M., Shah, S. V., Patel, Y. G. and Patel, J. H., 2022. Lactation performance of dairy cows on feeding rumen protected choline. Research Square Platform LLC. 1-15.

Mobeen, A., Riaz, M. and Yaqoob, M.U., 2017. Effect of by-pass fat supplementation on the performance of Sahiwal dairy cows. International Journal of Agriculture & Biology. 19(3): 423-426.

Mudgal, V., Baghel, R.P.S., Ganie, A. and Srivastava, S., 2012. Effect of feeding bypass fat on intake and production performance of lactating crossbred cows. Indian Journal of Animal Research. 46(1): 103-104.

Patel, A.P., Bhagwat, S.R., Prajapati, K.B., Sheikh, A.S., Ashwar, B.K., Pawar, M.M., Chauhan, H.D., Makwana, R.B., Ingle, P.B., Suresh, P. and Gaja, P.V., 2013. Influence of supplementation of bypass fat on nutrients intake and milk yield and its composition in crossbred lactating cows. Journal of Animal Feed Science and Technology. 1(2): 69-77.

Pineda, A. and Cardoso, F.C., 2015. Effects of rumen-protected choline with calcium salts of long chain fatty acids on milk yield and milk composition of middle and late lactation Holstein cows. Livestock Science. 175: 47-58.

Pinotti, L., Campagnoli, A., Dell'Orto, V. and Baldi, A., 2005. Choline: Is there a need in the lactating dairy cow? Livestock Production Science, 98(1-2), pp.149-152.

Pour, H.A., Hamedani, M.A., Nasab, M.E., Babazadeh, M.H. and Davoudi, S.M., 2014. Effect of choline on performance quality of non-ruminant. Entomology and Applied Science Letters. 1, pp.14-18.

Ranaweera, K.K.T.N., Mahipala, M.K. and Weerasinghe, W.M.P.B., 2020. Influence of rumen bypass fat supplementation during early lactation in tropical crossbred dairy cattle. Tropical animal health and production. 52: 1403-1411.

Reist, M., Erdin, D., Von Euw, D., Tschuemperlin, K., Leuenberger, H., Chilliard, Y., Hammon, H.M., Morel, C., Philipona, C., Zbinden, Y. and Kuenzi, N., 2002. Estimation of energy balance at the individual and herd level using blood and milk traits in high-yielding dairy cows. Journal of dairy science. 85(12), 3314-3327.

Roskopf, P.M., Tieri, M.P., Cuatrin, A., Cucchi, M.E.C., Gere, J.I. and Salado, E.E., 2023. Performance of dairy cows supplemented with by-pass Fat under Heat Stress conditions. Open Journal of Animal Sciences. 13(1): 82-97.

Shankhpal, S., Gupta, R.S., Parnerkar, S. and Dhami, A.J., 2016. Effect of feeding bypass fat and unprotected oil on feed intake, digestibility and production performance in lactating crossbred cows. Indian Journal of Animal Nutrition. 33(3): 266-272.

Sharma, B.K. and Erdman, R.A., 1989. Effects of dietary and abomasally infused choline on milk production responses of lactating dairy cows. The Journal of nutrition. 119(2): 248-254.

Sihag, S., Sihag, Z.S., Kumar, S., Dhaka, S.S. and Patil, C.S., 2020. Effect of bypass fat supplementation on productive and reproductive performance of crossbred cows. Indian Journal of Animal Nutrition. 37(3): 213-217.

Singh, M., J.P. Sehgal, A.K. Roy, S. Pandita, and G. Rajesh. 2014. Effect of prill fat supplementation on hormones, milk production, and energy metabolites during

mid-lactation in crossbred cows. Veterinary World. 7(6):384-388.

Sirohi, S.K., Walli, T.K. and Mohanta, R.K., 2010. Supplementation effect of bypass fat on production performance of lactating crossbred cows. Indian Journal of Animal Sciences. 80(8): 733-736.

Snedecor, G.W. and W.G. Cochran. 1994. Statistical Methods, 8th Edn. Oxford and IBH Publishing Co. Calcutta, India.

Swartz, T.H., Bradford, B.J., Malysheva, O., Caudill, M.A.,Mamedova, L.K. and Estes, K.A. 2022. Effects of dietary rumen-protected choline supplementation on colostrum yields, quality, and choline metabolites from dairy cattle. JDS communications. 3(4), pp.296-300.

Tyagi, N., Thakur, S.S. and Shelke, S.K. 2009. Effect of feeding bypass fat supplement on milk yield, its composition and nutrient utilization in crossbred cows. Indian Journal of Animal Nutrition. 26(1): 1-8.

Wadhwa, M., Grewal, R.S., Bakshi, M.P.S. and Brar, P.S. 2012. Effect of supplementing bypass fat on the performance of high yielding crossbred cows. Indian Journal of Animal Sciences. 82(2): 200-203.