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Bypass fat as a feed supplement in ruminants: A review

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Abstract
Supplements are the integral part of ruminant ration in the present era. Farmers used to supplement their animals as per specific requirements. Bypasss fat is such a supplement which has been used extensively in dairy animals as a source of high energy density. Bypass fat has been found to be very crucial in the diets of high producing animals. The requirement of high producing animals if 4-6% of fat in ration, which should be met through natural feed, oil seed and bypass fat in equal proportions. Supplementation of bypass fat leads to improvement in milk production, milk composition, body parameters and reproductive efficiency of dairy animals. Bypass fat supplementation is proved to be beneficial for farmers in terms of economics as it is found of increasing net income. Use of bypass fat is age old practice but it is still researched and improved by the workers to make it more profitable and accessible to farmers.

Keywords: Bypass, dairy, fat, production, supplement

Introduction
Supplementation is a technique which involves addition of small quantities of feed additives into animal ration and supposed to produce positive impact on desirable attribute. Several factors needs to be taken into account before deciding the supplementation like purpose, duration, economics and desired output from supplementation. The primary purpose of using bypass fat in animal feed is to supply energy. Fat has emerged as a valuable high-energy substitute for cereal grains and a modifier of metabolism [1]. Bypass fat is not degraded in the rumen of animal and gets digested in the lower alimentary tract (small intestine) of the animal. It does not affect the digestion in rumen [2]. Fatty acids present in the bypass fats are available for post-ruminal absorption. Individual fatty acids are being utilized for specific metabolic function inside the animal body.

Bypass fat containing different levels of fat are commercially available in the market and are in use among farmers. Bypass fat can be both natural and chemically prepared. Natural bypass fat includes whole oil seeds without processing [3] whereas chemically prepared includes calcium salts of long chain fatty acids (Ca-LCFA), crystalline or prilled fatty acids, formaldehyde treated protein encapsulated fatty acids and fatty acyl amides. Ever since their first development in the 1980s, number of commercial fat products based on Ca salts or prilled SFA is present in the dairy industry. Studies have been conducted on many commercial products of the bypass fat by various workers [4, 5, 6] Bypass fat supplementation to dairy feed has a positive effect on performance of dairy animals through a combination of nan-calorific and calorific effects. Calorific effects include increased energy content which ultimately leads to higher milk production and persistency of lactation. The non-calorific effects attributes to enhanced reproduction status and improved fatty acid profile of milk [7, 8].

As per NRC, the ration of dairy animal may contain about 3% fat and the total dietary fat in ration should not exceed 6-7% of the total DM. Theoretically, the nutrient utilization efficiency is maximal for milk production, when the amount of supplemented dietary fat provides 15-20% of the dietary metabolizable energy or 7-8% of the dietary fat on dry matter basis [9]. Milk production of the animals increased when bypass fat is added at the rate of 3-5% of total ration DM [10] but negative effect has also been reported on addition of more than 6% fat on DM basis [11]. Although bypass fat can be introduced in higher amount in the feed of dairy animals [12]; however, its supplementation beyond 9% of the dietary DM is not beneficial in lactating dairy cows [13]. Palmquist [14] recommended that the first 3% fat of the DM intake of the animal should be provided by oilseed sources and remaining 3% should be fed as bypass fat. Sharma [15] suggested that the ration of high yielders should contain 4-6% fat and this should come from natural feed, oil seed and bypass fat in equal proportions.

Several studies conducted on bypass fat supplementation recommended daily dose of 200-300g by pass fat in ration of crossbred cows [5, 6, 16, 17]. The researchers conducted at NDRI recommended supplementation of bypass fat @ 2.5% in lactating crossbred cattle [4] and 4 % in buffaloes on DM basis [18](Thakur and Shelke, 2010). However, Gowda [19] supplemented bypass fat @ 10g and Parnerkar [20] @ 20g per kg milk production in lactating cows and buffaloes, respectively. All of them reported significant increase in milk production and positive response in other health parameters.

Ranaweera [21] conducted a feeding trial on crossbred cows and supplemented them with rumen bypass fat @200 g/cow/day containing calcium salts of long-chain fatty acids. They found that body weight and dry matter intake of cows were not affected by supplementation of rumen bypass fat, whereas, significant increase in milk yield throughout the lactation is recorded in the supplemented group (1142 vs. 1010 l/cow). They also recorded that milk fat, solid non-fat (SNF), protein, and milk urea nitrogen (MUN) contents were not influenced by bypass fat supplementation. After assessing benefit cost ratio of bypass fat supplementation, they stated that there is a direct financial benefit of bypass fat supplementation.

Petit [22] analysed the effects of feeding n-3 fatty acids from formaldehyde-treated linseed or duodenal infusions of linseed oil in lactating cattle and observed that increased supply of n-3 fatty acid had beneficial effects on reproductive status, including larger CL as well as effects on prostaglandins that favoured higher pregnancy rates. Mosley [23] fed 87% palmitic acid product to Holstein Frisian cattle at 0, 500, 1,000, and 1,500 g/d and reported significant increase in DMI, milk yield, fat and protein yield by supplementing 500 g/d without further increases at higher levels of supplementation.

Effect of bypass fat supplementation on body weight

Kumar and Thakur [24] found that bypass fat supplementing @ 2.5% of DMI improves the feed conversion ratio and average daily gain in female buffalo calves. However, Lounglawan [25] reveal that bypass fat supplementation did not affects milk yield, milk composition, fatty acid composition of milk and body weight change in lactating dairy cow. Reports from Solorzano and Kertz [26] suggest that body weight loss can be minimized with a rapid body weight gain while milk production in dairy animals is maintained by feeding of fats during the postpartum stage. Body weight loss in buffaloes that were fed with calcium salt of palm oil fatty acids was significantly ($P<0.05$) lower (11.72±2.47 kg) as compared to control animals (38.30±2.91kg) [27]. Better recovery in body weight (-2.08 kg vs +14.13, kg) in crossbred cows during early lactation was reported by Naik *et al*. [16] by supplementing bypass fat. Improvement in the BW of the animals in the bypass fat supplemented group was also observed by Wadhwa [17] as compared to the non-supplemented group (551 vs 508, kg), but the differences were non-significant.

Tyagi [4] studied the effect of supplemental Ca-LCFA on BW of dairy cows and they reported better recovery of body weight losses in Ca-LCFA supplemented cows in early lactation. Difference in the BW changes did not differ among the Ca-LCFA supplemented dairy cows that suggest additional energy intake by cows fed with fat supplemented diets that may have contributed in preventing BW loss during early stage of lactation [28]. Singh [29] concluded that metabolic weight increased significantly ($P<0.05$) in prilled fat supplemented cows after 90 days of experiment as compared to control cows. Some researchers reported that supplementation of calcium salt of fatty acid had no significant effect on body weight of crossbred dairy cows [21, 30]. Katiyar [31] supplemented Murrah buffaloes with 15g rumen protected fat (Ca salt of long-chain fatty acids) per kg milk yield and found no effect on body weight of buffaloes.

Effect of fat supplementation on body condition score (BCS)

Improvement of BCS was observed by Garg and Mehta [32] due to bypass fat feeding, indicating that initial reduction in weight loss helped substantially in gaining after 90 days of feeding. Better recovery in BCS (-0.06 vs +0.02) in crossbred cows during early lactation in bypass fat supplemented group was reported by Naik [16]. Sharma [33] suggest that additional dietary fat could result in better energy partitioning and improved energy balance in dairy animals. In another study decline in BCS ($P<0.01$) was more in control cows than the prilled fat supplemented cows [29], whereas, Harrison [34] and Ganjkhanlou [28] did not find any influence on body condition scores of cows during early lactation.

Effect of fat supplementation on dry matter intake

Most of the researches revealed that the DM intake of dairy animals was not altered due to supplementation of bypass fat [5, 6, 16, 18] whereas Chouinard [35] recorded decrease in DM intake (23.5 vs 21.5, kg/ d), however, Tyagi [4] reported increase (3.16 vs 3.41; kg/100 kg BW/d) in DM intake in dairy animals fed bypass fat. Allen [36] in 11 out of 24 studies reported that calcium salts of palm fatty acids caused a linear decrease in DMI; where 22 out of the 24 studies report a numerical decrease in DMI. Decreases in DM intake in response to CaFA supplementation was associated with increase in cholecystokinin and glucagonlike peptide-1 [37]. Savsani [38] studied positive effect of supplementation of 10 g of bypass fat per litre milk production in lactating Jaffrabadi buffaloes and recorded lower DMI per kg of milk production. Prior to calving Shelke [39] observed that feed intake along with DMI/100 kg body weight was 1.63±0.02 kg in control and 1.60±0.02 kg in treatment group which was slightly lower in both the groups indicating that there was no adverse effect of rumen protected fat and protein supplementation on DMI of buffaloes. Likewise, Tyagi [7] reported statistically similar DM intake 13.84±0.47kg/d in control and 14.18±0.40 kg/d in treatment during post parturient period (210 days).

Effect of fat supplementation on milk yield

Effect of feeding calcium salts of palm oil fatty acids on performance of lactating crossbred cows is studied by various workers and significant increase has been reported in milk yield. Abd-El Moty [40] supplemented buffaloes with 10 and 15 % extra metabolizable energy requirements through the calcium salts of palm fatty acids and found an increase in FCM yield as 25.78 and 52.75% and the milk fat yield was also increased by 28.1and 58.6% for supplemented buffaloes. Petit [22] fed 4.6% calcium salts of palm oil to lactating cows and found that milk yield, FCM and milk fat yield increased by 27.0, 25.1 and 23.5%, respectively in comparison to the control diet.

Purushothaman [30] conducted an experiment on twenty lactating crossbred cows yielding 10 to 15 litres of milk daily during mid-lactation. They divided animals into four groups of five animals each and fed concentrate mixture containing 0 (no bypass fat), 2, 4 and 6% bypass fat. They got the best results in milk production at 2% supplementation of bypass fat. They also analysed the fatty acid profile of milk and reported improved milk quality in terms of polyunsaturated fatty acids without affecting the digestibility of nutrients at 4-6% bypass fat supplementation. Effect of supplementing bypass fat on milk yield is affected by breed, parity, stage of lactation, level of supplementation and type of protected fat (prill fat or Ca-LCFA) and fatty acid composition. Schroeder [41] found that cows in mid-lactation had a greater milk yield response to supplementation of fats than cows in early lactation. Increase in the milk yield by supplementation of fat by different workers can range from 5.5% to 21.7% [4, 5, 16, 17, 18, 19, 20].

In most of the studies increase in milk yield is shown but in few studies no effect on milk yield was observed when lactating animals were supplemented with Ca salts of CLA [42]. Davison [43] suggested that until cows are in a positive energy balance the maximum response to milk production through fat supplementation is not be achieved. Ranjan [44] supplemented lactating Murrah buffaloes with bypass fat at 1.4% of DMI (200 g day–1) and reported increase in the total milk production and feed efficiency of buffaloes. Rajesh [8] showed an increment of 6.02% in milk yield of crossbred cows during early lactation when fed 75g protected fat per day per animal. Weiss and Pinos-Rodríguez [45] postulated that supplementation of bypass fat converts gross energy and digestible energy to net energy for lactation more effectively and hence the milk yield increases. Lohrenz [46] found increase in milk production among bypass fat supplemented dairy cows despite unchanged DMI and proposed that the effect could be due to sparing of glucose.

Effect of fat supplementation on milk composition

Metabolic status of dairy animals markedly influences the milk production and its composition [47]. Milk fat is the most sensitive component of milk to any dietary changes. Bypass fat supplementation of lactating animals lead to either increased [5, 18, 20] or decreased [35] or not altered [4, 16] milk fat percentage. Naik [16] stated that the addition of bypass fat in diet normally increases the total milk fat yield due to increase in the milk production. In another study conducted by Tyagi [4] reported that due to supplementation of bypass fat in the diet of dairy cows increase in the total USFA (32.01 vs 39.22), LCFA (75.61 vs 77.17) and MUFA (29.68 vs 33.53) and decrease in the total SFA (63.28 vs 54.02) as percentage of the total fatty acids of milk.

Reports by several researchers [4, 5, 16, 18] reveals that the SNF content of milk is not altered, whereas, Wadhwa [17] found it increased; however, Naik [16] stated that the total SNF yield was increased due to increase in milk production.

Though Milk protein is more affected by feed than lactose, but Jenkins and McGuire [48] consider it to be less affected than fat. Generally, supplementation of bypass fat (Ca-LCFA) has negative effect on the milk protein percentage [35], an overall effect of -0.12 percentage unit. No change in milk protein percentage was reported by many researchers [4, 5, 16, 18] whereas increase in protein percentage by Wadhwa [17]. However, Naik [16] considers the total milk protein yield was increased due to the increase in milk production. Nawaz [49] supplemented fat in Nilliravi buffaloes @ 10, 20 and 30 g per liter of milk and found no significant change in milk protein and ash content.

The lactose [4, 16, 18] and total solid [16] contents were least affected or not affected by the supplementation of bypass fat. McNamara [50] stated that lactose concentration of milk gives only little information about energetic balances, as the content of lactose in milk of healthy dairy animal remains almost constant.

Ramteke [51] conducted an experiment on twenty-four pregnant buffaloes. In supplemented group buffaloes were given by pass fat @ 100 g/d for 30 days prepartum and 15g/kg milk yield per day for 120 days postpartum. They found significant increase in the yield (kg/head/d) of whole milk, fat, SNF, 6% FCM, SCM, ECM and fat percent in bypass fat supplemented group whereas no significant difference in the DMI of animals was found.

Dietary supplementation of bypass fats and fatty-acids also influences the fatty acid profiling of milk. Generally feeding of Ca-LCFA in the ration of lactating cows lowers the proportions of short and medium chain saturated fatty acids (C6:0 to C16:0) of milk fat and it is due to decrease in *de novo* fatty acid synthesis in mammary gland and increase in proportions of LCFA (C18:1, C18:2, C18:3) due to increased uptake of preformed LCFA from blood [52]. Rico [53] supplemented ration with greater than 98% C18:0 at 2% of DM and reported that it does not reduced de novo synthesis of milk fatty acids, but very little of supplemental C18:0 was transferred to milk fat as compared to response to C16:0.

Effect of fat supplementation on blood metabolites

Fat supplementation is considered as a way of protecting glucose from oxidation to be used in synthesis of lactose [54]. Supplementing Holstein cows with rumen protected fat @50 g/kg DM by Hammon [55] showed greater milk and lactose yields associated with rise in concentrations of lipids and glucagon despite lower plasma glucose concentration, suggesting a glucose-sparing effect allowing an increased lactose synthesis. A study conducted by Juchem [56] explains that supplemental fat would made availability of precursors for gluconeogenesis, thereby increasing blood glucose concentration, or that glycolysis of sugar was inhibited by supplemental dietary fat in order to improve their energy levels. The enhanced effect of bypass fat supplementation on milk yield was explained by Lohrenz [46]. They stated that this could be due to the sparing of glucose for the production of lactose, the major osmoregulator of milk in mammary gland wherein concentration remains relatively constant. Though Petit [22] found a significant increase amounted in plasma glucose by 5.09% for cows fed 4.6% calcium salts of palm oil. However, Tyagi [4] observed no effect of blood glucose level in Ca-LCFA supplemented group of cows. The dietary provision of rumen protected fat helps an animal to maintain the serum glucose, triglyceriedes and some other minerals in optimum levels, but in animals those not supplemented with rumen protected fats, glucose levels are altered adversely [57]. Singh [29] shows significant difference ($P \leq 0.05$) in cows supplemented with prilled fat in NEFA levels. The value of NEFA in supplemented group was found to be 0.14±0.03mM/L whereas it was 0.20±0.03mM/L in control animals. Some studies depicted no difference in plasma concentrations of NEFA on supplementation of bypass fat to animals [39]. Gowda [19] reported that the mean serum total cholesterol levels after calving depicted a linear increasing path whereas, Wadhwa [17] found a non-significantly higher cholesterol level in animals of the BPF supplemented group and suggested that it may have favorable effect on the synthesis of reproductive hormones which in turn may affect the reproductive performance. Buffaloes fed with protected fat supplemented rations by Abd-El Moty [40] showed higher plasma concentrations of total lipids, cholesterol and triglycerides. Singh [29] reported non-significant difference with the mean plasma cholesterol concentration in control (169.37 ± 11.31mg/dl) and prill fat fed cows (176.94 ± 12.16mg/dl) during mid-lactation.

Effect of fat supplementation on hematological parameters and immunoglobulins

Suharti [58] conducted a study on Bali cattle to evaluate the effect of calcium soap-soybean oil on blood profile and found that the use of fat did not affect blood metabolites and blood haematology except white blood cells and leucocyte differentiation such as neutrophil, lymphocytes and monocyte. Similar results were found in another study in which supplementation of bypass fat had no effect on white blood cell count (WBC), red blood cell count (RBC), hemoglobin (Hb) and pack cell volume (PCV) in postpartum Jaffrabadi buffaloes [59]. Shelke and Thakur [60] reported increased total immunoglobulins concentration in plasma by supplementation of fat and the value ranges from 25.09 to 29.02 and 27.24 to 33.54 mg/ml in control and treatment group respectively.

Effect of fat supplementation on reproduction

Fatty acids and fats are found to exert a major impact on reproductive performance of dairy animals. It was reported that the type of lipids consumed by the animal has more influence on reproduction than for the total intake of lipids [61]. The possible reason for improved reproduction was given as improvement in energy balance of animal and the effects of fatty acids on hormones which play a vital role in reproduction [62]. Garg [63] conducted a study on cattle in which they fed bypass fat @ 100-150 g /day 10 days before and 90 days after calving. They reported improvement in milk production and reproduction efficiency. Similarly, Shelke [60] recommended that feeding of protected fat and protein during early lactation enhanced the reproductive performance of Murrah buffaloes along with increment in the milk yield and its persistency.

McNamara [50] fed animals with fat supplements containing linoleic acid and revealed that supplemented groups had a shorter calving interval and almost complete involution of uterus in less time. Khalil [64] included protected fat in the diet at levels of 3 and 5% and found that there was reduction in period of placental drop ($P<0.05$) by about 3.6 days and uterine involution ($p\geq0.05$) by 3.1 days as compared to the control diet. Garg and Mehta [32] reported that bypass fat feeding leads to reduction in average period for conception after calving from 118 days to 92 days in cows. Reduction in calving-first service interval was reported from 62.6 days to 61.2 days for cows supplemented with 400 g of CaFA without any difference in live weight or body condition of cows [65]. Gowda [19] revealed that the time required for appearance of first heat was reduced ($P<0.05$) by 18 days in animals fed with protected fat in comparison to the control group animals. They also reported significant ($P<0.05$) reduction in the number of artificial insemination (AI) per conception from 2.4 to 1.8 in the protected fat fed group. Tyagi [4] found significant reduction in the time required for commencement of cyclicity, service period and AI/conception with supplementation of 2.5% bypass fat (on DMI basis) for 40 days prepartum to 90 days postpartum in crossbred cows. In another study, it was demonstrated that bypass fat inclusion in the diet of crossbred cows leads to reduced number of artificial inseminations required per conception (1.4 vs 1.2) which indicates better reproductive performance of cows [16]. Rajesh [8] supplemented cows with prilled fat and found that the conception rate was improved (62.5 vs 46.6%) and no. of A.I per conception was less (1.75 vs 2.00) in prilled fat supplemented cows. Bader [66] demonstrated that supplementation of fat in grazing cows increase the pregnancy rate at first service by 16% in comparison to cows which did not receive fat in the diet. Other studies showed that the size of the dominant follicle was increased in cows fed diets rich in PUFAs [67, 68].

Effect of fat supplementation on economics

Farmers are typically paid on the basis of the fat content of the milk they are producing, hence increase in fat percent and yield will increase revenue of the dairy farmers. It is possible to increase the income of dairy farmers owing to more milk production and fat content by the supplementation of bypass fat [69]. Several researchers estimated the economics of feeding indigenously prepared bypass fat to dairy animals and reported an additional profit of 34.50 rupees per cow per day [16], 39.66 rupees per buffalo per day [20] and11.60 rupees per cow per day [19] excluding improvement in health and reproductive performance of the animals. Yadav [70] conducted a study on Karan fries cows and calculated the economics after feeding with prilled fat @ 75g per day for 45 days before calving and 150g for 70 days after calving. They found that feeding prilled fat results in generating an additional income of 94.46 rupees per cow per day. Ranaweera [21] calculated benefit cost ratio of bypass fat supplementation and demonstrated that there was a direct financial benefit of bypass fat supplementation until 12.7th week of lactation.

Conclusion

Supplementing bypass fat continues to be a practical means of sustaining energy intake in high-producing dairy animals. Bypass fat was proved to increase milk yield, milk quality, body parameters and reproductive efficiency of dairy animals without any negative impact on animal’s health. However, the economic success of using supplemental fat depends not only on proper selection of fat sources but also on quantity of fat to be fed and time of feeding. Use of bypass fat is age old practice but it is still researched and improved by the workers to make it more profitable and accessible to farmers.

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