



## Effect of Feeding Calcium Salts of Palm Oil Fatty Acids on Performance of Lactating Crossbred Cows

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**ABSTRACT :** Twenty lactating crossbred cows yielding 10 to 15 litres of milk daily during mid lactation were selected and divided into four groups of five animals to assess the effect of feeding calcium soaps of palm oil fatty acids (bypass fat) on milk yield, milk composition and nutrient utilization in lactating crossbred cows. The animals in groups 1 (control), 2, 3 and 4 were fed concentrate mixture containing 0 (no bypass fat), 2, 4 and 6% bypass fat, respectively. The average daily dry matter consumption in the various groups ranged from 13.1 to 13.6 kg and showed no significant difference among treatment groups. There was no significant difference among different groups in digestibility of DM, OM, CP and CF, however, ether extract digestibility in cows of groups 2 and 4 was significantly ( $p < 0.05$ ) higher than the control group. The average milk yields of the cows in group 3 (4% bypass fat) showed a significantly ( $p < 0.05$ ) higher value than cows of groups 1 and 2. Similarly, a significant ( $p < 0.05$ ) increase in fat yield, 4% FCM yield and SNF yield was observed for the cows in group 3 (4% bypass fat). The milk composition in terms of total solids, fat, lactose, protein, solids-not-fat and ash percentage showed a varying response and bypass fat feeding did not have any effect on milk composition of cows in different groups. The gross and net energetic efficiency of milk production ranged from 23.6 to 27.5% and 37.1 to 44.4%, respectively, and showed no significant difference among different treatment groups. The gross and net efficiency of nitrogen utilization for milk production ranged from 24.0 to 28.7% and 37.2 to 43.5%, respectively, and no significant difference was noted among different treatment groups. The supplementation with calcium salts of palm oil fatty acid reduced the proportion of caproic, caprylic and capric acids and significantly ( $p < 0.01$ ) increased the concentration of palmitic, oleic, stearic, linoleic and linolenic acids in milk fat with increase in level of bypass fat supplementation. It was concluded that incorporation of calcium salts of palm oil fatty acids at a 4% level in the concentrate mixture of lactating crossbred cows improved the milk production and milk quality in terms of polyunsaturated fatty acids without affecting the digestibility of nutrients. (**Key Words :** Bypass Fat, Calcium Soap, Crossbred Cows, Milk Composition, Milk Yield, Nutrient Utilization, Palm Oil Fatty Acids)

## INTRODUCTION

High yielding dairy cows during early lactation are often in negative balance because of insufficient feed intake to meet energy requirements. Under this condition animals have to draw upon their body reserves to support the milk production, often resulting in metabolic disorders and sub optimal milk yield (Kronfeld, 1982). Maximizing energy intake by increasing the energy density of the diet is a logical feeding strategy for early lactating cows. Excessive

grain feeding increases energy density of the diet but rapid fermentation can lead to a suboptimal rumen environment and acidosis (Radostits et al., 2000) and decline in the concentration of milk fat. Fat supplementation also increases energy density of the diet, but high dietary fat can lead to a reduction in fibre digestion in the rumen and a decline in milk fat percentage, depending on the amount and type of fat fed (Palmquist and Jenkins, 1980). In order to counter effect these undesirable effects, dietary supplementation of fat as a salt of long chain fatty acids is a good alternative (Chalupa et al., 1984). Saturated and unsaturated long chain fatty acids have less effect on rumen fermentation when supplemented as calcium salt than as free fatty acids (Chalupa et al., 1985). Moreover, prevention of biohydrogenation of polyunsaturated essential fatty acids

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**Table 1.** Ingredient and proximate composition of experimental feeds and fodder (% DM basis)

Nutrients	Concentrate mixture I (Control)	Concentrate mixture II (2% bypass fat)	Concentrate mixture III (4% bypass fat)	Concentrate mixture IV (6% bypass fat)	Green oats +oats hay	Bypass fat (calcium salts of palm oil fatty acids)
Ingredient composition (%)						
Dairy feed*	100	98	96	94		
Calcium salts of palm oil fatty acids	0	2	4	6		
Proximate composition (% DM basis)						
Dry matter	86.3	86.4	86.5	86.6	24.5	92.7
Crude protein	19.4	18.9	18.5	18.2	8.5	-
Ether extract	6.0	6.9	7.7	8.5	3.4	51.5
Crude fiber	7.7	7.6	7.4	7.3	27.1	-
Nitrogen-free extract	54.2	53.1	52.2	51.1	52.2	-
Total ash	12.7	13.5	14.2	14.9	8.8	48.5

\* Dairy feed supplied by Anchal Feed Factory (Govt. Undertaking) contained (parts per 100 kg): Maize grain, 6; barley grain, 2; groundnut extraction, 7; soybean extraction, 5; deoiled mustard cake, 12; mustard oilseed cake, 5; deoiled rice bran, 29; rice bran, 19; wheat bran, 2; molasses, 9; urea, 1; limestone powder, 1; mineral mixture<sup>a</sup>, 1; common salt, 1; vitamin AD<sub>3</sub> <sup>b</sup> (10 g/100 kg) and anifed-herbal feed supplement (100 g/100 kg).

<sup>a</sup> Mineral mixture AGRIMIN (manufactured by Brinavan Phosphates Ltd. and marketed by Glaxo India) contained copper, 312 mg; cobalt, 45 mg; magnesium, 2.11 g; iron, 979 mg; zinc, 2.13 g; iodine, 156 mg; DL-methionine, 1.92 g; L-lysine monohydrochloride, 4.4 g per kg and 24% calcium and 12% phosphorus.

<sup>b</sup> Vitamin mixture (manufactured by Nicholas Piramale, Mumbai) contained 500,000 IU vitamin A and 50,000 IU vitamin D<sub>3</sub>.

in the rumen subsequently increase their absorption from the small intestine potentially increasing the supply of polyunsaturated fatty acids to the mammary gland. Such milk will be beneficial to those milk consumers who have heart problems (Maynard et al., 1979; Upritchard et al., 2005). The objective of the study was to examine the influence of feeding calcium salts of palm oil fatty acids on nutrient utilization, milk yield, milk composition and its quality in terms of fatty acids profile in lactating crossbred cows.

## MATERIALS AND METHODS

### Experimental animals and rations:

Twenty lactating crossbred cows yielding 10 to 15 litres milk during mid lactation were selected from the dairy cattle herd of Instructional Dairy Farm, G. B. Pant University of Agriculture and Technology, Pantnagar and were fed under a conventional feeding system with concentrate mixture, mixed fodder of green oats and oats hay as per requirements (NRC, 1989). After three weeks of feeding, which served as control period, cows were divided into four groups of five in such a way that the average milk yield of all the groups was similar. The four groups of cows were allotted randomly to four dietary treatments as follows:

- Treatment I (Control) :

Cows in group 1 were fed concentrate mixture I without calcium salts of palm oil fatty acids along with green oats+oats hay

- Treatment II (2% bypass fat) :

Cows in group 2 were fed concentrate mixture II containing 2% calcium salts of palm oil fatty acids (2

kg in 100 kg concentrate mixture) so as to provide 100 g/cow/day along with green oats+oats hay

- Treatment III (4% bypass fat) :

Cows in group 3 were fed concentrate mixture III containing 4% calcium salts of palm oil fatty acids (4 kg in 100 kg concentrate mixture) so as to provide 200 g/cow/day along with green oats+oats hay

- Treatment IV (6% bypass fat) :

Cows in group 4 were fed concentrate mixture IV containing 6% calcium salts of palm oil fatty acids (6 kg in 100 kg concentrate mixture) so as to provide 300 g/cow/day along with green oats+oats hay

The ingredient composition of different concentrate mixtures is given in Table 1. The calcium salts of Palm oil fatty acids were supplied by M/s Tinna Oils and Chemicals Ltd. New Delhi. During the experimental feeding period, all the animals were provided with a known quantity (25 to 30 kg per animal) of mixed roughage (green oats+oats hay) twice daily at 10.00 AM and 5.00 PM. and the known quantity of concentrate mixture as per NRC (1989) requirements were provided to different treatments groups in two installments at 2.30 AM and 3.30 PM daily before half an hour of milking. Animals were also offered fresh clean drinking water free choice thrice daily at 8.00 AM, 3.00 PM and 7.00 PM. All the cows were weighed at the start and end of both the control and the experimental feeding periods before feeding and watering in the morning for three consecutive days. All the animals were housed in a well ventilated shed having cemented concrete floor with individual feeding arrangement. The experimental feeding period lasted for 90 days. The leftover feed was weighed and recorded daily. The dry matter content of the feeds offered and refused was determined weekly. The samples of

concentrate mixtures, green fodders and refused were analysed for chemical composition as per standard methods of AOAC (1990).

### Digestion trial

A six day digestibility trial was conducted in the middle of the experimental period (after 60<sup>th</sup> day of feeding trial) to determine nutrient utilization in each treatment group. During this period feed and fodder offered, residue left and faeces voided were accurately weighed and recorded and representative samples were analysed for proximate principles as per AOAC (1990). During digestion trial period, the faeces of individual cows were carefully collected manually wherein round the clock vigilance was made to ensure that the entire amount of faeces voided during 24 h was collected without mixing with urine. After mixing thoroughly an aliquot of 1/100<sup>th</sup> part of total faeces voided out by each animal was kept for dry matter estimation as per the method described by Bratzler and Swift (1959). Thereafter six day pooled dried faecal samples were used for determination of proximate principles, viz., moisture, ether extract, crude fibre and ash. Simultaneously an aliquot of 1/1,000<sup>th</sup> part of total faeces voided from each cow was preserved in 20 ml of 40% H<sub>2</sub>SO<sub>4</sub> and six day pooled samples were used for crude protein estimation.

### Milk recording, sampling and analysis

Daily milk produce of each animal was recorded throughout the experimental feeding period of 90 days. Daily hand milking was done at 3.00 AM and 4.00 PM. Milk samples of each animal were collected at fortnightly intervals. Total solids, fat, protein (N×6.38) and ash contents of the milk were estimated as per the methods described by Gupta et al. (1992). Solids-not-fat (SNF) content was calculated by subtracting fat content from total solids content, and lactose content was calculated by subtracting the sum of protein and ash contents from SNF content. Gross energy of milk was calculated by the following formula given by Tyrell and Reid (1965):

$$\text{Gross energy of milk (kcal/kg)} = 92.25F + 49.15S - 56.40$$

where, 'F' is Fat % and 'S' is SNF % in milk.

### Efficiency of energy and nitrogen utilization

The gross energetic efficiency for milk production was calculated as per the following formula presuming that one kg TDN is equivalent to 4,400 kcal digestible energy (NRC 1989):

$$\text{Gross energetic efficiency (\%)} = \frac{\text{Gross energy of total milk/day (kcal)}}{4,400 \times \text{TDN intake (kg/day)}} \times 100$$

$$\text{Net energetic efficiency (\%)} = \frac{\text{Gross energy of milk produced/day (kcal)}}{4,400 \times (\text{TDN intake (kg/day)} - \text{TDN required for maintenance as } 35.2 \text{ g/kg } W^{0.75})} \times 100$$

The net energetic efficiency of milk production was calculated by subtracting the TDN required for maintenance (35.2g/ kg W<sup>0.75</sup>) as per NRC (1989) from the total TDN intake as given below:

$$\text{Net energetic efficiency (\%)} = \frac{\text{Gross energy of milk produced/day (kcal)}}{4,400 \times (\text{TDN intake (kg/day)} - \text{TDN required for maintenance as } 35.2 \text{ g/kg } W^{0.75})} \times 100$$

The gross and net efficiencies of nitrogen utilization for milk production were calculated using the following formulae:

$$\text{Gross efficiency of N utilization (\%)} = \frac{\text{Milk N secreted}}{\text{Feed N intake}} \times 100$$

$$\text{Net efficiency of N utilization (\%)} = \frac{\text{Milk N secreted}}{\text{Digestible N intake}} \times 100$$

### Milk fatty acids profile

Milk samples were collected individually from all animals twice during the experimental feeding trial period, one at the middle of feeding trial and another towards the end of feeding trial. The milk collected was first converted into cream by centrifugal method in the cream separator and thereafter *ghee* (butter fat) was obtained by creamery butter method as described by De (2005). The individual animals' *ghee* samples were stored in refrigerator for further analysis for fatty acids profile. The fatty acid methyl esters of milk fat (*ghee*) were prepared by base-catalyzed transmethylation reaction using sodium-methoxide method (Christie, 1982). Milk fat and 0.025 N sodium methoxide in the ratio of 1:4 (100 µl of milk fat and 400 µl of sodium methoxide) were placed into glass stoppered test tubes. The test tubes were sealed and the contents were mixed using vortex mixer. The tubes were then kept in an oven at 80°C for esterification of fatty acids until a uniform layer was formed. Then quantification of fatty acid methyl esters was done using a gas chromatograph (Perkin-Elmer Auto system XL) fitted with flame-ionization detector (FID). The column used was diethyl-glycosuccinate packed column with a column length of 10 ft. The oven temperature was initially 80°C, then increased at a rate of 3°C per min to 220°C and maintained for 5 min. Injector and detector temperatures were 270°C and 275°C, respectively. The carrier gas used was nitrogen

**Table 2.** Average daily dry matter consumption and concentrate: roughage ratio in experimental lactating crossbred cows fed rations containing calcium salts of palm oil fatty acids (bypass fat) during feeding trial of 90 days

Particulars	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Average body weight (kg)	413.1±19.0	388.0±10.1	421.8±26.9	427.8±12.9
Roughage dry matter intake (kg)	8.8±0.1	8.8±0.1	9.0±0.9	8.9±0.1
Concentrate dry matter intake (kg)	4.5±0.6	4.3±0.7	4.5±0.7	4.7±0.6
Concentrate: roughage ratio	1:2.1±0.3	1:2.4±0.5	1:2.2±0.3	1:2.0±0.2
Total dry matter intake (kg)	13.4±0.5	13.1±0.7	13.5±0.8	13.6±0.6
Dry matter intake/100 kg BW (kg)	3.3±0.3	3.4±0.2	3.2±0.2	3.2±0.1
Dry matter intake/kg W <sup>0.75</sup> (g)	147.4±0.1	150.5±0.9	146.1±0.7	144.3±0.5
Feed efficiency (kg milk yield/kg DM intake)	0.9±0.1	0.9±0.1	1.0±0.1	0.9±0.1
Live weight change (g/d)	90.0	40.0	60.0	30.0

**Table 3.** Average daily dry matter and nutrients intake and concentrate:roughage ratio in experimental lactating crossbred cows fed rations containing calcium salts of palm oil fatty acids (bypass fat) during digestion trial

Particulars	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Average body weight (kg)	418.4±20.4	383.7±13.4	424.7±27.1	428.5±13.0
Roughage dry matter intake (kg)	8.8±0.4	8.6±0.3	9.1±0.4	9.1±0.3
Concentrate dry matter intake (kg)	4.5±0.6	4.3±0.7	4.5±0.6	4.7±0.6
Concentrate:roughage ratio	1:2.1±0.2	1:2.3±0.5	1:2.1±0.3	1:2.1±0.3
Total dry matter intake (kg)	13.3±0.9	12.9±0.8	13.6±0.9	13.8±0.8
Dry matter intake/100 kg BW (kg)	3.2±0.3	3.4±0.2	3.2±0.2	3.2±0.1
Dry matter intake/kg W <sup>0.75</sup> (g)	145.9±13.3	148.5±9.6	145.2±8.3	146.0±5.7
Total digestible nutrients intake (kg)	8.6±0.7	8.5±0.6	8.7±0.6	9.0±0.6
Total digestible nutrients intake/100 kg BW (kg)	2.1±0.2	2.2±0.1	2.1±0.1	2.1±0.9
Total digestible nutrients intake/kg W <sup>0.75</sup> (g)	94.5±9.3	98.1±6.3	93.6±5.2	95.4±4.5
Digestible crude protein intake (kg)	1.1±0.1	1.1±0.1	1.1±0.1	1.0±0.1
Digestible crude protein intake/100 kg BW (g)	260.7±35.1	275.1±20.4	254.9±13.6	241.0±16.7
Digestible crude protein intake/kg W <sup>0.75</sup> (g)	11.7±1.5	12.2±0.9	11.2±0.9	11.0±0.8

at a flow rate of 30 ml/min, hydrogen gas flow rate was 33 ml/min and air flow was 330 ml/min. One µl sample was injected for analysis and the fatty acid peaks were identified using GCMS (Gas chromatograph mass spectrum). The GCMS data was obtained on a Shimadzu QP-2000 instrument at 70 eV and 250°C. Specifications of gas chromatograph column used for GCMS were fused silica capillary column 0.25 mm×50 M with film thickness of 0.25 micron. Carrier gas used was helium at a flow rate of 2ml/min. The scan obtained was identified for individual fatty acid by comparing with standard spectrum of methyl esters of individual fatty acid as given in 8 peak mass spectrum index.

#### Statistical analysis

The data for average milk yield, fat-corrected milk yield, fat yield, SNF yield and milk composition data of control and experimental periods were subjected to analysis of covariance for comparison amongst the different treatment groups as per the procedure described by Snedecor and Cochran (1980) and for other parameters the data obtained

from the experiment were subjected to the analysis of variance (ANOVA) using General Linear Model (GLM) of the SAS computer package (SAS, 1989). Treatment means were compared using least significant difference (LSD).

## RESULTS AND DISCUSSION

#### Chemical composition of feeds and fodder

The chemical compositions of all the four concentrate mixtures viz., I (control, without bypass fat), II (2% bypass fat), III (4% bypass fat), and IV (6% bypass fat) did not differ except ether extract content (Table 1). Ether extract content was lowest in control (6.0%) while it increased gradually with increase in level of bypass fat supplementation and was highest in concentrate mixture IV (8.6%). The DM content of bypass fat (calcium salts of palm oil fatty acids) was 92.7 per cent. Bypass fat contained 51.5 per cent ether extract and 48.5 per cent total ash on DM basis. Mixed fodder (green oats+oats hay) showed considerable variation in dry matter and crude protein content throughout the experimental feeding period with an

**Table 4.** Nutrient digestibility (%) of rations in different groups of lactating crossbred cows fed rations containing calcium salts of palm oil fatty acids (bypass fat)

Nutrients	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Dry matter	64.3±1.1	64.3±1.1	64.0±1.0	64.7±1.1
Organic matter	67.0±1.1	67.0±1.2	66.6±0.9	68.0±0.9
Crude protein	65.0±2.4	67.3±1.3	65.5±1.1	64.6±1.4
Crude fiber	65.0±1.4	64.9±0.3	64.6±1.2	66.2±1.7
Ether extract*	83.3 <sup>b</sup> ±1.5	88.6 <sup>a</sup> ±1.8	84.7 <sup>ab</sup> ±1.4	88.0 <sup>a</sup> ±0.7
Nitrogen-free extract	67.1±0.7	65.6±1.9	65.9±1.6	66.0±0.9

<sup>a,b</sup> Values bearing different superscripts in a row differ significantly from each other. \*  $p < 0.05$ .

average of 24.5 and 8.5% on dry matter basis, respectively.

### Nutrients intake

The data on total dry matter intake, roughage dry matter intake, concentrate dry matter intake, concentrate: roughage ratio, dry matter intake/100 kg body weight and dry matter intake/kg  $W^{0.75}$  among different groups of lactating crossbred cows due to supplementation of bypass fat as calcium salts of palm oil fatty acids in the ration during entire experimental period are presented in Table 2 and 3.

The lactating crossbred cows consumed 13.4, 13.1, 13.5 and 13.6 kg dry matter/day fed rations containing 0, 2, 4 and 6% of calcium salts of palm oil fatty acids, respectively and the differences were non significant (Table 2). The daily dry matter intake in the present study was slightly higher than those reported by Lade (2004) and Ravikumar et al. (2005) in lactating crossbred cows ranging from 10.6 to 12.1 kg and 12.9 to 13.5 kg, respectively. The similar dry matter intake in all the groups of cows in the present study can be ascribed to the fact that the added inert fat is likely to have remain largely unavailable in the rumen because of its low solubility and high melting point (Canale et al., 1990), thereby not impairing rumen fibre digestibility and avoiding an increase in gut fill that can limit dry matter intake. Jenkins and Palmquist (1984) observed no significant difference in dry matter intake by addition of calcium soaps of fatty acids in rations of lactating Holstein cows. Sarwar et al. (2004) reported daily dry matter intake ranging from 10.8 to 11.0 kg in different groups of lactating Nili-Ravi buffalos fed 0 to 6 per cent ruminally protected fat, which was statistically non significant. Garg and Mehta (1998) also did not find any significant effect of bypass fat on dry matter intake which corroborates the findings of the present study. In contrary to the present findings, Schauff and Clark (1992) found a linear decrease in dry matter intake when cows were fed rations containing 3, 6, and 9 per cent of protected fat as calcium soaps of long chain fatty acids and attributed to the worse palatability of the supplemental fat.

The TDN intake per 100 kg body weight for groups 1, 2, 3 and 4 was 2.1, 2.2, 2.1 and 2.1 kg, respectively, whereas the daily TDN intakes/kg  $W^{0.75}$  for the corresponding

groups were 94.5, 98.1, 93.6 and 95.4 g. The TDN intakes did not differ significantly among the different groups of cows. The DCP intake per 100 kg body weight for the groups 1, 2, 3 and 4 was 260.7, 275.1, 254.9 and 241.0 g, whereas, DCP intake/kg  $W^{0.75}$  was 11.7, 12.2, 11.2 and 11.0 g, respectively. There was no significant difference in daily DCP intakes among different treatment groups of lactating crossbred cows. Sarwar et al. (2004) also observed a non significant effect on crude protein intake of buffaloes fed with varying levels of ruminally protected fat. Lade (2004) reported that the daily TDN and DCP intake in lactating crossbred cows fed conventional versus complete ration ranged from 71.0 to 87.0 and 6.5 to 8.5 g/kg  $W^{0.75}$ , respectively. Ravikumar et al. (2005) observed TDN and DCP intake in lactating crossbred cows fed different levels of undegradable dietary protein and planes of nutrition ranging from 75.2 to 82.4 and 7.5 to 9.2 g/kg  $W^{0.75}$ , respectively. The TDN and DCP intakes as reported by Ravikumar et al. (2005) and Lade (2004) were lower than that observed in the present study. All the cows gained body weight during the experimental period, however, there was no significant difference in body weight change among the different groups (Table 2).

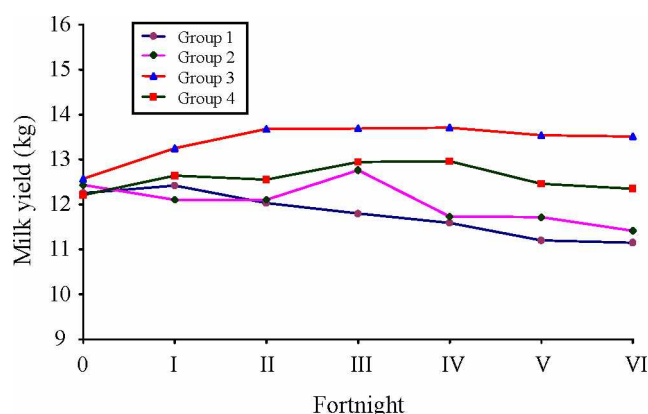
### Nutrients digestibility

The digestibility coefficient values for ether extract differed significantly ( $p < 0.05$ ) among the different treatment groups of cows fed ration containing calcium salts of palm oil fatty acids but digestibility coefficients for dry matter, crude protein, organic matter, crude fibre and nitrogen-free extract did not differ significantly among each other (Table 4). The digestibility of ether extract was significantly ( $p < 0.05$ ) higher in cows of groups 2 (88.6%) and 4 (88.0%) than in cows of group 1 (83.3%). However, the ether extract digestibility did not differ significantly between groups 1 (83.3%) and 3 (84.7%) and also between groups 2 (88.6%) and 4 (88.0%). Similar to the present study Grummer (1988) reported that feeding 0.68 kg of calcium salts of palm oil fatty acids daily along with basal diet increased total dietary lipid digestibility, while dry matter, organic matter, crude protein and crude fibre

**Table 5.** Overall average daily milk yield and milk composition of different treatment groups of lactating crossbred cows fed rations containing bypass fat during experimental feeding period of 90 days

Parameters	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Milk yield (kg) *	11.7 <sup>b</sup> ±1.4	12.0 <sup>b</sup> ±1.2	13.6 <sup>a</sup> ±1.3	12.7 <sup>ab</sup> ±1.5
Total solids (%)*	13.3 <sup>a</sup> ±0.2	13.1 <sup>ab</sup> ±0.1	13.3 <sup>a</sup> ±0.1	12.8 <sup>b</sup> ±0.2
Fat (%)	4.0±0.1	4.0±0.1	4.1±0.1	3.9±0.2
Protein (%)	3.5±0.1	3.5±0.1	3.5±0.1	3.4±0.1
Lactose (%)*	5.2 <sup>a</sup> ±0.1	4.8 <sup>b</sup> ±0.1	5.2 <sup>a</sup> ±0.1	4.9 <sup>b</sup> ±0.1
Ash (%)	0.7±0.0	0.7±0.0	0.7±0.0	0.7±0.0
Solid-not-fat (%)*	9.3 <sup>a</sup> ±0.1	9.1 <sup>a</sup> ±0.0	9.3 <sup>a</sup> ±0.1	8.9 <sup>b</sup> ±0.0
4% fat-corrected milk yield (kg)*	11.8 <sup>b</sup> ±1.5	12.1 <sup>b</sup> ±1.4	13.8 <sup>a</sup> ±1.6	12.5 <sup>ab</sup> ±1.9
Fat yield (kg)*	0.5 <sup>b</sup> ±0.1	0.5 <sup>b</sup> ±0.1	0.6 <sup>a</sup> ±0.1	0.5 <sup>ab</sup> ±0.1
Gross energy of milk (kcal/kg)	769.7±16.9	762.7±6.2	774.1±7.9	737.1±18.2

<sup>a,b</sup> Values bearing different superscripts in a row differ significantly from each other. \*  $p < 0.05$ .

**Figure 1.** Effect of bypass fat supplementation on milk yield in lactating crossbred cows.

digestion remained unchanged. Elliot et al. (1996) did not find any effect on rumen fermentation characteristics or nutrient digestibility in lactating Holstein cows fed hydrogenated palm oil fatty acids. Reddy et al. (2001) also did not observe any adverse effect on dry matter digestibility in sheep due to inclusion of calcium soaps of palm oil fatty acids up to 5% level. Chalupa et al. (1984) and Banks et al. (1984) also reported no significant difference in dry matter and fibre digestibility by supplementation of ration with unesterified long chain fatty acids which corroborated with the findings of the current study. In contrary to these findings, Estridge and Firkins (1991) reported a reduction in dry matter and organic matter digestibility when diets were supplemented with hydrogenated fat, whereas Sarwar et al. (2004) reported a linear increase in apparent dry matter digestibility and significant increase in crude protein digestibility in early lactating Nili-Ravi buffaloes fed diets containing 6% rumen protected fat. Filley et al. (1987) and Maeng et al. (1993) reported lower crude protein and crude fiber digestibilities in dairy cows and sheep, respectively fed calcium salts of

palm oil fatty acids in the ration which is contrary to the findings of the present study, whereas similar to the present study, higher digestibility of crude fat has been reported.

#### Milk yield, fat yield and 4% fat corrected milk yield

The data for average milk yield, fat yield, FCM yield and milk composition are presented in Table 5. The fortnightly milk yield in different groups of cows fed rations containing calcium salts of palm oil fatty acids is depicted in Figure 1. The average daily milk yield was significantly ( $p < 0.05$ ) higher in cows of group 3 (13.6 kg) that were fed 4% bypass fat than in cows of groups 1 (11.7 kg) and 2 (12.0 kg). But there was no significant difference in milk yield between the cows of groups 3 and 4 (12.7 kg). The cows fed 4% bypass fat (group 3) in the ration produced significantly ( $p < 0.05$ ) more milk (109.5%) as percentage of control period milk followed by group 4 (102.6%), group 2 (97.0%) and group 1 (96.1%). Feed efficiency (kg milk yield/kg DM intake) was highest in group 3 in which cows were fed ration containing 4% bypass fat (Table 2). Shaver (1990) observed an average increase of daily milk yield by 1.5 to 2 kg per cow fed 0.45 kg of supplemental fat that corroborates with our findings. King et al. (1990) also reported that a supplement of predominantly saturated and unesterified long chain fatty acids in the ration of cows increased the yield of milk and 4% FCM by 3.3 and 6.3 kg/cow/day, respectively when the intake of cows was increased by 1.0 kg fatty acid. An increase in milk production has also been reported by Palmquist (1984) and Sarwar et al. (2003) in cows supplemented with rumen-protected fat up to 6%. These results are in agreement with the findings of present study as the 4% bypass fat supplementation showed a significant ( $p < 0.05$ ) increase in milk yield (19.0%) as compared to control (Table 5). The improvement in milk yield associated with supplemental fat can largely be attributed to an improvement in energy balance (Grummer and Carroll,

**Table 6.** Average energetic efficiency for milk production in lactating crossbred cows fed different experimental ration containing bypass fat

Particulars	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Metabolic body size (kg)	91.5±3.1	86.2±2.5	93.0±4.5	94.0±2.1
Milk yield (kg/d)	11.7±1.4	12.0±1.2	13.6±1.3	12.7±1.5
TDN consumption (kg/d)	8.6±0.7	8.6±0.6	8.7±0.6	9.0±0.6
TDN used for maintenance (kg/d)	3.2±0.1	3.0±0.9	3.3±0.2	3.3±0.1
TDN available for milk production (kg)	5.4±0.7	5.6±0.6	5.5±0.5	5.7±0.5
Gross energy of milk production (kcal/kg)	769.7±16.9	762.7±6.2	774.1±7.9	737.1±18.2
Gross energetic efficiency (%)	23.6±1.8	24.2±1.7	27.5±2.1	27.1±6.0
Net energetic efficiency (%)	38.6±2.2	37.9±2.9	44.4±3.5	37.1±2.7

1991). Maeng et al. (1993) also reported a significant ( $p<0.05$ ) increase in milk production in cows supplemented with calcium salt of long chain fatty acids which corroborates with the findings of present study. In contrary to the present finding Johnson et al. (1988), Casper et al. (1990) and Elliot et al. (1993) reported no effect of supplemental fat on 4% FCM yield.

In the present study the daily fat yield was significantly ( $p<0.05$ ) higher (by 17.0%) in cows fed ration containing 4% bypass fat (0.6 kg) than cows fed control (0.5 kg) ration (Table 6). Similar observations were also made by Jerred et al. (1990) who found an increase in milk fat yield by 0.1 kg/d with addition of 1.1 kg fat/d in the ration. The increase in milk fat yield might be due to higher proportion of fatty acid intake that was directly transferred to the milk fat. In contrast, Smith and Harris (1992) and Tacket et al. (1996) did not find any significant effect on milk fat yield in cows fed ration supplemented with 6% fat.

### Milk composition

Compositional changes due to treatments varied irregularly. In milk samples collected in the first and fourth fortnights of the experimental period, lactose content of milk showed a variable trend with increasing bypass fat supplementation and remaining components did not show any significant difference. In I, III and V fortnights milk sampling, there was no significant difference in total solids, fat, protein, lactose, solid-not-fat and ash per cent among different treatments. The average total solids contents of milk in cows of groups 1, 2, 3 and 4 were 13.3, 13.1, 13.3 and 12.8 per cent, respectively (Table 5). A significantly ( $p<0.05$ ) higher total solid content was observed in groups 1 and 3 than in group 4. The mean values of SNF content in milk of cows under groups 1, 2, 3 and 4 were 9.3, 9.1, 9.3 and 8.9 per cent, respectively. The SNF content in milk of cows under groups 1, 2 and 3 was significantly ( $p<0.05$ ) higher than group 4. There was no significant difference in fat, protein, lactose, ash and gross energy content in milk among the different treatment groups of cows. Thus overall the milk components were not affected due to

supplementation of calcium salts of palm oil fatty acids in the ration of lactating crossbred cows. Schneider et al. (1988), Jerred et al. (1990) and Klusmeyer et al. (1991) reported that milk protein percentage was unaffected by addition of calcium salts of long chain fatty acids. Similarly, Brzoska et al. (1999) reported that increasing amount of calcium salt of palm oil fatty acids had no negative effect on milk fat, protein and lactose contents of milk which corroborated to the findings of the present study. In contrary to present results, Sarwar et al. (2003) observed an increase in milk fat and protein percentage in buffalos and Solomon et al. (2000) observed increased milk fat percentage in cows with supplemental fat in the diets. Whereas Palmquist (1984) and Grummer and Carrol (1991) observed reduction in milk fat percentage when unprotected tallow was fed to dairy cows which was attributed to reduced fibre digestion and altered acetate: propionate ratio. The increase in protein percentage in milk due to addition of inert fat might be due to reduction in use of amino acid as fuel and thus spared for casein synthesis (Sarwar et al., 2003). All the animals during experimental period gained body weight (Table 2). The average adjusted values for body weight gain/day in different groups of animals fed ration containing bypass fat were 0.09, 0.04, 0.06 and 0.03 kg/d. There was no significant difference among the treatment groups.

### Energetic efficiency of milk production

The gross and net energetic efficiencies for milk production in the present study ranged from 23.6 to 27.1 and 37.1 to 44.4 per cent, respectively (Table 6). There was no significant difference in gross and net efficiency of energy utilization in various treatment groups of cows; however, improvement in gross and net efficiency of energy utilization at 4 per cent bypass fat supplementation in the ration was observed. The values for gross and net energetic efficiencies in the present study were similar to the observations made by Lade (2004) which ranges from 22.7 to 29.4 per cent for gross energetic efficiency and 31.7 to 51.3 per cent for net energetic efficiency. The values of gross and net energetic efficiency of milk production



**Table 7.** Average gross and net efficiency of nitrogen utilization for milk production in lactating crossbred cattle fed different experimental ration containing bypass fat

Particulars	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Feed nitrogen intake (g/d)	260.0±22.2	258.2±24.2	256.5±22.6	255.4±17.0
Faecal nitrogen excreted (g/d)	89.8±6.7	81.6±10.0	86.0±7.7	88.6±4.0
Digestible nitrogen intake (g/d)	170.2±18.5	156.6±35.0	170.5±15.9	166.5±14.0
Total nitrogen secreted in milk (g/d)	63.0±8.0	65.6±6.5	73.8±8.5	66.9±8.5
Gross efficiency of nitrogen utilization (%)	24.0±1.8	25.6±1.5	28.7±1.6	25.7±1.9
Net efficiency of nitrogen utilization (%)	37.3±3.5	37.4±2.6	43.5±3.2	39.4±2.3

**Table 8.** Average fatty acid concentration in the milk fat (g/100 g) of different treatment groups of lactating crossbred cows fed rations containing bypass fat

Attributes	Experimental groups			
	Group 1 (Control)	Group 2 (2% bypass fat)	Group 3 (4% bypass fat)	Group 4 (6% bypass fat)
Butyric acid	5.0±0.1	4.8±0.2	4.5±0.1	5.0±0.4
Caproic acid*	3.5 <sup>a</sup> ±0.1	3.1 <sup>b</sup> ±0.2	3.1 <sup>b</sup> ±0.2	2.9 <sup>b</sup> ±0.2
Caprylic acid*	2.5 <sup>a</sup> ±0.1	2.1 <sup>ab</sup> ±0.1	1.8 <sup>b</sup> ±0.2	1.8 <sup>b</sup> ±0.1
Capric acid*	5.7 <sup>a</sup> ±0.4	5.3 <sup>ab</sup> ±0.2	5.0 <sup>b</sup> ±0.2	4.8 <sup>b</sup> ±0.1
Lauric acid	6.4±0.2	6.1±0.2	6.0±0.2	5.8±0.1
Myristic acid	10.9±0.3	10.9±0.1	10.5±0.2	10.4±0.1
Palmitic acid*	26.6 <sup>c</sup> ±0.3	28.1 <sup>b</sup> ±0.3	28.8 <sup>b</sup> ±0.3	29.8 <sup>a</sup> ±0.2
Stearic acid*	6.8 <sup>b</sup> ±0.2	7.9 <sup>a</sup> ±0.2	7.8 <sup>a</sup> ±0.2	8.3 <sup>a</sup> ±0.2
Oleic acid*	16.7 <sup>c</sup> ±0.2	17.8 <sup>b</sup> ±0.3	18.3 <sup>b</sup> ±0.3	19.5 <sup>a</sup> ±0.3
Linoleic acid*	2.2 <sup>b</sup> ±0.01	2.5 <sup>a</sup> ±0.1	2.6 <sup>a</sup> ±0.1	2.6 <sup>a</sup> ±0.1
Linolenic acid*	0.6 <sup>b</sup> ±0.0	0.7 <sup>b</sup> ±0.0	0.7 <sup>b</sup> ±0.1	1.0 <sup>a</sup> ±0.1
Arachidonic acid*	0.4±0.0	0.7±0.1	0.7±0.2	0.8±0.1

<sup>a,b,c</sup> Values bearing different superscripts in a row differ significantly from each other. \*  $p < 0.05$ .

observed by Tiwari and Patle (1983) in lactating buffaloes ranged from 10.5 to 13.8 per cent and 19.8 to 22.8 per cent, respectively. Ravikumar (2005) reported the gross energetic efficiency as 18.5 to 19.4 per cent and net energetic efficiency as 31.5 to 35.5 per cent in lactating crossbred cows fed bypass protein and all the above observations were slightly lower than the values observed in the present study.

#### Efficiency of nitrogen utilization

The values for gross and net efficiencies of nitrogen utilization in the present study ranged from 24.0 to 28.7 and 37.3 to 43.5 per cent, respectively (Table 7). There was no significant difference in gross and net efficiency of nitrogen utilization for milk production among different treatment groups. Lade (2004) reported gross and net efficiencies of nitrogen utilization in crossbred lactating cows for milk production as 22.7 to 29.4 per cent and 34.8 to 50.9 per cent respectively and corroborates with those of the present study. Tiwari and Patle (1983) reported gross and net efficiencies of nitrogen utilization in lactating buffaloes as 13.7 to 17.2 per cent and 23.9 to 34.4 per cent, respectively, whereas Ravikumar (2005) reported the values for gross and net efficiency of nitrogen utilization in crossbred

lactating cows for milk production ranging from 16.1 to 19.2 per cent and 25.8 to 36.3 per cent, respectively. These observations were lower than the values of the present study.

#### Milk fatty acids profile

The concentration of butyric acid in milk fat of various groups showed no significant difference while caproic acid, caprylic acid and capric acid showed significantly ( $p < 0.05$ ) higher values in cows of group 1 (control, without bypass fat) than in the cows of groups 2, 3 and 4 (Table 8). Lauric acid and myristic acid concentration in milk showed a non significant difference, while palmitic acid concentration was significantly ( $p < 0.05$ ) highest in cows of group 4 fed ration containing 6% bypass fat. A similar trend was observed in oleic acid concentration. Stearic acid concentration in milk fat of cows in groups 2, 3 and 4 showed significantly ( $p < 0.01$ ) higher values than group 1. Linoleic acid concentration among treatments was also significantly ( $p < 0.01$ ) higher in all the bypass fat fed cows. The linolenic acid concentration showed higher value in group 4 and it differed significantly ( $p < 0.01$ ) from other groups. Arachidonic acid concentration showed a non significant effect across the treatments. The concentration of unsaturated fatty acids was increased in the milk of cows



fed bypass fat supplemented ration. The results are in agreement with the findings of Beaulieu and Palmquist (1995) who observed an increase in proportion of  $C_{16}$  to  $C_{18}$  fatty acids and decrease in proportion of  $C_8$  to  $C_{14}$  fatty acids while butyric acid and caproic acid concentration were unaffected due to dietary fat supplementation in the form of calcium salts of palm oil fatty acids. The lower concentration of caproic, caprylic and capric acid in milk fat of cows supplemented with fat was also observed by Jenkins and Jenny (1989). Pantoja et al. (1996) found that supplemental dietary fat had no effect on concentration of  $C_{40}$  i.e. butyric acid in milk fat. These results reflect the origin of  $C_{40}$  from pathways independent of acetyl-coenzyme-A-carboxylase, which is inhibited by the presence of long chain fatty acids (Palmquist, 1988). Similar observations were also made by Drackley and Elliot (1993) and Wonsil et al. (1994). These results are characteristics of increased *de novo* synthesis of fatty acids and incorporation of preformed  $C_{18}$  fatty acid into milk, which is well described by the increase in oleic acid concentration to a higher level in treatment groups, when compared to control groups. Pantoja et al. (1996) observed a linear increase in concentration of total  $C_{18}$  fatty acid in milk fat as fat unsaturation increases in the diet. Ward et al. (2002) reported an increased proportion of  $C_{18:0}$  as a per cent of total fatty acids and increase in linolenic acid concentration in the milk of the cows fed the oil seed diets compared to control diet. These results corroborate the findings of the present study related to fatty acid concentration in milk fat due to feeding of calcium salts of palm oil fatty acids in the ration of lactating crossbred cows.

From the findings of the present study it was concluded that supplementing the ration of lactating cows with calcium salts of palm oil fatty acids caused a substantial improvement in the milk yield, 4% FCM yield and fat yield in milk of cow's fed with bypass fat at 4 to 6% level coupled with improved ether extract digestibility without any effect on crude fibre digestibility. Milk fatty acid profile revealed an increase of unsaturated fatty acids like oleic acid, linoleic and linolenic acid in milk of cows fed calcium salts of palm oil fatty acids. Increase in unsaturated fatty acids of milk may be beneficial to consumers for cardiovascular health. Thus supplementing the ration of lactating cows with bypass fat can improve the milk production as well as milk quality.

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