# THE EFFECT OF RUMINAL BYPASS FAT ON MILK YIELDS AND MILK COMPOSITION OF LACTATING DAIRY COW

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## Abstract

**A study was conducted to determine the effect of feeding rumen-bypass fat on performance of dairy cows. Twenty four Holstein Friesian crossbred (>87.5% Holstein Friesian) lactating dairy cows in early-mid lactation, averaging 23.3 $\pm$ 3.5 kg of milk, 85 $\pm$ 5 days in milk, 60.8 $\pm$ 5.9 months old and 464 $\pm$ 43 kg live weight, were stratified for milk yield, days in milk, age, stage of lactation and body weight, and then randomly allocated to two treatment groups. All cows were fed approximately 10 kg of concentrate together with *ad libitum* grass silage and freely access to clean water. Nil or 300 g of rumen-bypass fat was supplemented to the cows according to the treatment groups. All cows consumed similar amount of concentrate, roughage and total dry matter (DM) and crude protein (CP). There were no significant differences in milk yields and milk composition yields. All cows had similar fat, protein, lactose, solid not fat and total solid percentage in milk. All cows lost similar live weight. Rumen-bypass fat supplementation significantly ($p<0.05$) reduced C4:0 but increased C12:0 and C14:0 fatty acids of the cows' milk. The present study indicated that supplementation of rumen-bypass fat did not enhance milk yields, milk composition and live weight change.**

**Keywords: Rumen-bypass fat, milk production, milk composition, dairy cattle**

## Introduction

During early lactation, the amount of energy required for maintenance of body tissues and milk production often exceeds the amount of energy available from the diet (Goff and Horst, 1997), thus forcing mobilization of body fat reserves to satisfy energy requirement. Prilled saturated fatty acids and calcium (Ca) salts of long-chain fatty acids have been shown to be effective as ruminally inert fat supplements for lactating cows (Grummer, 1988; Palmquist, 1991). Rumen inert fats, such as Ca salts of long-chain fatty acids or other forms of rumen-bypass fat, are often fed to increase the dietary energy supply. Responses to supplementation of dairy cow diets with rumen-bypass fat have been variable. For example, feeding rumen-bypass fat to dairy cows has been reported to increase fat-corrected milk yield (Erickson *et al*., 1992), milk and fat-corrected milk yields (Klusmeyer *et al*., 1991a; Rodriguez *et al*., 1997), and milk fat percentage (Klusmeyer *et al*., 1991a, 1991b; Sklan *et al*.,

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1992; Elliott *et al*., 1996) without affecting the digestibility of other dietary nutrients (Klusmeyer *et al*., 1991a). The objective of this study was to determine the effect on milk yield and milk compositions of feeding rumen-bypass fat to early-mid lactating dairy cows.

## Materials and Methods

### Animal, Diet, and Experimental Design

Twenty four Holstein Friesian crossbred (>87.5% Holstein Friesian) lactating dairy cows in early-mid lactation, averaging $23.3 \pm 3.5$ kg of milk, $85 \pm 5$ days in milk, $60.8 \pm 5.9$ months old and $464 \pm 43$ kg live weight, were stratified for milk yield, days in milk, age, stage of lactation and body weight, and then randomly allocated to two treatment groups (12 cows in each group). All cows were fed approximately 10 kg of commercial concentrate together with *ad libitum* grass silage and free access to clean water. Nil or 300 g of rumen-bypass fat (Bergafat T 300, Berg & Schmidt (M) Sdn. Bhd., Malaysia) were supplemented to the cows according to the treatment groups. The experiment lasted for 10 weeks (2 weeks for the adjustment period and 8 weeks for the measurement period).

### Sample Collection and Chemical Analysis

All cows were individually housed in a $2 \times 3$ $m^2$ pen and were individually fed 10 kg of commercial concentrate daily, divided into three equal meals, at 07:00, 11:30, and 16:30 h. Feed intake was measured on two consecutive days weekly and samples of feed were collected for laboratory analyses. After being dried (60°C) and ground to pass a 1 mm screen in a Wiley mill, feed samples were analyzed in duplicate for dry matter (DM) by drying a 1 g sample in duplicate at 60°C in a conventional oven for 36 h; for ash by burning a 2 g sample at 500°C for 3 h in a muffle furnace (Method 942.05; AOAC, 1995); for ether extract (Method 920.39; AOAC, 1995); for nitrogen (N) (Method 984.13; AOAC, 1995); for crude fiber (CF) (Method 978.10; AOAC, 1995); for neutral detergent fiber with residual ash (NDF), using $\alpha$-amylase and sodium sulfite); for acid detergent fiber (ADF); and for acid detergent lignin (ADL) (Van Soest *et al.,* 1991)

Energy values were evaluated using equations recommended by the NRC (2001) as follow:

$TDN_{1X}$ = total digestible nutrient at maintenance level

= tdNFC + tdCP + (tdFA × 2.25) + tdNDF – 7

where tdNFC (truly digestible non-fiber carbohy drates)

= 0.98 (100 - [(NDF – NDICP) + CP + EE + Ash])

tdCPf (truly digestible CP for forages)

= $CP \times \exp^{[-1.2 \times (ADICP/CP)]}$

tdCPc (truly digestible CP for concentrates)

= $[1 - (0.4 \times (ADICP/CP))] \times CP$

tdFA (truly digestible fatty acid)

= FA where FA = EE – 1.0, If EE<1.0 then FA = 0

tdNDF (truly digestible neutral detergent fiber)

= $0.75\,(NDF_N - \text{Lignin})\,[1 - (\text{Lignin}/NDF_N)^{0.667}]$

$DE_P$ (digestible energy at production level)

= $DE_{1X} \times [(TDN_{1X} - [(0.18 \times TDN_{1X}) - 10.3]) \times \text{intake})]/TDN_{1X}$

where $DE_{1X}$ = $[(tdNFC/100) \times 4.2] + [(tdNDF/100) \times 4.2] + [(tdCP/100) \times 5.6] + [(FA/100) \times 9.4] - 0.3$

Intake = intake above maintenance

$ME_P$ (metabolizable energy at production level)

= $[1.01 \times (DE_P) - 0.45] + [0.0046 \times (EE - 3)]$

$NE_{LP}$ = $[0.703 \times ME_P\ (\text{Mcal/kg})] - 0.19$

All cows were milked twice a day at 05:00 and 15:00 h Milk yields were individually recorded daily. Samples of milk from individual cows were collected on two consecutive days weekly and then subjected to laboratory analyses. Fat, protein, lactose, solid not fat (SNF) and total solid (TS) contents of the milk were analyzed by Milko Scan (Foss Electric, Denmark). Live weights of all cows were individually recorded on two consecutive days immediately after morning milking at the start and at fortnightly intervals until the end of the experimental period.

For fatty acid composition, milk samples were centrifuged. Fat cakes were recovered, placed in sample vials, flushed with $N_2$, capped, and then placed in a –20°C freezer. Lipid extraction was followed the procedures of Hara and Radin (1978) using a volume of 18 ml of hexane and isopropanol (3:2, vol/vol)/g of fat cake. After vortexing, a sodium sulfate solution (6.7% $NaSO_4$ in distilled $H_2O$) was added at a volume of 12 ml/g of fat cake. The hexane layer was transferred to a tube containing 1 g of $NaSO_4$, and, after 30 min, the hexane layer was removed and stored under $N_2$ gas at –20°C until methylation.

Approximately 30 mg of the extracted oil was placed into a 15-mL reaction tube fitted with a teflon-lined screw cap. One and a half ml of 0.5 M sodium hydroxide in methanol was added. The tubes were flushed with nitrogen, capped, heated at 100°C for 5 min with occasional shaking and then cooled to room temperature. One ml of C17:0 internal standard (2.0 mg/ml in hexane) and 2 ml of boron trifluoride in methanol were added and heated at 100°C for 5 min with occasional shaking. After methylation was completed, 10 ml of deionized water was added. The solution was transferred to a 40 ml centrifuged tube and 6 ml of hexane was added for FAME extraction. The solution was centrifuged at 2,000 × g, at 10°C for 20 min and then the hexane layer was dried over sodium sulfate and analyzed by gas chromatography (GC)

Fatty acid methyl esters were analyzed by GC (Hewlett Packard GC system HP6890 A; Hewlett Packard, Avondale, PA) equipped with a 100 m × 0.25 mm fused silica capillary column (SP2560, Supelco Inc, Bellefonte, PA, USA). Injector and detector temperatures were 240°C. The column temperature was kept at 70°C for 4 min, then increased at 13°C/min to 175°C and held at 175°C for 27 min, then increased at 4°C/min to 215°C and held at 215°C for 31 min.

### Statistical Analysis

All data collected and recorded were statistically analyzed by either *t*-test using the procedures described by SAS (1996). Significance was declared at $P < 0.05$.

## Results and Discussion

The chemical and nutrient compositions of feeds used in the experiment are shown in Table 1. The dry matter (DM), crude protein (CP) and net energy for lactation at production level ($NE_{LP}$) intakes of experimental cows are given in Table 2. All cows consumed similar amount of concentrate, roughage and total DM, CP and $NE_{LP}$. Rodriguez *et al*. (1997) found a 6% reduction in DM intake for Holsteins when rumen-bypass fat (Calcium soaps of fatty acid (CSFA)) was added to the diet. Similar reduction in DM intake attributable to dietary CSFA has been reported (Kim *et al*., 1993) while other reports indicated no difference in DM intake (Schneider *et al*., 1988; Erickson *et al*., 1992). Similar DM intake, as noted in the present study, might not have been a result of metabolic control (NRC, 2001) because $NE_{LP}$ intake was similar for both dietary treatments. The effects of fat supplementation on DM intake might be more pronounced for cows during early lactation (Grummer *et al*., 1990) than for cows during early to mid lactation, as were used in the present study.

All cows had similar milk yields and milk composition yields, final body weight and body weight change (Table 3). The lack of an increase in milk production for cows fed rumen-bypass fat compared with that of cows fed the control diet in the present experiment might have been due to the cows being in early-mid lactation and in positive energy balance; therefore a large milk production response to supplemental fat was not observed. Erickson *et al*. (1992) found an increase in milk yield by cows fed calcium salts of long-chain fatty acid in early lactation. Similar results were also reported (Schneider *et al*., 1988; Klusmeyer *et al*., 1991a; Erickson *et al*., 1992; Wu *et al*., 1993; Tomlinson *et al*., 1994; Rodriguez *et al*., 1997). In contrast, West and Hill (1990) found no difference when cows were fed CSFA. However, Sklan *et al*. (1989) reported that fat corrected milk yield was increased with Ca salts of fatty acid supplementation despite nonsignificant changes in milk yield and fat contents. Some researchers reported when rumen-bypass fat was supplemented to the diet of dairy cows the reduction of fat and crude protein contents (Erickson *et al*., 1992; Sklan *et al*., 1992; Rodriguez *et al*., 1997), while other researchers found the increase of milk fat content (Klusmeyer *et al*., 1991a, 1991b; Sklan *et al*., 1992; Elliott *et al*., 1996). A reduction in milk protein contents might be a result of reducing microbial protein production (Rodriguez *et al*., 1997) or insufficient essential amino acids to meet the requirements of dairy cows for milk production. Similar responses were also observed (West and Hill, 1990; Kim *et al*., 1993; Wu *et al*., 1993). However, no difference in milk protein composition from dietary CSFA has been reported (Schneider *et al*., 1988). Similarly, others reported no improvement in milk yields (Schauff and Clark, 1989; Skarr *et al*., 1989; Klusmeyer *et al*., 1991b; Sklan *et al*., 1992; Elliott *et al*., 1996) or milk fat contents (Atwal *et al*., 1990; Garcia-Bojalil *et al*., 1998) from feeding rumen-bypass fat.

Rumen-bypass fat supplementation significantly ($p<0.05$) reduced C4:0, increased C12:0 and C14:0, and there was no change ($p>0.05$) for other fatty acids of the cows' milk (Table 4). In contrast to the present study, Elliot *et al.* (1996) found that the contents of short and medium-chain fatty acids were decreased when supplemental rumen-bypass fat was fed while long-chain fatty acids were increased. These

**Table 1. Chemical and nutrient compositions of feeds used in the experiment**

| Composition | Concentrate | Grass silage | Rumen-bypass fat |
|---|---|---|---|
| Dry matter (%) | 90.30 | 37.00 | 99.90 |
| Crude protein (%) | 21.30 | 6.50 | - |
| Crude fiber (%) | 13.60 | 36.00 | - |
| Ether extract (%) | 3.60 | 1.40 | 99.00 |
| Ash (%) | 9.50 | 10.60 | - |
| Neutral detergent fiber (%) | 36.40 | 60.00 | - |
| Acid detergent fiber (%) | 13.90 | 29.90 | - |
| Acid detergent lignin (%) | 2.10 | 5.10 | - |
| Neutral insoluble nitrogen (%) | 1.40 | 0.70 | - |
| Acid detergent insoluble nitrogen (%) | 1.20 | 0.60 | - |
| $TDN_{1X}$ [1/] | 70.10 | 52.90 | 182.30 |
| $DE_P$ [2/] | 2.98 | 2.43 | 5.75 |
| $ME_P$ [3/] | 2.56 | 1.99 | 5.75 |
| $NE_{LP}$ [4/] | 1.61 | 1.21 | 4.60 |
| *dg* of CP | 0.68 | 0.48 | - |

[1/] $TDN_{1X}$ (%) = tdNFC + tdCP + (tdFA × 2.25) + tdNDF – 7)

[2/] $DE_P$ (Mcal/kg) = $\{[(TDN_{1X} - [(0.18 \times TDN_{1X}) - 10.3]) \times Intake]/ TDN_{1X}\} \times DE_{1X}$

[3/] $ME_P$ (Mcal/kg) = $[1.01 \times (DE_p) - 0.45] + [0.0046 \times (EE - 3)]$

[4/] $NE_{LP}$ (Mcal/kg) = $[0.703 \times ME_p] - 0.19$ (EE ≤ 3%)

[4/] $NE_{LP}$ (Mcal/kg) = $([0.703 \times ME_p] - 0.19) + [(0.097 \times ME_p)/97] \times [(EE - 30]$ (EE > 3%)

$TDN_{1X}$ = total digestible nutrient at maintenance level.

$DE_P$ = digestible energy at production level.

$ME_P$ = metabolizable energy at production level.

$NE_{LP}$ = net energy for lactation at production level.

*dg* = degradability.

**Table 2. Intakes of dry matter, crude protein and net energy for lactation at production level of control and rumen-bypass fat supplemented cows**

| Item | Control | Rumen-bypass fat | Pr > T | SEM |
|---|---|---|---|---|
| DM Intake (kg/d) | | | | |
| Concentrate | 9.03 | 9.03 | - | 0.00 |
| Roughage | 8.07 | 8.12 | 0.82 | 0.31 |
| Rumen-bypass fat | - | 0.30 | - | - |
| Total | 17.10 | 17.45 | 0.82 | 0.31 |
| CP Intake (g/d) | | | | |
| Concentrate | 1,896 | 1,896 | - | 0.00 |
| Roughage | 686 | 690 | 0.87 | 8.24 |
| Rumen-bypass fat | - | - | - | - |
| Total | 2,582 | 2,586 | 0.87 | 8.24 |
| $NE_{LP}$ Intake (Mcal/d) | | | | |
| Concentrate | 14.50 | 14.50 | - | 0.00 |
| Roughage | 9.80 | 9.80 | 0.99 | 0.18 |
| Rumen-bypass fat | - | 1.40 | - | - |
| Total | 24.30 | 25.70 | 0.89 | 0.72 |

SEM = standard error of the mean.

**Table 3. Milk yield, milk composition yields, initial weight, final weight and body weight change of control and rumen-bypass fat supplemented cows**

| Item | Control | Rumen-bypass fat | Pr > T | SEM |
|---|---|---|---|---|
| Milk yield (kg/d) | 20.93 | 20.42 | 0.78 | 1.78 |
| 3.5%FCM | 20.59 | 20.97 | 0.83 | 1.67 |
| Fat yield (g/d) | 718 | 766 | 0.56 | 68.00 |
| Protein yield (g/d) | 571 | 598 | 0.70 | 36.00 |
| Lactose yield (g/d) | 921 | 896 | 0.85 | 85.00 |
| SNF yield (g/d) | 1,681 | 1,685 | 0.95 | 132.00 |
| TS yield (g/d) | 2,401 | 2,454 | 0.87 | 186.00 |
| Milk fat (%) | 3.43 | 3.75 | 0.33 | 0.31 |
| Milk protein (%) | 2.73 | 2.93 | 0.15 | 0.13 |
| Lactose (%) | 4.40 | 4.39 | 0.93 | 0.10 |
| Solid not fat, SNF (%) | 8.03 | 8.25 | 0.20 | 0.16 |
| Total solid, TS (%) | 11.47 | 12.02 | 0.23 | 0.44 |
| Initial BW (kg) | 461.00 | 467.00 | 0.84 | 26.00 |
| Final BW (kg) | 455.00 | 462.00 | 0.77 | 22.00 |
| Body weight change (g/d) | -171.00 | -89.00 | 0.10 | 43.00 |

SEM = standard error of the mean.

results were consistent with research utilizing supplemental dietary fat (Palmquist *et al*., 1993). Differences in fatty acid composition of the milk reflected differences in the fatty acid composition of the rations.

When combining the data for milk yield and body weight (BW) change, it was possible to compare the effect of different rations on the apparent utilization of the net energy for lactation at production ($NE_{LP}$) intake (Table 5). Both groups of cows consumed similar $NE_{LP}$, therefore the partitioning of energy between milk productions was also similar.

Both groups of cows had a considerable supply of $NE_{LP}$ but the milk yields were lower than would have been expected from $NE_{LP}$ intakes. The respective intakes of 24.3 and 25.7 Mcal daily by cows in the control and supplemented groups, in theory, should be able to produce approximately 24.5 and 25.2 kg milk/d respectively. The lower milk yield than what would be expected from the $NE_{LP}$ available could

**Table 4. Effect of rumen-bypass fat supplementation on fatty acid content of cow's milk**

| Item | Control | Rumen-bypass fat | Pr > T | SEM |
|---|---|---|---|---|
| % of total fatty acid | | | | |
| C4:0 | 1.93[a] | 1.08[b] | 0.05 | 0.36 |
| C6:0 | 1.53 | 1.10 | 0.14 | 0.25 |
| C8:0 | 1.00 | 0.93 | 0.59 | 0.12 |
| C10:0 | 2.14 | 2.25 | 0.60 | 0.20 |
| C11:0 | 0.35 | 0.34 | 0.68 | 0.04 |
| C12:0 | 6.66[b] | 7.55[a] | 0.02 | 0.31 |
| C13:0 | 0.32 | 0.33 | 0.97 | 0.04 |
| C14:0 | 11.55[b] | 13.30[a] | 0.01 | 0.51 |
| C14:1 | 2.44 | 2.03 | 0.23 | 0.30 |
| C15:0 | 1.07 | 1.02 | 0.86 | 0.25 |
| C16:0 | 27.95 | 26.45 | 0.18 | 0.97 |
| C16:1 | 5.05 | 3.73 | 0.15 | 0.80 |
| C18:0 | 4.87 | 5.89 | 0.16 | 0.63 |
| C18:1n9t | 2.39 | 2.17 | 0.41 | 0.24 |
| C18:1n9c | 27.70 | 29.18 | 0.39 | 1.55 |
| C18:2n6t | 0.17 | 0.17 | 0.27 | 0.02 |
| C18:2n6c | 1.74 | 1.61 | 0.42 | 0.14 |
| C20:0 | 0.24 | 0.08 | 0.35 | 0.15 |
| C18:3n6 | 0.19 | 0.01 | 0.28 | 0.15 |
| CLA[1] | 0.53 | 0.42 | 0.17 | 0.07 |
| C22:0 | 0.01 | 0.02 | 0.35 | 0.01 |
| C20:3n6 | 0.14 | 0.13 | 0.31 | 0.01 |
| Short chain fatty acid | 13.93 | 13.58 | 0.78 | 1.10 |
| Medium chain fatty acid | 48.05 | 46.53 | 0.52 | 2.11 |
| Long chain fatty acid | 38.02 | 39.89 | 0.42 | 2.06 |
| Saturated fatty acid | 59.62 | 60.35 | 0.54 | 1.07 |
| Unsaturated fatty acid | 40.39 | 39.65 | 0.54 | 1.07 |

[a-b] values with no common superscript differ significantly ($p<0.05$)

SEM = standard error of the mean.

[1] Conjugated linoleic acid (cis 9, trans 11 octadecadienoic acid)

**Table 5. Estimates of the partitioning of net energy intake (Mcal/d)**

| | Control | Rumen-bypass fat | Pr>T | SEM |
|---|---|---|---|---|
| $NE_{LP}$ intake | 24.30 | 25.70 | 0.89 | 0.72 |
| $NE_{LM}$ | 7.90 | 8.00 | 0.99 | 0.02 |
| $NE_{LG}$ | -0.70 | -0.50 | 0.93 | 0.03 |
| $NE_{LL}$ | 13.40 | 13.90 | 0.95 | 0.10 |
| $NE_{LR}$ | 20.60 | 21.40 | 0.89 | 0.38 |

$NE_{LP}$ : net energy for lactation at production level.
$NE_{LM}$ : net energy requirement for maintenance = $0.08 \times LW^{0.75}$
$NE_{LG}$ : net energy requirement for gain = reserve energy × (0.64/0.75)
$NE_{LL}$ : net energy requirement for lactation = 0.0929 × %fat + 0.0547 × %CP + 0.0395 × %lactose.
$NE_{LR}$ : net energy retention.
SEM = standard error of the mean.

be attributed to the probable underestimates of the net energy for lactation at maintenance ($NE_{LM}$) for dairy cows in the tropics. Since dairy cows in the tropics are fed lower quality feeds than cows in the United States, the use of the equation suggested by the NRC (2001) might be inappropriate. AAC (1990) recommended that dairy cattle consuming feeds containing energy lower than 10 MJ metabolizable energy (ME)/kg DM needed more energy for maintenance. The present study used a net energy maintenance value of 0.08 Mcal/kg $BW^{0.75}$ for predicting $NE_{LM}$. If the hypothesis by AAC (1990) is true, with the assumption that the average net energy values of milk and body weight change are unaffected by the quality of feeds as in case of $NE_{LM}$, the average net energy maintenance value of 0.120 Mcal/kg $BW^{0.75}$ should be used in this study. This is approximately 50% higher than the NRC (2001) recommendation. Suksombat and Junpanichcharoen (2005) suggested that, in the tropics, the average net energy maintenance value of 0.106 Mcal/kg $BW^{0.75}$ would be more appropriate than the value of 0.08 Mcal/kg $BW^{0.75}$ recommended by NRC (2001). Before a conclusion can be reached, further research is needed.

The present study indicated that supplementation of rumen-bypass fat did not enhance milk yield, milk composition, fatty acid composition of milk and body weight change of lactating dairy cow.

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