Effects of Feeding Glycerol to Lactating Dairy Cows on Milk Production and Composition

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***Abstract*—**A study was conducted to determine the effect of feeding glycerol on dairy cows performance. Twenty four Holstein Friesian crossbred (>87.5% Holstein Friesian) lactating dairy cows in early lactation; averaging 13±2.4 kg of milk, 64±45 days in milk, 55±16 months old and 325±26 kg live weight, were stratified for milk yield, days in milk, age, stage of lactation and body weight, and then randomly allocated to three treatment groups. All cows were fed approximate 8 kg of concentrate together with *ad libitum* corn silage and freely access to clean water. Nil or 150 and 300g of glycerol were supplemented to the cows according to treatment groups. All cows consumed similar concentrate, corn silage and total DM and NE_{LP}. There were no significant differences in DM intake, CP intake, NE_{LP} intake, milk and milk composition yields. All cows had similar fat, protein, lactose, solid not fat and total solid percentage. All cows gain similar live weight. The present study indicated that, supplementation of glycerol did not enhance milk yield, milk composition and live weight change.

***Keywords*—**Glycerol, Milk production and composition, Dairy cattle

I. 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 [1], thus forcing mobilization of body fat reserves to satisfy energy requirements. Glycerol is a byproduct of base-catalyzed transesterification of oil in the formation of methyl and ethyl fatty acid esters in the production of biodiesel [2] and is a main by-product of ethanol fermentation processing [3]. Approximately 0.92 kg of crude glycerol is produced for every 10 L of biodiesel produced. Recent growth of the biofuels industry, including biodiesel production, has prompted forecasting of glycerol surpluses [4]. Glycerol is an important structural component of triglycerides and phospholipids. The glucogenic property of glycerol is well established [5]. Surplus glycerin from biodiesel fuel production will likely flood glycerin supplies for the traditional uses, although there are many applications for glycerin, such as using it as an energy source in livestock diets. From very limited research, glycerin has been fed as a feed ingredient to replace energy sources such as corn for up to 10% of the total ration DM for broiler chickens [6]. Glycerin has been fed to early postpartum dairy cows [6] - [8] or cows in early [9] to midlactation [10] as an energy supplement rather than as a major feed ingredient. Glycerin, when fed as a glucogenic supplement, did not improve milk yield when compared with propylene glycol [7], [10] or when it was substituted for barley [11]. The objective of this study was to determine the effect of feeding glycol to lactating dairy cows on milk yield and composition.

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II. MATERIALS AND METHOD

Twenty four Holstein Friesian crossbred (>87.5% Holstein Friesian) lactating dairy cows in early lactation; averaging 13±2.4 kg of milk, 64±45 days in milk, 55±16 months old and 325±26 kg live weight, were stratified for milk yield, days in milk, age, stage of lactation and body weight, and then randomly allocated to three treatment groups (8 cows in each group). All cows were fed approximate 10 kg of concentrate together with *ad libitum* roughage and freely access to clean water. Nil or 150 and 300 g of glycerol were supplemented to the cows according to treatment groups. The experiment lasted for 10 weeks (2 weeks for adjustment period and 8 weeks for measurement period).

All cows were individually housed in a 2 x 3 m^2 pen and were individually fed 8 kg 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 analysis. After being dried (60°C) and ground to pass a 1 mm screen in a Wiley mill, feed samples were analyzed for 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 in duplicate at 500 C for 3 h in a muffle furnace [12], for ether extract [12], for N [12], for neutral detergent fiber with residual ash (NDF), for acid detergent fiber (ADF), and for acid detergent lignin (ADL) [13].

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 cow were collected on two consecutive days weekly and then subjected to laboratory analysis. Fat, protein, lactose, solid not fat (SNF) and total solid (TS) contents of 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 interval until the end of the experimental period. All data collected and recorded were subjected to analysis of variance by the procedures described by SAS [14].

III. RESULTS AND DISCUSSION

Chemical and nutrient compositions of feeds used in the experiment are shown in Table 1. 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 concentrate, corn silage and total DM and NE_{LP}. Dry matter intake and milk yield increased as lactation progressed but did not differ significantly between treatments. Recent research indicates no effect of glycerol on feed intake. Glycerol administered as a topdress from −14 to +21 d relative to calving decreased prepartum intake but was without effect during the postpartum interval [8]. A recent experiment in which a dry glycerol product was fed to transition cows during the prepartum period showed no effect on intake [15]. In contrast, feeding 300 or 500 mL of glycerol per day beginning at calving had a transient effect of increasing DMI after 5 wk of feeding [15].

TABLE I
CHEMICAL COMPOSITION (% OF DM) OF FEED USED IN THE EXPERIMENT

% Dry matter	Concentrate	Corn silage
Dry matter	92.37 ± 0. 02	33.68 ± 0.04
Crude protein	17.21 + 0.04	4.44 + 0.13
Crude fat	5.17 + 0.23	2.02 + 0.16
Ash	6.16 + 0.26	9.85 + 0.25
Crude fiber	9.01 + 1.38	27.73 + 0.95
Crude NFC	27.92 + 0.38	10.48 + 0.22
NDF	38.4 + 0.52	73.21 + 1.77
ADF	28.02 + 0.71	38.90 + 1.59
ADL	9.16 + 0.52	9.42 + 0.38
NDIN	1.35 + 0.27	0.59 + 0.24
ADIN	0.37 + 0.04	0.14 + 0.12
TDN_{1X} (%)1	67.27	46.80
DE_P (Mcal/kg)2	2.63	2.27
ME_P (Mcal/kg)3	2.21	1.84
NE_{LP} (Mcal/kg)4	1.37	1.11

[1]TDN_{1X} (%) = tdNFC + tdCP + (tdFA x 2.25) + tdNDF – 7 [16]
[2]DE_{1X} (Mcal/kg) = [(tdNFC/100)x4.2]+[(tdNDF/100) x 4.2]+[(tdCP/100) x 5.6]+[(FA/100) x 9.4] –0.3
[3]DE_P (Mcal/kgDM) = DE_{1X} x Discount [16]
[4]ME_p = [1.01 x (DE_p) – 0.45] + [0.0046 x (EE – 3)] [16]
[5]NE_{LP} = ([0.703 x ME_p (Mcal/kg)] – 0.19) + ([(0.097 x ME_p + 0.19)/97] x [EE – 3]) [16]

No effect of glycerol supplementation on milk yield in this study is consistent with several recent studies ([8], [9], [15]) in which glycerol was fed to early postpartum dairy cows. Some reference [15] found milk yield increased as lactation progressed, but did not differ between control and glycerol supplemental cows. In contrast, [11] reported milk production of cows fed supplemented glycerol at 300 and 500ml/day was increased by 14.6 and 12.5%, respectively, during 10 weeks of lactation. The trend towards lower milk fat content of cows fed glycerol *versus* control cows is consistent with [9], who reported tendencies for a lower milk fat yield when glycerol was fed. This reduction in glycerol on milk fat proportion, however, did not occur in other studies [8], [9].

TABLE II
DRY MATTER (DM), CRUDE PROTEIN (CP), AND NET ENERGY FOR LACTATION (NELP) INTAKES OF EXPERIMENTAL COWS.

	Control	Glycerol		SEM	P-value
		150g/d	300g/d		
DM intake (kg/d)					
Concentrate	8.8	8.8	8.8	-	-
Roughages	6.8	7.3	7.2	0.38	0.34
Total	15.6	16.1	16.0	0.38	0.35
CP intake (g/d)					
Concentrate	1514	1514	1514	-	-
Roughages	301	325	320	17.2	0.35
Total	1815	1839	1835	16.9	0.36
NE_{LP} intake (Mcal/d)					
Concentrate	12.1	12.1	12.1	-	-
Roughages	7.5	8.1	8.0	0.42	0.35
Total	19.6	20.2	20.1	0.42	0.35

SEM = standard error of the mean; NELP = net energy for lactation

TABLE III
MILK YIELD, MILK COMPOSITION YIELD, MILK COMPOSITIONS, INITIAL WEIGHT, FINAL WEIGHT, AND LIVE WEIGHT (LW) CHANGE OF EXPERIMENTAL COWS

	Control	Glycerol		SEM	P-value
		150g/d	300g/d		
Milk yield (kg/day)	13.9	13.4	13.2	0.65	0.59
3.5% FCM (kg/day)	14.8	14.4	13.7	0.67	0.30
Fat yield (g/d)	541	534	495	30.6	0.29
Protein yield (g/d)	385	363	363	17.9	0.39
Lactose yield (g/d)	598	567	566	27.3	0.43
SNF yield (g/d)	1117	1058	1057	42.1	0.24
Total solid yield (g/d)	1657	1592	1551	71.3	0.34
Fat (%)	3.92	4.00	3.77	0.23	0.61
Protein (%)	2.78	2.71	2.75	0.11	0.41
Lactose (%)	4.32	4.24	4.29	0.17	0.39
SNF (%)	8.06	7.92	8.00	0.04	0.29
Total solid (%)	11.98	11.92	11.77	0.28	0.76
Initial BW (Kg)	421	413	416	28.4	0.93
Final BW (Kg)	432	435	437	21.7	0.98
BW Change (g/d)	301	595	561	170	0.19

SEM = standard error of the mean; FCM = fat corrected milk

All 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 19.6, 20.2, and 20.1 Mcal daily by cows in the control, 150 and 300 g/d glycerol groups, in theory, should be able to produce approximately 18 - 19 kg of milk/d. The lower milk yield than what would be expected from the NE_{LP} available could 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 [16] might be inappropriate. AAC [17] 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 [17] is true, with the assumption that the average net energy values of milk and BW change are unaffected by the quality of feeds as in the 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 [16] recommendation. Multiple references [18], [19] suggested that, in the tropics, the average net energy maintenance value of 0.083 and 0.106 Mcal/kg $BW^{0.75}$, respectively, would be more appropriate than the value of 0.08 Mcal/kg $BW^{0.75}$ recommended by NRC [16]. Before a conclusion can be reached, further research is needed.

The estimated supplies of rumen degradable protein (RDP) and rumen undegradable protein (RUP) to the cows can be calculated using the protein degradability values of each feed (determined by the nylon bag technique; Table 5; NRC [16]. All cows consumed similar RDP and RUP, however, all cows received adequate RDP but inadequate RUP. The present study indicated that feeding glycerol did not affect milk yield, milk composition and body weight change of lactating dairy cow.

TABLE IV
ESTIMATES OF THE DISTRIBUTION OF NET ENERGY INTAKE

	Control	Glycerol		SEM	P-value
		150g/d	300g/d		
NE_{LP} intake (Mcal/d)	19.6	20.2	20.1	0.42	0.35
NE_{LM} (Mcal/d)	7.51	7.47	7.49	0.28	0.99
NE_{LL} (Mcal/d)	9.79	9.51	9.12	0.44	0.33
NE_{LG} (Mcal/d)	1.30	2.47	1.86	0.85	0.34
NE_{LR} (Mcal/d)	18.6	19.5	18.5	1.03	0.56
Efficiency of NE_{LP} utilization	0.92	0.95	0.89	0.09	0.77

NE_{LP}: net energy for lactation at production level.
NE_{LM}: net energy requirement for maintenance = 0.08 x $LW^{0.75}$
NE_{LG}: net energy requirement for gain = reserve energy x (0.64/0.75)
NE_{LG}: net energy requirement for loss = reserve energy x (0.82)
NE_{LL}: net energy requirement for lactation = 0.0929 x % fat + 0.0547 x % CP + 0.0395 x % lactose.
NE_{LR}: net energy retention.
Efficiency of NE_{LP} utilization = NE_{LR}/NE_{LP} intake.
SEM = standard error of the mean

TABLE V
THE ESTIMATED SUPPLY OF RUMEN DEGRADABLE PROTEIN AND RUMEN UNDEGRADABLE PROTEIN

	Control	Glycerol		SEM	P-value
		150g/d	300g/d		
RDP_{req}	1065	1174	1156	76.2	0.32
RDP_{sup}	1469	1492	1488	16.5	0.35
Deficit/Surplus	193	180	182	9.5	0.35
MCP_{sup}	1084	1115	1110	22.2	0.35
MP_R	1283	1343	1347	63.8	0.53
RUP_{req}	975	1048	1062	112.2	0.71
RUP_{sup}	939	965	960	18.7	0.35
Deficit/Surplus	-38	-83	-101	110.8	0.83

SEM = standard error of the mean; $RDP_{sup} = CP_{intake} \times dg$; $RUP_{sup} = CP_{intake} - RDP_{sup}$

IV. Conclusion

Supplementation of Holstein dairy cow diets with up to 300 g of glycerol during the early lactation. There were no deleterious effects on feed intake, milk production, or milk composition.

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