

Effect of Feeding Supplemental Tallow on the Performance of Lactating Nili-Ravi Buffaloes

Haq NAWAZ^{1,*}, Muhammad YAQOOB², Muhammad ABDULLAH³

¹Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad, PAKISTAN

²Department of Livestock Management, University of Agriculture, Faisalabad, PAKISTAN

³University of Veterinary and Animal Sciences, Lahore, PAKISTAN

Received: 03.11.2006

Abstract: In order to determine the feeding value of tallow for lactating Nili-Ravi buffaloes, 4 buffaloes were fed 0%, 2%, 4%, or 6% tallow in a 4 × 4 Latin square experiment. The intakes of dry matter (DM), organic matter (OM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) decreased ($P < 0.01$), but the intakes of ether extract (EE) ($P < 0.01$) and digestible energy (DE) ($P < 0.05$) increased with increasing levels of tallow in the diets. Intake of net energy for lactation (NE_L) did not differ ($P < 0.01$) with varying levels of supplemental tallow. Daily milk yield increased ($P < 0.01$) from 11.00 to 13.2 kg/day. Production of 4% fat corrected milk (FCM), solid corrected milk (SCM), and energy corrected milk (ECM) increased quadratically ($P < 0.05$) with the increasing level of tallow in the diets. Milk fat content and total milk fat increased linearly ($P < 0.01$) and quadratically ($P < 0.05$), respectively, as the level of tallow in the diet increased. There was no difference in protein and lactose content due to feeding tallow. Total solid content increased quadratically ($P < 0.05$) from 16.45% to 17.67% but solid not fat (SNF) percentages did not vary with varying levels of tallow. The gross energy (GE) of the milk increased from 1096 to 1160 Kcal/kg ($P < 0.01$) with increasing levels of tallow in the diets. Energetic efficiency of milk production improved in a quadratic ($P < 0.05$) manner with 2%, 4%, and 6% tallow, with the highest being 47.6% with 4% supplemental tallow. The proportion of $C_{8,0}$ to $C_{16,1}$ fatty acids (FA) decreased from 53.66% to 35.52%, whereas the concentration of $C_{18,0}$ to $C_{20,0}$ increased (44.93% to 62.84%) in the milk fat of buffaloes fed diets containing different levels of tallow. Gains in body weight (BW) were higher ($P < 0.05$) in buffaloes fed diets containing supplemental tallow as compared to those fed the control diet. This study suggests that tallow up to 6% of diet DM is a suitable fat supplement as an economical energy source for lactating buffaloes.

Key Words: Tallow, Nili-Ravi buffalo, nutrient intake, milk composition, energetic efficiency, income/cost ratio

Introduction

The dairy industry in Pakistan is buffalo oriented. Pakistan has approximately 26.3 million buffaloes. Buffaloes in milk contribute 74.3% of the total milk produced in the country (1). Various research studies on different aspects of buffalo production have been conducted in the last decade. Several studies have been conducted to compare the efficiency of the inclusion of different feedstuffs in buffalo diets. Buffaloes are superior to domesticated cattle (*Bos sp.*) because they digest feed more efficiently than cattle do, particularly when the feed is of poor quality and is high in cellulose. Buffalo milk is therefore cheaper to produce (2). Moreover, buffaloes take less time to adjust to changes in the diet composition as compared to cows (2).

During early lactation, dairy animals are in negative energy balance for the first 8 to 12 weeks because energy intake is insufficient to meet the energy requirement. To overcome this negative energy balance, energy density of the diet is increased with grains; however, this often causes undesirable ruminal fermentation and depresses milk fat synthesis. Supplemental fat, however, tends to increase the energy density of the diet without causing any negative impacts on rumen fermentation associated with excessive grain and concentrate feeding (3). Annual production of tallow in Pakistan is 0.47 million tons (1). However, little research has been undertaken on feeding tallow to lactating buffaloes. Thus, it is important to study the effects of tallow in lactating buffaloes. Therefore, this

* E-mail: dr_haq_nawaz@yahoo.com

study was conducted to determine the effect of feeding tallow on nutrient intake, milk production, composition, energetic efficiency, fatty acid composition of milk fat, and gains in body weight and cost of milk production in lactating Nili-Ravi buffaloes.

Materials and Methods

An experiment was conducted in a 4 × 4 Latin square design at the Animal Nutrition Research Center, University of Agriculture, Faisalabad, Pakistan, to determine the nutritive value of rations containing different levels of tallow. In the trial, 4 early lactating Nili-Ravi buffaloes of approximately the same age, lactation number, lactation stage, body weight, and milk yield were used. Four experimental diets (Table 1) that either contained no added fat or had tallow as 2%, 4%, and 6% of dietary dry matter (DM) were formulated and fed as a total mixed ration according to nutrient requirements of dairy animals (4). The trial consisted of 4 periods of 21

days each: the first 14 days were allowed for adjustment to the diet, followed by 7 days for sample collection. Buffaloes were individually fed diets ad libitum twice daily (i.e. 0500 and 1700 hours) in a tie-stall barn. The amounts of feed offered and refused were recorded daily and proportionate samples were taken during the last 7 days of each trial. The samples of feed offered and refused were composited to have 1 sample per buffalo per period. DM was determined by drying the samples in a forced draft hot air oven at 60 °C for 48 h. Composited dried samples were ground through a 1 mm screen in a Wiley mill and were stored at -20 °C until analyzed for organic matter (OM), crude protein (CP), ether extract (EE), acid detergent fiber (ADF), and neutral detergent fiber (NDF) content (5).

Buffaloes were milked twice a day and milk production was recorded at each milking throughout the trial. Individual milk samples were collected at each milking during the last 7 days of each trial in 50 ml plastic vials containing approximately 50 mg of potassium

Table 1. Percent ingredient and nutrient composition of the experimental diets (DM basis).

Ingredients	A Control	B (2%)	C (4%)	D (6%)
Berseem (Egyptian clover*)	39.46	36.59	35.73	33.76
Wheat straw	21.99	21.19	18.39	16.93
Cottonseed cake	11.72	12.22	12.73	13.16
Maize oil cake	11.92	12.44	12.95	13.39
Wheat bran	14.18	14.80	15.41	15.93
Tallow	-	2.00	4.00	6.00
Dicalcium phosphate	0.73	0.76	0.79	0.83
Total	100	100	100	100
Dry matter%	30.30	31.95	32.47	34.01
Organic matter%	91.36	91.53	91.65	91.81
Crude protein%	12.10	12.60	12.70	12.60
Ether extract%	4	5.90	7.90	9.90
ADF%	26.89	26.13	24.93	23.87
NDF%	47.73	46.60	45.47	44.54
DE Mcal/kg DM	2.15	2.32	2.50	2.64
NE _L Mcal/kg DM	1.43	1.47	1.54	1.58
Calcium%	0.58	0.57	0.58	0.58
Phosphorus%	0.44	0.45	0.46	0.46

* *Trifolium alexandrinum*

dichromate ($K_2Cr_2O_7$). The milk samples were composited daily for each buffalo according to milk production to provide 1 sample per buffalo per period and were stored at $-20\text{ }^\circ\text{C}$ until analyzed for milk fat percentage, protein, lactose, total solids, solids not fat (SNFs), and ash content (5). Milk fat was separated and composited by period for each buffalo and frozen at $-20\text{ }^\circ\text{C}$ until analyzed for fatty acids (6). In the study, 4% fat corrected milk (FCM), solid corrected milk (SCM), and energy corrected milk (ECM) were calculated using the equations below (7):

$$\text{FCM (kg/day)} = 0.4 \times \text{kg milk} + 15 \times \text{kg fat}$$

$$\text{SCM (kg/day)} = 12.3 \times \text{kg fat} + 6.56 \times \text{kg SNF} - 0.0752 \times \text{kg milk}$$

$$\text{ECM (kg/day)} = [(41.63 \times \text{milk fat}\% + 24.13 \times \text{milk protein}\% + 21.60 \times \text{milk lactose}\%) \times \text{milk (kg/day)}] / 340$$

Energetic efficiency of milk production was calculated by dividing milk energy by digestible energy (DE) of the feed consumed (7). The specific gravity of milk was determined using a lactometer. The buffaloes were weighed during the first 3 days and the last 3 days of each experimental period (21 days) to record changes in body weights (BW). The data were subjected to analysis of variance using a 4×4 Latin square design (8). The following statistical model was used for this purpose:

$$Y_{ijk} = \mu + A_i + P_j + T_k + e_{ijk}$$

where $i, j, k, = 1, \dots, 4$

and

Y_{ijk} is the observation of the i^{th} animal fed the k^{th} treatment in the j^{th} period.

A_i is the effect of the i^{th} animal

P_j is the effect of the j^{th} period

T_k is the effect of the k^{th} treatment

e_{ijk} is the random error associated with the observation of the i^{th} animal fed the k^{th} treatment in the j^{th} period. It is further assumed that e_{ijk} is normally and independently distributed with a mean 0 and variance δ^2 , i.e. $e_{ijk} \sim N(0, \delta^2)$. A comparison of the mean difference was made by Duncan's multiple range test (8).

Results

Total DM intake, as well as that of percentage of BW, decreased linearly ($P < 0.05$) with increasing levels of tallow in the diets. Intakes of OM and CP decreased linearly ($P < 0.05$) in buffaloes fed varying levels of supplemental tallow compared to the control group (Table 2). The intake of EE increased linearly ($P < 0.01$)

Table 2. Daily nutrient intake in Nili-Ravi buffaloes fed diets containing different levels of tallow.

Item	Diets				SEM	Contrasts		
	A	B	C	D		L	Q	C
	(Control)	(2%)	(4%)	(6%)		Probabilities for contrasts		
DM (kg)	14.4 ^a	13.1 ^b	12.7 ^b	12.6 ^b	0.310	0.007	NS	NS
DM (%BW)	3.39 ^a	3.08 ^b	3.00 ^b	2.91 ^b	0.071	0.003	NS	NS
OM (kg)	13.2 ^a	12.0 ^b	11.7 ^b	11.6 ^b	0.286	0.008	NS	NS
CP (kg)	1.83 ^a	1.65 ^b	1.61 ^b	1.60 ^b	0.039	0.005	NS	NS
EE (kg)	0.58 ^d	0.77 ^c	1.00 ^b	1.25 ^a	0.023	0.000	NS	NS
ADF (kg)	3.87 ^a	3.41 ^b	3.23 ^{bc}	3.02 ^c	0.091	0.001	NS	NS
NDF (kg)	6.86 ^a	6.09 ^b	5.82 ^b	5.63 ^b	0.150	0.001	NS	NS
NE _L (Mcal/day)	20.6 ^a	19.2 ^a	19.5 ^a	20.0 ^a	0.465	NS	NS	NS
DE (Mcal/day)	30.9 ^{ab}	30.2 ^b	31.8 ^{ab}	33.4 ^a	0.760	0.040	NS	NS

Means with the same superscript in a row show non-significant difference ($P > 0.05$)

SEM = Standard error of means

NS = Probability is greater than 0.05

L, Q, C = Linear, quadratic and cubic effect of increasing tallow, respectively

with increasing quantities of tallow in the diets. Intakes of ADF and NDF were lower ($P < 0.01$) for buffaloes fed diets containing different levels of tallow compared to those fed the control diet. No differences ($P > 0.05$) in NE_L (Mcal/day) intake were observed in buffaloes fed the control diet and in those fed diets containing varying levels of tallow. Intake of DE (Mcal/day) was higher ($P < 0.05$) for buffaloes fed 6% tallow compared to those assigned to the diet containing 2% tallow. The intakes of both NE_L and DE did not decrease with the reduction in DM intake in animals fed varying levels of supplemental tallow as compared to the control diet.

Daily milk production (kg/day) of buffaloes fed diets containing varying levels of supplemental tallow increased linearly ($P < 0.01$) with increasing level of tallow in the diets because of higher efficiency of milk synthesis (Table 3). Production of 4% FCM, SCM, and ECM was higher (P

< 0.01) in buffaloes fed supplemental tallow than in those fed the control diet. Milk fat content and fat produced per day were higher ($P < 0.01$) for buffaloes assigned to the diets containing varying levels of supplemental tallow than for the control diet.

Milk protein contents were not different ($P > 0.05$) between buffaloes fed the control diet and those fed diets supplemented with different levels of tallow. Milk protein depression in buffaloes fed tallow may have been due to insufficient critical amino acids for milk protein synthesis. No differences ($P > 0.05$) in milk lactose contents were noted between buffaloes fed diets containing 2% to 6% tallow and those on the control diet. Milk total solids content was higher ($P < 0.05$) for buffaloes fed diets containing different levels of tallow as compared to the control group. Increasing the dietary concentrations of tallow increased ($P < 0.05$) milk total solids content. The

Table 3. Milk production, milk composition, and body weight gains in Nili-Ravi buffaloes fed diets containing different levels of tallow.

Item	Diets				SEM	Contrasts		
	A	B	C	D		L	Q	C
	(Control)	(2%)	(4%)	(6%)		Probabilities for contrasts		
Milk (kg/day)	11.0 ^b	12.6 ^a	13.0 ^a	13.2 ^a	0.311	0.003	NS	NS
4% FCM (kg/day)	17.2 ^c	20.2 ^b	21.5 ^{ab}	22.0 ^a	0.461	0.000	0.035	NS
SCM (kg/day)	16.2 ^b	19.2 ^a	20.3 ^a	20.1 ^a	0.547	0.002	0.029	NS
ECM (kg/day)	16.2 ^b	19.1 ^a	20.2 ^a	20.5 ^a	0.466	0.001	0.028	NS
Milk fat%	7.74 ^c	7.98 ^b	8.37 ^a	8.43 ^a	0.052	0.000	NS	NS
Milk fat (kg/day)	0.86 ^c	1.01 ^b	1.09 ^{ab}	1.11 ^a	0.023	0.000	0.028	NS
Milk protein%	3.90 ^a	3.84 ^a	3.77 ^a	3.71 ^a	0.208	NS	NS	NS
Lactose%	4.14 ^a	4.41 ^a	4.55 ^a	4.42 ^a	0.188	NS	NS	NS
Total solid%	16.45 ^b	17.36 ^a	17.67 ^a	17.49 ^a	0.222	0.013	0.049	NS
SNF%	9.05 ^a	9.28 ^a	9.30 ^a	9.06 ^a	0.180	NS	NS	NS
SNF (kg/day)	1.00 ^b	1.17 ^a	1.21 ^a	1.19 ^a	0.037	0.007	0.036	NS
Ash (%)	1.01 ^a	0.84 ^a	0.98 ^a	0.96 ^a	0.050	NS	NS	NS
Specific gravity	1.029 ^a	1.029 ^a	1.028 ^a	1.027 ^a	0.001	NS	NS	NS
GE (Kcal/g of fat)	9.39 ^a	9.33 ^{ab}	9.32 ^{ab}	9.28 ^b	0.029	0.035	NS	NS
GE (Kcal/kg of milk)	1096 ^c	1128 ^{bc}	1165 ^a	1160 ^{ab}	10.167	0.002	NS	NS
Total GE of milk (Mcal/day)	12.1 ^b	14.3 ^a	15.1 ^a	15.3 ^a	0.356	0.001	0.032	NS
Gains in BW (kg/day)	0.20 ^b	0.29 ^a	0.31 ^a	0.33 ^a	0.024	0.007	NS	NS

Means with the same superscript in a row show non-significant difference ($P > 0.05$)

SEM = Standard error of means

NS = Probability is greater than 0.05

L, Q, C = Linear, quadratic and cubic effect of increasing tallow, respectively

contents of SNF, milk ash, and specific gravity of milk did not differ ($P > 0.05$) in buffaloes fed diets supplemented with varying levels of tallow compared to the control diet. However, daily production of SNF (kg/day) increased ($P < 0.05$) with increasing levels of tallow in the diets.

Gross energy (GE) of milk fat increased linearly ($P < 0.05$) with increasing quantities of dietary tallow. Total GE of milk (Mcal/day) was higher ($P < 0.01$) in buffaloes fed varying levels of tallow than in those fed the control diet. Increasing dietary levels of tallow linearly increased ($P < 0.01$) the GE per kilogram of milk and the total GE of milk (Mcal/day). Gains in BW were higher ($P < 0.05$) and increased linearly ($P < 0.01$) with increasing amounts of tallow in the diets.

The efficiency of milk production in Nili-Ravi buffaloes fed diets containing different levels of tallow is given in Table 4. Milk production per kilogram of DM intake increased ($P < 0.05$) in buffaloes fed varying levels of supplemental tallow. Diets containing added fat had greater energetic efficiency, which could support greater milk yield with less DM intake. Milk production per NE_L intake (kg/Mcal) was observed to be higher ($P < 0.05$) in buffaloes fed different levels of tallow than in the control. Production of 4% FCM per kilogram of DM intake and

4% FCM per NE_L intake (kg/Mcal) were higher ($P < 0.01$) in buffaloes fed supplemental tallow compared to the control diet. Production of milk per NE_L intake, 4% FCM per kilogram of DM intake, and 4% FCM per NE_L intake increased ($P < 0.05$) with increasing levels of tallow (Table 4). Milk fat production per kilogram of fat intake was higher ($P < 0.01$) in buffaloes fed the control diet compared to those fed diets containing different levels of supplemental tallow (Table 4). Among the tallow fed groups, the ratio between milk fat produced and fat intake was higher ($P < 0.05$) at 2% level but lower ($P < 0.05$) at 6% level. Energetic efficiency of milk production was higher ($P < 0.05$) for buffaloes fed diets containing tallow as compared to the control diet (Table 4). Higher DM intake by buffaloes consuming the control diet resulted in less efficient utilization of feed energy.

The proportion of $C_{8:0}$ to $C_{16:1}$ FA was lower in milk fat of buffaloes fed tallow as compared to the control diet (Table 5). The contents of $C_{16:0}$ also decreased linearly ($P < 0.01$) due to added tallow (Table 5). The severity of the depression in short-chain FA in milk fat increased as the level of tallow in the diets increased. The concentrations of $C_{18:0}$ to $C_{20:0}$ were higher in the milk fat of buffaloes fed supplemental tallow compared to those fed the control diet.

Table 4. Efficiency of milk production in Nili-Ravi buffaloes fed diets containing different levels of tallow.

Item	Diets				SEM	Contrasts		
	A (Control)	B (2%)	C (4%)	D (6%)		L	Q	C
Probabilities for contrasts								
Milk/DM intake (kg/kg)	0.77 ^b	0.97 ^a	1.01 ^a	1.05 ^a	0.035	0.003	0.032	NS
4% FCM/DM intake (kg/kg)	1.20 ^b	1.55 ^a	1.69 ^a	1.74 ^a	0.057	0.000	0.038	NS
Milk/ NE_L intake (kg/Mcal)	0.54 ^b	0.66 ^a	0.66 ^a	0.66 ^a	0.023	0.008	0.036	NS
4% FCM/ NE_L intake (kg/Mcal)	0.84 ^b	1.06 ^a	1.10 ^a	1.10 ^a	0.038	0.001	0.049	NS
Milk fat/EE intake (kg/kg)	1.48 ^a	1.32 ^b	1.07 ^c	0.89 ^d	0.039	0.001	NS	NS
Energetic efficiency of milk production (%)	39.0 ^b	47.3 ^a	47.6 ^a	46.1 ^a	1.795	0.037	0.034	NS

Means with the same superscript in a row show non-significant difference ($P > 0.05$)

SEM = Standard error of means

NS = Probability is greater than 0.05

L, Q, C = Linear, quadratic and cubic effect of increasing tallow, respectively

Table 5. Fatty acid composition of milk fat (g/100g) in buffaloes fed diets containing different levels of tallow.

Item	Diets				SEM	Contrasts		
	A	B	C	D		L	Q	C
	(Control)	(2%)	(4%)	(6%)		Probabilities for contrasts		
Caprylic acid (C _{8:0})	1.06 ^a	0.89 ^a	0.45 ^b	0.41 ^b	0.076	0.000	NS	NS
Capric acid (C _{10:0})	2.10 ^a	1.73 ^b	1.38 ^c	1.01 ^d	0.039	0.000	NS	NS
Lauric acid (C _{12:0})	4.55 ^a	3.99 ^b	2.54 ^c	2.19 ^d	0.079	0.000	NS	0.001
Myristic acid (C _{14:0})	16.16 ^a	12.06 ^b	8.21 ^c	7.66 ^c	0.249	0.000	0.000	0.033
Palmitic acid (C _{16:0})	25.71 ^a	21.20 ^b	18.24 ^c	14.03 ^d	0.234	0.000	NS	0.037
Palmitoleic acid (C _{16:1})	4.08 ^a	3.81 ^{ab}	3.47 ^{ab}	3.39 ^b	0.180	0.024	NS	NS
Stearic acid (C _{18:0})	13.21 ^c	18.75 ^b	20.00 ^{ab}	20.94 ^a	0.482	0.000	0.003	NS
Oleic acid (C _{18:1})	25.31 ^b	26.31 ^b	30.04 ^a	31.60 ^a	0.489	0.000	NS	NS
Linoleic acid (C _{18:2})	4.16 ^d	6.30 ^c	6.98 ^b	8.20 ^a	0.072	0.000	0.001	0.001
Linolenic acid (C _{18:3})	0.94 ^c	1.22 ^c	3.91 ^b	4.29 ^a	0.087	0.000	NS	0.000
Arachidic acid (C _{20:0})	1.31 ^d	2.16 ^c	3.04 ^b	4.79 ^a	0.045	0.000	0.000	0.006

Means with the same superscript in a row show non-significant difference ($P > 0.05$)

SEM = Standard error of means

NS = Probability is greater than 0.05

L, Q, C = Linear, quadratic and cubic effect of increasing tallow, respectively

Feeding cost per buffalo was higher ($P < 0.05$) in buffaloes on the diet containing 6% supplemental tallow than in those fed the control diet or the diet containing 2% supplemental tallow (Table 6). Feeding cost per buffalo increased linearly ($P < 0.01$) with increasing amounts of tallow in the diets. Production cost per kilogram of milk from buffaloes fed 2% dietary tallow was lower compared to those on the control diet. There

were no differences ($P > 0.05$) between the control and 6% tallow supplemented groups. Income from milk produced (Rs/day/buffalo) increased linearly ($P < 0.05$) with increasing levels of tallow in the diets. Income over feed cost was higher ($P < 0.05$) in buffaloes fed 2% supplemental tallow compared to those fed the control diet.

Table 6. Cost of milk production in Nili-Ravi buffaloes fed diets containing different levels of tallow.

Item	Diets				SEM	Contrasts		
	A	B	C	D		L	Q	C
	(Control)	(2%)	(4%)	(6%)		Probabilities for contrasts		
Feed cost (Rs/d/b)	83.98 ^b	83.46 ^b	89.44 ^{ab}	95.84 ^a	1.636	0.004	NS	NS
Production cost (Rs/kg of milk)	7.67 ^a	6.57 ^b	6.93 ^{ab}	7.28 ^{ab}	0.204	NS	0.035	NS
Income from milk produced (Rs/d/b)	200.33 ^b	230.0 ^a	235.82 ^a	239.85 ^a	4.420	0.003	NS	NS
Income over feed cost	2.38 ^b	2.76 ^a	2.64 ^{ab}	2.50 ^{ab}	0.101	NS	0.039	NS

Means with the same superscript in a row show non-significant difference ($P > 0.05$) Rs/d/b = Rupee/day/buffalo

SEM = Standard error of means

NS = Probability is greater than 0.05

L, Q, C = Linear, quadratic and cubic effect of increasing tallow, respectively.

1 Pakistani Rupee (PKR) = 0.0165 USD (US\$) or 1 US\$ = 60.64 PKR.

Discussion

Average total DM intake and DM intake as percentage of BW decreased linearly ($P < 0.05$) with increasing levels of tallow in the diets. The results of the study confirmed the findings of previous studies (9) showing that tallow supplementation in the diets linearly decreased the DM intake in Holstein lactating cows. Similar findings were also reported in another study (10), in which cows fed diets with 5% saturated tallow or vegetable fat tended to have lower DM intake compared to those fed the control diet. However, these results did not support the findings of a previous study (11), in which there was no effect of increasing levels of fat on the DM intake in crossbred cows. Lower intakes of OM and CP were similar to the results of other researchers (12), who noted that feeding supplemental fat decreased the OM intake in lactating cows. The intakes of ADF and NDF were lower ($P < 0.01$) for buffaloes fed diets containing different levels of tallow compared to those fed the control diet. The results of this study are similar to the results of a previous study (13), which showed that added dietary fat decreased the intakes of ADF and NDF in lactating Jersey and Holstein cows. The intakes of NE_L and DE did not decrease with the reduction in DM intake in animals fed varying levels of supplemental tallow as compared to the control diet. The chemo-static mechanisms might have been responsible for the control of the DM intake. This might be due to the fact that the DE contents of the diets increased with increasing levels of tallow in the diets; therefore, decreased DM intake did not decrease the DE intake in buffaloes. These results confirmed the findings reported by other researchers (14), who found that, when fat supplementation decreased the DM intake, energy intake did not decrease.

Daily milk production (kg/day) of buffaloes fed diets containing varying levels of supplemental tallow increased linearly ($P < 0.01$) with increasing levels of tallow in the diets because of higher efficiency of milk synthesis. The higher milk yields in tallow supplemented groups might be due to lower heat increment and lower methane production. The results of this study are in line with the results of a previous study (15), which showed higher milk yield for cows fed supplemental tallow. However, other researchers reported that tallow supplementation in the diets of lactating cows had no effect on milk production (3). They further reported that a possible explanation for the lack of response towards

supplemental tallow was that cows were not yielding enough to respond to supplemental fat. It was also reported in a previous study (16) that milk production increased with an increase in supplemental fat up to 6% of dietary DM but it decreased when fat levels exceeded 6% of the dietary DM, which was not tested in the current study. The depressed production was probably caused by the effects of fat, especially unesterified fatty acids (FA), on rumen cellulolytic microbial activity.

Higher production of 4% FCM, SCM, and ECM in buffaloes fed supplemental tallow compared to those fed the control diet was in agreement with the results of a previous study (17) that showed a similar improvement in the lactating cows fed supplemental fat. However, the results of our study did not support the findings published by other researchers (18), who reported that FCM yields were not influenced by 2.5% or 5% dietary supplemental tallow in dairy cows.

Higher milk fat content and fat produced in buffaloes assigned to diets containing varying levels of supplemental tallow compared to the control diet confirmed the findings of a previous study (19), which reported higher milk fat percentage and fat yield in Murrah buffaloes as a result of feeding supplemental fat. Milk fat content and yield increased in groups fed tallow probably because of an increase in the exogenous supply of fatty acids that are incorporated directly into milk fat. Similar findings were also reported by other researchers (20), who fed supplemental whole cottonseeds or whole cottonseeds plus Ca-salts to lactating dairy cows. However, in a previous study (15), a reduction in milk fat content and milk fat yield was noted in lactating dairy cows fed diets containing supplemental tallow. The differences in milk fat might be due to feed type and feed intake. Ruminal pH, volatile fatty acids, and ruminal biohydrogenation affect milk fat and its composition but these parameters were not investigated in the current study.

Milk protein depression in buffaloes fed tallow may have been due to insufficient critical amino acids for milk protein synthesis. It is theorized that reduced milk protein synthesis associated with added fat was due to energy dependent changes relative to milk yield, mammary blood flow, or substrate supply. Similar findings were reported by other researchers (21), who noted that feeding supplemental fat decreased milk protein concentration. No difference ($P > 0.05$) was

observed in milk lactose content between buffaloes fed diets containing 2% to 6% tallow and those on the control diet. However, an apparent higher milk lactose percentage noted in buffaloes fed diets containing tallow confirmed the findings of a previous study (22) showing that the inclusion of saturated fatty acids in the concentrate mixture fed to lactating cows resulted in an increase in milk lactose content. Dietary fat might have spared glucose from oxidation in the mammary glands, which increased the lactose content in milk. Increasing the dietary level of tallow increased ($P < 0.05$) milk total solids, whereas SNF, milk ash, and specific gravity of milk did not differ ($P > 0.05$). The findings published by previous researchers (3) partially supported the present results and they reported that supplemental tallow did not affect milk SNF contents or yields in dairy cows. However, daily production of SNF (kg/day) increased ($P < 0.05$) with increasing levels of tallow in the diets.

The finding that the gross energy of milk fat increased ($P < 0.05$) with increasing quantities of dietary tallow did not support the findings of a previous study (23), which reported that milk energy production tended to decline linearly with increasing dietary inclusion of fat. Increasing dietary levels of tallow linearly increased ($P < 0.01$) GE per kilogram of milk and total GE of milk (Mcal/day). Gains in BW increased linearly ($P < 0.01$) with increasing amounts of tallow in the diets. Similar results were reported by other researchers (10), who noted an improved mean body condition score (BCS) of early lactating cows fed supplemental tallow. However, the findings of the present study are not in agreement with the results of a previous study (3), which reported that BW and BCS were not influenced by the addition of 2.7% tallow in the diets of lactating cows.

Milk production per kilogram of DM intake increased in a quadratic ($P < 0.05$) pattern, indicating that diets containing added fat had a greater energetic efficiency, which could support greater milk yield with less DM intake. Similar observations were also reported by other researchers (24), who fed whole sunflower seeds as supplemental fat to lactating dairy cows. Milk production per NE_L intake (kg/Mcal), production of 4% FCM per kilogram of DM intake, and 4% FCM per NE_L intake (kg/Mcal) were higher ($P < 0.01$) in buffaloes fed supplemental tallow compared to the control (Table 4). These results supported the findings reported by other researchers (25), who made similar observations

regarding lactating dairy cows fed diets containing supplemental tallow. Among the tallow fed groups, the ratio between milk fat produced and fat intake was higher ($P < 0.05$) at 2% level but lower ($P < 0.05$) at 6% level (Table 4). Depression in milk fat produced per unit of fat intake was reported to be common when supplemental fat was fed to lactating dairy cows (15).

Higher energetic efficiency of milk production in buffaloes fed supplemental tallow confirmed the findings of a study (24) showing that cows fed added dietary fat had a greater energetic efficiency, which could support greater milk yield with less DM intake. The results also confirmed the findings of another study (25), which reported that higher milk production efficiency was for cows fed 2% dietary tallow as compared to the control. It was observed that dietary tallow beyond 4% manifested a decline in the energetic efficiency of milk production.

The proportion of $C_{8:0}$ to $C_{16:1}$ FA was lower in milk fat of buffaloes fed tallow as compared to the control. The severity of the depression in short-chain FA in milk fat increased as the level of tallow in the diets increased. A similar reduction in short-chain FA of cow milk fat due to feeding supplemental fat was reported (26). The results of the present study also supported the findings reported by other researchers (27), who noted that supplemental fat caused decreases in the proportion and yield of $C_{6:0}$ to $C_{16:0}$ FA in milk fat. The concentrations of $C_{18:0}$ to $C_{20:0}$ were higher in the milk fat of buffaloes fed supplemental tallow compared to those fed the control diet (Table 5). A similar increase in the proportion of $C_{18:0}$ and $C_{18:1}$ in milk fat of cows fed supplemental tallow was also noted (28). This change was reported as important for humans (29) because $C_{12:0}$, $C_{14:0}$, and $C_{16:0}$ have hypercholesterolemic effects in human diets and $C_{18:0}$ and $C_{18:1}$ are effective in decreasing plasma cholesterol. Mammary glands possess desaturase activity specific for the conversion of $C_{18:0}$ to $C_{18:1}$. Dietary fat supplementation provides additional long-chain FA for milk fat synthesis; increased uptake of long-chain FA by mammary glands might inhibit the synthesis of short- and medium-chain FA because of negative feedback inhibitions on acetyl coenzyme A carboxylase and increased incorporation of long-chain FA into milk fat. This inhibition may be because of the formation of *trans* isomers resulting from biohydrogenation of long-chain FA in the rumen.

Income from milk produced (Rs/day/buffalo) increased linearly ($P < 0.05$) with increasing levels of tallow in the diets. Income over feed cost was ($P < 0.05$) higher in buffaloes fed 2% supplemental tallow compared to those fed the control diet. The results of this study support the findings of other researchers (30), who reported that fat is the dietary variable that is most likely to optimize production efficiency. The findings of the

present study are also in agreement with the results of a previous study (25), which reported that estimated return from tallow supplemented diets was higher compared to the control.

The present study suggests that tallow up to 6% of diet dry matter is a suitable fat supplement as an economical energy source for early lactating buffaloes.

References

1. Finance Division, Government of Pakistan: Economic Survey of Pakistan. Government of Pakistan, Islamabad, 2006; 18.
2. Fahimuddin, M.: Domestic Water Buffalo. 2nd Ed. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, India, 1989.
3. Markus, S.B., Wittenberg, K.M., Ingalls, J.R., Undi, M.: Production responses by early lactation cows to whole sunflower seed or tallow supplementation of a diet based on barley. *J. Dairy Sci.*, 1996; 79: 1817-1825.
4. NRC: Nutrient Requirements of Dairy Cattle, 6th Rev. Edn. Natl. Acad. Press, Washington, D.C., 2001.
5. Association of Official Analytical Chemists: Official Methods of Analysis. 15th Edn. AOAC, Washington, DC., 1990.
6. Sukhija, P.S., Palmquist, D.L.: Rapid method for determination of total fatty acid content and composition of feed-stuffs and feces. *J. Agric. Food Chem.*, 1988; 36: 1202-1206.
7. Tyrrell, H.F., Reid, J.T.: Prediction of the energy value of cow's milk. *J. Dairy Sci.*, 1965; 48: 1215-1223.
8. Steel, R.G.D., Torrie, J.H., Dicky, D.A.: Principles and Procedures of Statistics - a Biometrical Approach. 3rd Edn. McGraw Hill Book Co. Inc., New York, USA, 1997.
9. Ruppert, L.D., Drackley, J.K., Bremmer, D.R., Clark, J.H.: Effect of tallow in the diets based on corn silage or alfalfa silage on digestion and nutrient use by lactating dairy cows. *J. Dairy Sci.*, 2003; 86: 593-609.
10. Pantoja, J., Firkins, J.L., Eastridge, M.L., Hull, B.L.: Fatty acid digestion in lactating dairy cows fed fats varying in degree of saturation and different fiber sources. *J. Dairy Sci.*, 1996; 79: 575-584.
11. Sarwar, M., Sohaib, A., Ajmal Khan, M., Nisa, M.: Effect of feeding saturated fat on milk production and composition in crossbred dairy cows. *Asian Australas. J. Anim. Sci.*, 2003; 16: 204-210.
12. Klusmeyer, T.H., Lynch, G.L., Clark, J.H., Nelson, D.R.: Effects of calcium salts of fatty acids and protein source on ruminal fermentation and nutrient flow to duodenum of cows. *J. Dairy Sci.*, 1991; 74: 2206-2219.
13. Rodriguez, L.A., Stallings, C.C., Herbein, J.H., McGilliard, M.L.: Effect of degradability of dietary protein and fat on the ruminal, blood and milk components of Jersey and Holstein cows. *J. Dairy Sci.*, 1997; 80: 353-363.
14. Gagliostro, G., Chilliard, Y.: Duodenal rapeseed oil infusion in early and mid-lactation cows. 2. Voluntary intake, milk production and composition. *J. Dairy Sci.*, 1991; 74: 499-509.
15. Onetti, S.G., Grummer R.R.: Response of lactating cows to three supplemental fat sources as affected by forage in the diet and stage of lactation: a meta-analysis of literature. *Anim. Feed Sci. Technol.*, 2004; 115: 67-82.
16. Jenkins, T.C., Palmquist, D.L.: Effect of fatty acids or calcium soaps on rumen and total nutrient digestibility of dairy rations. *J. Dairy Sci.*, 1984; 67: 978-986.
17. Sklan, D., Ashkenazi, R., Braun, A., Devorin, A., Tabori, K.: Fatty acids, calcium soaps of fatty acids and cottonseeds fed to high yielding cows. *J. Dairy Sci.*, 1992; 75: 2463-2472.
18. Elliott, J.P., Drackley, J.K., Schauff, D.J., Jaster, E.H.: Diets containing high oil corn and tallow for dairy cows during early lactation. *J. Dairy Sci.*, 1993; 76: 775-789.
19. Srivastava, A., Mathur, M.P., Mudgal, V.D.: Influence of feeding protected fat to buffaloes on some enzymes in milk. *Indian J. Dairy Sci.*, 1990; 42: 354-355.
20. Harrison, J.H., Kincaid, R.L., McNamara, J.P., Waltner, S., Loney, K.A., Riley, R.E., Cronrath, J.D.: Effect of whole cottonseeds and calcium salts of long-chain fatty acids on performance of lactating dairy cows. *J. Dairy Sci.*, 1995; 78: 181-193.
21. Tackett, V.L., Bertrand, J.A., Jenkins, T.C., Pardue, F.E., Grimes, L.W.: Interaction of dietary fat and acid detergent fiber diets of lactating dairy cows. *J. Dairy Sci.*, 1996; 79: 270-275.
22. Steele, W.: The effects of dietary palmitic and stearic acids on milk yield and composition in the cow. *J. Dairy Res.*, 1969; 36: 369-373.
23. Khorasani, G.R., Robinson, P.H., De Boer, G., Kennelly, J.J.: Influence of canola fat on yield, fat percentage, fatty acid profile, and nitrogen fractions in Holstein milk. *J. Dairy Sci.*, 1991; 74: 1904-1911.

24. Rafalowski, W., Park, C.S.: Whole sunflower seed as a fat supplement for lactating cows. *J. Dairy Sci.*, 1982; 65: 1484-1492.
25. Maiga, H.A., Schingoethe, D.J., Ludens, F.C.: Evaluation of diets containing supplemental fat with different sources of carbohydrates for lactating dairy cows. *J. Dairy Sci.*, 1995; 78: 1122-1130
26. Smith, N.E., Collar, L.S., Bath, D.L., Dunkley, W.L., Franke, A.A.: Digestibility and effects of whole cottonseed fed to lactating cows. *J. Dairy Sci.*, 1981; 64: 2209-2215.
27. Banks, W., Clapperton, J.L., Girdler, A.K., Steele, W.: Effect of inclusion of different forms of dietary fatty acids on the yield and composition of cow's milk. *J. Dairy Res.*, 1984; 51: 387-395.
28. Banks, W. Clapperton, J.L., Steele, W.: Dietary manipulation of the content and fatty acid composition of milk fat. *Proc. Nutr. Soc.*, 1983; 42: 399-406.
29. Grummer, R.R.: Effect of feed on the composition of milk fat. *J. Dairy Sci.*, 1991; 74: 3244-3257.
30. Chalupa, W., Vecchiarelli, B., Elser, A.E., Kronfeld, D.S., Sklan, D., Palmquist, D.L.: Ruminant fermentation in vivo as influenced by long-chain fatty acids. *J. Dairy Sci.*, 1986; 69: 1293-1301.