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FEEDING OF FAT DURING HEAT STRESS CONDITIONS AND COMBINATIONS OF FAT SOURCES

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SUMMARY

Data from five experiments (132 cows) conducted in the last two years at the University of Arizona on use of fat for lactating dairy cows in the Southwestern U.S. were summarized. Additions of 2.5% fat to diets containing 8-12% whole cottonseed increased milk yields an average of 1.5 kg/d in 4 trials. Responses were similar for hot or normal weather conditions, and were not significantly different when Energy Booster, Megalac, tallow, or safflower oil were included as fat supplements. However, Energy Booster was evaluated in 4 of the 5 studies, which provided a large volume of data demonstrating an enhancing effect of this fat source on milk production. Steam-flaking sorghum grain sustained milk protein concentrations when Megalac was added to diets. Available data showed normal digestibilities of DM, CP, and ADF, but decreased digestibility of fatty acids when dietary fat was

increased from 3.7 to 6.2%. Results indicate that cows producing 33 kg/d or more milk respond with increased milk yield to fat from commercial supplements when added to typical Southwest diets containing whole cottonseed and alfalfa hay.

INTRODUCTION

Lactation response of dairy cows to supplementation of dietary fat has been inconsistent, suggesting the existence of interactions between supplemental fat and other factors. In Southwestern U.S., alfalfa hay, whole cottonseed, cottonseed hulls, corn, and sorghum grain are the major ingredients in dairy rations. This contrasts with other areas where rations are based primarily on corn grain and alfalfa and corn silages. Although research has evaluated inclusion of whole cottonseed as a partial supplemental fat source, little information is available on addition of commercial fats to dairy diets which contain whole cottonseed.

Cows in the Southwestern U.S. experience heat stress due to hot summer temperatures, which can be as high as 48^0 C. Substitution of fat for other feedstuffs in the diet may be advantageous in dealing with heat stress because of the low heat increment of fat, thus resulting in higher milk production and more efficient feed utilization.

A series of studies were recently conducted at the University of Arizona on fat supplementation of lactating cows. Objectives were to determine effects on lactational performance of additional fat to typical Southwestern diets containing 8-12% whole cottonseed. This manuscript will discuss sources and levels of fat, interactions between added fat and starch degradabilities, as well as response to supplemental fat under various environmental conditions.

EXPERIMENTAL PROCEDURES

Diets used in these trials contained 8-12% whole cottonseed, 32-43% alfalfa hay, 3-6% cottonseed hulls, and 39-57% concentrate (grain, protein supplement, byproducts, minerals, and vitamins). When whole cottonseed was included, dietary ether extract (EE) was 4.5 to 5.0%. Addition of fat was from 2.2 to 2.5%, provided from Energy Booster (EB) (Milk Specialties Co., Dundee, IL), Megalac (M) (Church & Dwight Co., Inc., Princeton, NJ), tallow (TW), or safflower oil (S). Diets were fed as total mixed rations to allow 10% refusal. Milk yield and feed intake were measured daily, and milk composition weekly. All trials except one (Simas et al., 1992) consisted of a pretreatment period (14 d), during which all cows were fed the herd ration, and a treatment period ranging from 56 to 91 d. Pretreatment performance was used to allocate cows to treatment, and to adjust treatment effects by covariance. Nutrient digestibilities were determined by feeding .1% Cr_2O_3 for 14d, and analyzing Cr recoveries in feces sampled twice daily during the last 5 d of the feeding period. However, digestibility data from only two trials (Simas et al., 1992; Wu et al., 1992) are presently available.

OVERALL RESPONSE IN MILK PRODUCTION AND FEED INTAKE

Changes in milk yield and dry matter intake (DMI) due to fat supplementation from individual trials are summarized in Table 1. Dry matter intake were not significantly altered by inclusion of any of the fat sources used in these trials except for Megalac fed to immediately postpartum cows (Simias et al., 1992) which resulted in a 20% decrease in DMI. In the study of Wu et al., (1992) where DMI were not significantly depressed, cows averaged 92 d in milk when the trial commenced. Energy Booster was evaluated in 4 trials and did not affect feed intake compared to controls, but increased milk yields an average of 1.6 kg/d.

SOURCE OF SUPPLEMENTAL FAT

The physical-chemical nature of fat supplements affects their feeding value, so source of fat was studied in two trials. Fatty acid composition of the different commercial supplements are in Table 2. Major characteristics of supplements are: 1) fatty acids of M are in the form of insoluble Ca soaps; 2) EB is a highly saturated fatty acid source; and 3) fatty acids of TW and S are in the form of triglycerides. However, TW and S differ greatly in their composition; about 43% of the fatty acids of TW is palmitic and stearic, and 43% is oleic; whereas S is high in linoleic (75%).

In the first trial of Wu et al. (1992), the control diet (C) contained 3.7% fat. The three experimental diets were formed by adding 2.5% fat as M, EB, or TW to diets for 24 cows (72 d). The grain source of the diets was steam-flaked sorghum. Megalac or EB was mixed directly into the TMR, while TW was first blended with steam-flaked sorghum before adding to the TMR. Addition of fat did not change DMI, but increased milk yield an average of 2.1 kg/d. The increase was similar among added fat sources (Table 3). Milk protein content, but not yield, was lower for all fat treatments than for C. Digestibilities of DM and ADF were highest for the TW diet, while addition of other fat sources did not affect digestibilities. It was possible that added tallow interacted with highly degradable starch of the steam-flaked sorghum, which might otherwise inhibit ruminal fiber digestion. Such an interaction might have been facilitated when TW was blended with sorghum. Clary et al. (1991) reported that addition of tallow reduced in vitro rates of starch degradation.

In another trial by Wu et al. (unpublished data), EB or S was added (2.5%) to diets containing 12% whole cottonseed as a part of the experimental treatments. Each diet was fed to 6 mid-lactation cows for 75 d. Preliminary data (Table 4) showed that milk yield was increased 2.4 Kg/d by S, and 1.7 Kg/d by EB, with no significant difference between the two fat sources. Intake of DM appeared to be highest for the S diet.

Results of the two above-mentioned trials showed that M, EB, TW or S had similar effects on milk production when added at about 2.5% to TMR, and that the fat sources did not interfere with fiber digestion. It is generally believed that free oils are less desirable than inert fat sources. The low supplemental fat level, the diet formulation (38-43% alfalfa hay, 8-12% whole cottonseed, and 4-6% cottonseed hulls), or possible interactions between free oils and sorghum grain on fiber digestion might explain the lack of negative results with TW and S on NDF digestibility. Also, it appeared that diets containing tallow or safflower oil had an appealing odor. We think that higher levels (> 5%) of TW and S would inhibit fiber digestion and intake, but at 2.5%, a stimulating effect was evident.

LEVEL OF FAT SUPPLEMENTATION

The general recommendation is that dietary fat for lactating cows not exceed 7-8% (Palmquist, 1984). This level is based on maximal efficiency of energy utilization and minimal inhibition to ruminal fermentation. The advent of ruminally inert fat and higher milk yields of cows might suggest an increase in maximum fat levels. Also, combinations of fat sources might allow utilization of higher fat in dairy diets. These hypotheses were tested in a trial by Wu et al. (unpublished data) using the following dietary treatments: control (C, 3.1% EE); 12% whole cottonseed substituted for 4.5% concentrate mix, 2.5% cottonseed hulls, and 5% alfalfa hay (CS, 5.2% EE); Energy Booster added to CS at 2.2% (CSE 7.4% EE) or 4.4% (CSEE 9.6% EE) and S added at 2.2% to CS (CSS 7.4% EE). Diets were fed to 30 cows averaging 50 d in milk. Milk yield increased 2.1 Kg/d ($P < .05$, Table 4) when dietary EE was increased from 5.2 to 7.4%. However, further addition of fat to increase EE to 9.6% resulted in decreased feed intake and milk yield, suggesting an inability of cows to utilize such a high level of fatty acids. Our strategy of using whole cottonseed to bring dietary EE to 5%, and then adding a commercial fat supplement to further increase to 7% for high producing cows was apparently successful.

INTERACTION OF ADDED FAT AND RUMINAL STARCH DEGRADABILITY

We have studied extensively the effect of processing sorghum grain on lactation performance of dairy cows. Results show that increased ruminal starch degradability (from 50 to 80%) through steam-flaking of sorghum increased milk yield (10%) and milk protein yield (16%). Since supplemental fat has been associated with decreased milk protein content, an experiment (Simas et al., 1992) was conducted to determine interactions between steam-flaked sorghum and added fat on milk protein content and yield. Four diets in a 2 X 2 factorial arrangement of treatments were fed to 36 cows from d 5 to 96 postpartum. Factors were: 1) dry-rolling vs. steam-flaking of sorghum grain (40% of diet DM); and 2) added (2.5%) vs. no added Megalac. Addition of fat decreased DMI, but did not significantly change milk yield, resulting in increased FCM:DMI (Table 5). Milk protein percentage was decreased when fat was added to the dry-rolled sorghum diet (2.93% vs. 2.79%), but the decrease was reversed by steam-flaking sorghum (3.00% vs. 2.99%), suggesting an interaction between steam-flaking of sorghum and supplementation of fat. To a lesser extent, supplementation of fat reversed decreased milk fat concentrations caused by steam-flaked sorghum. Digestibilities of OM and CP were higher for added-fat diets, apparently reflecting lower intakes.

The reason steam-flaked sorghum increased milk protein content might be due to increased microbial protein synthesis resulting from greater starch availability to rumen microbes. Oliveira (1991) showed larger amounts of bacterial protein reaching the duodenum in cows fed steam-flaked than dry-rolled sorghum. Moreover, apparent digestibility of CP and efficiency of rumen microbial protein synthesis often increased when fat was added to diets, suggesting more protein available for digestion in the small intestine. Finally, some studies (Calane et al., 1990; Chow et al., 1990), but not all (Goodling et al., 1992) reported positive effects of postruminal supplementation of amino acids on milk protein content in cows fed diets of added fat. We believe that increasing ruminal starch degradability has provided an additional avenue for resolving the decreased milk protein percentage associated with fat supplementation, but further research is needed.

INTERACTION OF ADDED FAT AND HEAT STRESS

Data from one study (Chan et al., 1992) showed that fat supplementation increased milk yield of cows suffering heat stress (Table 6), while in a second study interaction of fat supplementation and environmental modification was determined (Chan et al., unpublished data). Four diets were fed to 24 cows in a 2 X 2 factorial arrangement of treatments with the following factors: 1) fat level: medium (MF, 4.9% EE) vs. high (HF, 7.7% EE, increased by EB); and 2) environment modification: pen shade (S) vs. pen shade with evaporative cooling (EC). the experimental period was 56 d in the hog summer (from 7/17/92 to 9/11/92). Milk yield was increased by EC compared to shade, but only slightly by supplementation of fat (Table 7). Milk protein percentage did not differ between treatments. Interestingly, neither respiration rates nor rectal temperatures were reduced by fat supplementation or evaporative cooling; though cooled cows experienced less heat-stress and produced more milk. Results from this trial suggest no interaction between fat supplementation and environmental temperatures.

FATTY ACID DIGESTIBILITY

Digestibility of fatty acids was decreased by overall fat supplementation, while it did not differ among the fat sources (Table 3, Wu et al., 1992). Apparent digestibility of EE has been reported to increase with moderate addition of fat due to dilution of indigestible ether extractable materials by supplemental fat. In the study of Wu et al., (1992), the C diet contained high enough FA (3.7%) to negate this dilution effect. Palmquist (1991) suggested that at high intakes, incomplete hydrolysis of fat in the rumen may limit FA absorption in the small intestine. Regression analyses show a strong relationship between amounts of fatty acids digested and consumed (r = .97). The estimate of true digestibility of fatty acids was 71% at intakes ranging from 1,000 to 2,000 g/d.

AREAS OF FUTURE RESEARCH

Increasing ruminal starch digestibility by steam-flaking of sorghum grain reversed milk protein depression in early lactation cows fed Megalac diets. Such research needs to be expanded to other fat sources and lactation stages. Also, research should examine interactive effects of additional methods of increasing ruminally available starch. Although tallow and safflower oil showed similar effects as Megalac and Energy Booster at low levels of supplementation, these fat sources need to be further evaluated at higher levels for effects on milk fat and fatty acid composition as well as production parameters. An observation still not well explained is why milk oleic acid increases with high intakes of tallow, safflower, and sunflower oils. Finally, combinations of fats for cows at different stages of lactation and production levels deserve more defined and complex studies.

CONCLUSIONS

Addition of 2 to 2.5% fat, regardless of source, to typical Southwest dairy diets containing whole cottonseed, alfalfa hay and concentrate increased milk yield of cows in early or mid lactation, and at high or normal ambient temperatures. Higher addition to increase dietary ether extract to 9.7% decreased feed intake in cows producing about 33 kg/d milk. Increasing ruminal starch degradability by processing grains is a possible technique for maintaining normal milk protein concentrations when fat is added to lactation diets.

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Table 1. Summary of milk yield and DMI in dairy cows fed control (C, 4.5-5% EE) or fat-supplemented diets (F, 7-7.5% EE).

		DMI (kg/d)			Milk (kg/d)		
Trial	Fat source[1]	C	F	SEM	C	F	SEM
Simas et al., 1992 36 cows	M	22.3	18.6	1.1[a]	36.8	34.9	1.6
Chan et al., 1992 24 cows	EB	22.8	23.9	.8	32.9	34.1	.7[b]
Wu et al., 1992 24 cows	EB, M, TW	24.2	25.2	1.0	31.6	33.7	.9[a]
Chan et al., unpub. 24 cows	EB	25.8	24.7	1.2	30.2	30.8	.8
Wu et al., unpub. 24 cows	EB, S	28.2	29.0	1.0	32.5	34.7	1.0[c]

[1] Sources of fat added independently to diets: M = Megalac, EB = Energy Booster, TW = tallow, and S = safflower oil.

[a] $P < .01$.

[b] $P < .11$.

[c] $P < .05$.

Table 2. Fatty acid composition (%) of tallow (TW), Megalac (M), Energy Booster (EB), and safflower oil (S).

Fatty acid	TW	M	EB	S
$C_{14:0}$	3.7	1.5	3.3	ND[1]
$C_{16:0}$	28.3	51.5	44.8	8.0
$C_{16:1}$	4.0	ND	1.0	ND
$C_{18:0}$	15.5	4.1	41.9	3.0
$C_{18:1}$	43.3	35.6	7.0	13.5
$C_{18:2}$	2.6	7.4	ND	75.0

[1] Nondetectable.

Table 3. Dry matter intake, milk yield, milk protein content, and nutrient digestibilities in cows fed diets supplemented with different sources of fat.[1]

	Diet[2]				
Item	C	TW	M	EB	SEM
DMI, kg/d	24.2	26.3	23.9	25.3	1.0
Milk, kg/d	31.6	33.9	32.9	34.2	.9[a]
FCM:DMI	1.27	1.25	1.36	1.31	.06
Milk protein, %	3.13	3.05	2.97	3.01	.04[a]
kg/d	.98	1.03	.98	1.02	.03
Digestibility, %					
DM	63.8	64.4	62.8	61.8	.8[b]
ADF	34.3	37.0	32.1	30.9	1.8[b]
Fatty acid	78.8	76.8	75.2	74.8	1.5[a]

[1] Wu et al. (1992).

[2] Dietary treatments: C = control, TW = tallow, M = Megalac, EB = Energy Booster. Tallow, M, or EB were added to C as fat supplements.

[a] Effect of fat supplementation (*P* < .07).

[b] TW vs. M + EB (*P* < .07).

Table 4. Feed intake and milk yield in cows fed a control diet (C), a diet containing 12% whole cottonseed (CS), and diets formulated by adding to CS 2.2% safflower oil (CSS), 2.2% Energy Booster (CSE), or 4.4% Energy Booster (CSEE).[1]

	Diet					
Item	C	CS	CSS	CSE	CSEE	SEM
DMI, kg/d	28.9	28.3	29.7	27.7	25.6	1.0[a]
Milk, kg/d	32.5	32.6	35.0	34.3	33.1	1.0[b]

[1] Wu et al. (unpublished data).

[a] CSEE was lowest (*P* < .05).

[b] CSS + CSE was higher than C + CS (P < .05).

Table 5. Effect of sorghum grain processing and fat supplementation on lactation performance of dairy cows.[1]

	Diet[2]				
Item	DC	SC	DF	SF	SEM
DMI, kg/d	21.6	23.1	17.8	19.5	1.1[a]
Milk, kg/d	34.3	39.3	33.4	36.5	1.6[b]
FCM:DMI	1.45	1.51	1.76	1.67	.09[a]
Milk protein, %	2.93	3.00	2.79	2.99	.05[c]
Milk fat, %	3.16	2.91	3.23	3.05	.09[b]
Digestibility, %					
OM	58.3	68.2	61.5	72.4	1.8[a,b]
CP	63.2	68.7	65.6	73.2	1.7[a,b]
Starch	76.9	97.5	79.5	96.9	2.3[b]
NDF	43.5	40.2	41.0	46.0	3.7

[1] Simas et al. (1992).

[2] DC = dry rolled sorghum control, SC = steam flaked sorghum control, DF = dry rolled sorghum added with fat, SF = steam flaked sorghum added with fat.

[a] Fat effect (*P* < .06).

[b] Sorghum processing effect (*P* < .05).

[c] DF was lower than all others (*P* < .06).

Table 6. Effect of fat supplementation and protein source on performance of dairy cows suffering heat stress.[1]

	Diet[2]				
Item	MFCM	HFCM	MFFB	HFFB	SEM
DMI, kg/d	23.7	25.1	22.0	22.8	.8[a]
Milk, kg/d	33.5	35.2	32.3	33.0	1.0[a,b]
Milk fat, %	3.31	3.41	3.08	3.39	.08[c]
Milk protein, %	3.20	3.10	3.08	3.09	.04[a]

[1] Chan et al. (1992).

[2] MFCM = medium fat (4.5%), cottonseed meal; HFCM = high fat (7.0%), cottonseed meal; MFFB = medium fat, fish and blood meals; HFFB = high fat, fish and blood meals.

[a] Protein source effect (*P* < .08).

[b] Supplemental fat effect (*P* < .11).

[c] Supplemental fat effect (*P* < .02).

Table 7. Effect of fat supplementation and cooling method on performance of dairy cows in the hot summer.[1]

	Treatment[2]				
Item	MFS	HFS	MFEC	HFEC	SEM
DMI, kg/d	26.2	24.7	25.5	24.6	1.2
Milk, kg/d	29.5	30.0	31.0	31.7	.8[a]
Milk protein, %	2.99	2.95	2.90	2.94	.04
Milk fat, %	2.93	3.23	3.25	3.13	.12
Breaths/min	81.1	85.7	81.2	84.4	5.2
Rectal temperature, °F	102.9	102.9	102.4	102.9	.32

[1] Chan et al. (unpublished data).

[2] MFS = medium fat (4.9%), pen shade; HFS = high fat (7.7%), pen shade; MFEC = medium fat, evaporative cooling; HFEC = high fat, evaporative cooling.

[a] Cooling effect ($P < .1$).