Dietary medium- or long-chain triglycerides improve body condition of lean-genotype sows and increase suckling pig growth[1,2]

L. Averette Gatlin*, J. Odle*[3], J. Soede*[4], and J. A. Hansen†[5]

*Department of Animal Science, North Carolina State University, Raleigh 27695 and
†Murphy Farms, Inc., Rose Hill, NC 28458

ABSTRACT: In a field trial conducted on a commercial swine farm, lean-genotype sows (n = 485) were fed diets containing 0 or 10% supplemental fat as either medium-chain triglyceride or choice white grease from d 90 of gestation until weaning (15.5 d). Effects on standard sow and litter production traits were examined together with assessment of sow body condition using live ultrasound. Daily feed intake during lactation was 10% higher in sows consuming diets without added fat (7.2 vs 6.5 kg; $P < 0.01$); however, lactation ME (23.9 Mcal/d) and digestible lysine (54 g/d) intakes were unaffected ($P > 0.10$). Sows supplemented with fat were 4 kg heavier on d 109 of gestation (220 vs 224 kg; $P \le 0.01$), 1 d after farrowing (210 vs 214 kg; $P \le 0.01$), and at weaning (210 vs 214 kg; $P \le 0.01$). Expressed as overall gain, this amounted to a 23% increase (0.66 vs 0.86 kg/d; $P \le 0.01$) and was accompanied by a 49% increase in backfat (0.82 vs 1.68 mm; $P \le 0.03$) from d 90 to farrowing. Changes in sow weight (–0.01 kg/d) and backfat (+4.2 mm) over lactation were minimal and were not affected by fat supplementation ($P \ge 0.10$). Longissimus muscle area at weaning was slightly greater (44.96 vs 46.2 cm^2) in sows consuming fat than in control sows ($P \le 0.05$), but changes in longissimus muscle area were not significant from d 90 to weaning ($P \ge 0.10$). Gestation length, pigs born alive, average birth weight, survival (d 3 to weaning), and days to estrus were not affected by diet ($P > 0.10$). However, supplemental fat increased pig ADG (192 vs 203 g/d; $P < 0.01$) and average pig weaning weight (4.3 vs 4.5 kg) at 15.5 d ($P \le 0.02$). No differences between the two fat sources were detected. This large-scale study demonstrated that supplemental fat during gestation and lactation effectively improved sow condition and improved suckling pig performance without affecting energy intake during lactation, implying improved efficiency of sow energy utilization.

Key Words: Growth, Lactation, Medium-Chain Triacylglycerols, Pigs, Reproductive Efficiency

©2002 American Society of Animal Science. All rights reserved. J. Anim. Sci. 2002. 80:38–44

Introduction

Feeding supplemental fat to sows in late gestation and(or) lactation increased milk IGF-I concentration and pig weight gains up to 25%, and the gain was composed predominantly of body fat (Averette et al., 1999; Tilton et al., 1999, van den Brand et al., 2000b). In addition to increased weaning weight, a plethora of studies (see Pettigrew, 1981 for review) has indicated that added fat will improve pig survival when herd baseline survival is < 80%.

Because of limited energy stores in neonatal pigs (Curtis et al., 1966; Seerley et al., 1974), and because of the unique nutritional and metabolic attributes of medium-chain triglycerides (**MCT**), others have examined supplementation of pigs with MCT (Odle, 1998). As an alternative to gavaging individual pigs, Azain (1993) determined survival of pigs from sows fed MCT and found that survival of pigs weighing < 900 g was 36% greater than that of pigs from sows fed starch. Similarly, Jean and Chiang (1999) noted a twofold improvement in survival along with increased liver and muscle glycogen content of low-birth-weight pigs nursing sows supplemented with MCT. An increase in nutrients within maternal circulation (e.g., glucose, fatty acids, ketone bodies; Kasser et al., 1981) together with increased milkfat percentage observed when dietary fat is provided to the dam may be the basis for improved survival of pigs.

[1]This research was supported in part by the Fats and Proteins Research Foundation (Bloomington, IL 61704) and the North Carolina Agric. Res. Serv. of North Carolina State Univ., Raleigh.

[2]Special appreciation is given to M. T. Coffey, G. Pratt, and R. Cavenaugh at Murphy Farms, Inc. for their assistance in design and implementation of this field study.

[3]Correspondence: Box 7621 (phone: 919-515-4050; fax: 919-515-7780; E-mail: jack_odle@ncsu.edu).

[4]Present address: Provimi B.V., Veerlaan 17-23, P.O. Box 5063, NL-3008 AB Rotterdam, The Netherlands.

Received June 8, 2001.

Accepted September 5, 2001.

Table 1. Composition of diets[a]

Item	Gestation			Lactation		
	0% Fat	10% MCT[b]	10% LCT	0% Fat	10% MCT	10% LCT
Ingredient, %						
Corn	82.90	70.60	70.60	78.00	61.60	61.60
Soybean meal (48% CP)	13.90	16.30	16.30	19.50	24.50	24.50
Lysine (78.8% CP)	—	—	—	0.10	0.10	0.10
Fat[b]	—	10.00	10.00	—	10.00	10.00
Defluorinated phosphate	2.17	2.22	2.22	2.05	2.10	2.10
Potassium/magnesium sulfate[c]	—	—	—	0.75	0.75	0.75
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin/mineral premix[d]	0.15	0.20	0.20	0.15	0.20	0.20
Choline chloride[e]	0.10	0.13	0.13	0.10	0.13	0.13
Se premix[f]	0.05	0.05	0.05	0.05	0.05	0.05
Myc-out 65[g]	0.05	0.05	0.05	0.05	0.05	0.05
Calculated composition						
Crude protein, %	13.26	13.45	13.45	15.59	16.85	16.85
Lysine, %	0.66	0.71	0.71	0.90	1.02	1.02
Phosphorus, %	0.65	0.65	0.65	0.65	0.67	0.67
Calcium, %	0.75	0.77	0.77	0.72	0.75	0.75
ME, kcal/kg	3,312	3,740	3,740	3,285	3,712	3,712
Analyzed composition						
Ether extract, %	2.95	10.90	12.68	2.89	10.50	13.40

[a]As-fed basis.
[b]Fat was provided as medium-chain triglyceride (MCT: C8/C10) or as long-chain triglyceride (LCT: choice white grease).
[c]Added as a laxative. Each kilogram contained the following: 222.8 g S, 184.1 g K, 115 g Mg, 12 g Cl, 7 g Na, 1.1 g Fe, 0.02 g Cu, 0.1 g Zn, and 0.1 g Mn.
[d]Each kilogram of mix contained the following: 44.7 g Ca, 38.6 g S, 83.4 g Zn as ZnO, 67.7 g Fe as $FeSO_4$, 33.43 g Mn as $MnSO_4$, 10 g Cu as $CuSO_4$, 340 mg I, 7,343,700 IU vitamin A, 1,175,500 IU total vitamin D, 44,001.7 IU vitamin E, 4,440.7 mg vitamin K activity, 1,468.5 mg menadione, 22 mg vitamin B_{12}, 5,867.8 mg riboflavin, 14,671 mg D-pantothenic acid, 77,339 mg niacin, 740.9 mg thiamin, 2,940.2 mg pyridoxine, 1,100.1 mg folic acid, and 146 mg biotin.
[e]Each kilogram provided 519.7 mg choline.
[f]Each kilogram provided 600 mg Se.
[g]Added as a mold inhibitor (Keystone Ingredients, North Troy, VT).

Sow body condition also may be improved by feeding supplemental fat, especially in lean-genotype sows. Increasing ME intake with supplemental fat may decrease the severity of the changes in sow body condition and improve performance, because large fluctuations in BW or condition can harm reproduction (Reese et al., 1982). Therefore, the objective of this experiment was to determine the effects of supplemental dietary fat fed as either MCT or long-chain triglycerides (**LCT**) on reproduction/lactation performance and body condition of sows within a large-scale, commercial-farm environment.

Materials and Methods

Four hundred eighty-five sows (PIC line 42) located on a corporate swine farm in North Carolina were randomly assigned to one of three dietary treatments (Table 1). Diets contained one of three sources of supplemental fat as follows: 0% (n = 164), 10% MCT (n = 159), or 10% LCT (n = 159). Three sows were removed from the study due to death or false pregnancy. All animal procedures were approved by the Institutional Animal Care and Use Committee of North Carolina State University. This experiment was completed in a 9-wk period occurring from mid-May to late July, and maximum daily temperature averaged 29 ± 5°C. There were 97 first-parity sows; the other sows ranged from the second to the ninth parity with a mean of 3.47. Sows were housed and fed individually throughout the experiment. Sows were housed in a commercial-style gestation barn with individual crates and a trough feeder. Beginning on d 90 of gestation, sows were provided with 2.0 kg/d of their respective diets. Fat was provided as either MCT (C8/C10; Lonza, Fair Lawn, NJ) or as choice white grease (LCT; Carolina By-Products, Smithfield, NC). Gestation diets met or exceeded NRC (1998) requirements. For both gestation and lactation, the ME content of the diets was greater than the NRC (1998) value of 3,265 kcal/kg. The control diet and fat-supplemented diets were not isocaloric but were formulated to equalize the lysine:ME ratio. Sows were fed 2.0 kg/d of their respective lactation diets (Table 1) from d 109 ± 2 after being moved into the farrowing house. The CP and lysine content of the lactation diets exceeded the NRC (1998) requirements to include a safety margin. After parturition, sows were fed five times daily to provide continuously fresh feed and to maximize lactation feed intakes.

Sows were individually weighed on d 90 ± 1, d 109 ± 2, 1 d after farrowing, and at weaning. Change in sow weights was determined as the weight on d 109 minus the weight on d 90 (gestation) and for lactation as the weight at weaning minus the weight 1 d after farrowing. Body condition scores of each sow were recorded on d 90 ± 1, 1 d after farrowing, and at weaning. A scale of 1 to 5 was used to visually evaluate the body condition; a value of 1 was assigned to a very thin sow and 5 to a very fat sow, and the optimum score was given a value of 3 (Patience and Thacker, 1989). Backfat and longissimus muscle area at the 10th rib were also measured on d 90 ± 1, d 1 ± 2 of lactation, and within 2 d of weaning by real-time ultrasound (Aloka 500 V, Aloka Co., Tokyo, Japan). These measurements were made by a certified ultrasound technician. Change in backfat and longissimus muscle area during gestation was determined as the measurement at farrowing minus the value on d 90. Change in backfat and longissimus muscle area during lactation was determined as the measurement at weaning minus the measurement at farrowing.

Heat lamps were provided for pigs from farrowing to d 3. Heat pads were provided throughout lactation for litters. Litter weight, number of pigs born alive, number of stillborns, and the number of mummies were recorded on d 1 of lactation. According to rigid farm management practices, pigs were cross-fostered within treatment until d 3 to standardize litter size at 10 to 12 pigs. On d 3 the litter was weighed and the number of pigs was recorded. From d 3 to weaning, only pigs considered terminally ill were removed from the study so that survival from d 3 to weaning could be determined. Litters were weighed at weaning (avg 15.5 ± 0.17 d). After weaning, sows were returned to the breeding barn and number of days to first service was recorded.

Statistical Analysis. Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) as a completely randomized design. Residual error was used to test treatment differences. The number of stillborns/litter; number of mummies/litter; individual pig birth weight; days to estrus; gestation weight change; lactation weight change; body condition score at farrowing and weaning; change in body condition score from d 90 to weaning and from d 0 to weaning; backfat depth on d 90, d 0, and at weaning; and longissimus muscle area on d 90 and at weaning were analyzed using sow weight on d 90 as a covariate. The number of pigs alive at weaning was analyzed using pig age at weaning and number of pigs on d 3 as covariates. Individual pig weaning weight was analyzed using pig age at weaning and pig weight on d 3 as covariates. Survival from d 3 to weaning was analyzed using pig weight on d 3 and number of pigs on d 3 as covariates. Treatments were compared using single-degree-of-freedom orthogonal contrasts (Steel and Torrie, 1980). These comparisons included both level of supplemental fat (0% vs. 10%) and source of supplemental fat (MCT vs LCT).

Results

Litter Performance. The number of pigs born alive was not affected by dietary treatment (Table 2; $P > 0.10$). The prevalence of mummies and stillborns was higher ($P < 0.02$) when supplemental fat was fed. The number of stillborns was greater ($P < 0.03$) with the MCT than with the LCT treatment. Overall pig survival from birth to d 3 averaged 92.1%. Percentage of survival averaged 94.3 ± 0.9% from d 3 to weaning and was unaffected by treatment. Pigs nursing sows fed supplemental fat had a 6% greater ADG ($P < 0.002$), resulting in greater weaning weights (Table 2), but no differences between fat sources were detected ($P > 0.10$).

Sow Performance. Lactation feed intake of sows was 10% lower ($P < 0.01$) when fat was supplemented (Table 3); however, ME (23.9 Mcal/d) and digestible lysine (54 g/d) intakes were unaffected. Supplemental fat did not affect the weaning-to-estrus interval. Initial sow weight on d 90 was different ($P < 0.01$) between the MCT and LCT treatments (Figure 1), so weight on d 90 was used as a covariate in the statistical analysis (Figure 1). A 23% (4 kg) greater increase in sow weight over gestation was observed in the groups fed 10% fat ($P < 0.01$; Figure 1). The resulting difference in weights observed on d 109 persisted throughout the study until pigs were weaned; however, treatment effects on subsequent sow weight gains were not detected (Table 3, $P > 0.10$). Surprisingly, there was essentially no weight gain or loss in sows over lactation, regardless of treatment. Body condition scores recorded on d 90 (2.76), after farrowing (2.72), and at weaning (2.63) were not different (Table 3). However, the overall decrease in body condition score from gestation (d 90) to weaning was lower ($P < 0.07$) in sows receiving supplemental fat than in control sows, and 67% of this difference occurred during the lactation period. Backfat depth was not affected by treatment (Table 4); however, changes in backfat depth (within an animal) were 49% greater ($P < 0.01$) in sows consuming fat during gestation than in sows fed the control diet (Table 4). Backfat depth increased by > 4 mm during lactation, but treatment effects were not detected ($P > 0.10$). Longissimus muscle area on d 90 of gestation and at parturition was not affected by fat supplementation (Table 4). At weaning, longissimus muscle area was 2.5% greater ($P < 0.05$) in sows consuming 10% dietary fat.

Discussion

Fat addition is one method used to manipulate the energy density of the diet to improve energy intake. In many cases, provision of a lipid product such as tallow or lard may be more cost-effective than use of carbohydrate energy sources (Doreau and Chilliard, 1997). Improvements in energy intakes are needed because the energy demands of lactating sows are high (≥ 15 to 20 Mcal ME/d). Typically, the amount of feed needed to provide this quantity of ME is not voluntarily consumed by the sow, and thus lactational weight loss occurs. The typical lactation diet contains 3,265 kcal of ME/kg (NRC, 1998), and a sow would need to ingest an average of 6.1 kg of feed daily over lactation to ingest 20 Mcal

Table 2. Effect of dietary medium-chain (MCT) or long-chain triglyceride (LCT) during gestation and lactation on litter variables (least squares means)

	Dietary treatment				Contrast *P*-value	
Pig criterion	0% FAT (n = 164)	10% MCT[a] (n = 159)	10% LCT[a] (n = 159)	SEM	0 vs 10% fat	MCT vs LCT
Alive at birth, no./litter	10.78	10.55	10.73	0.24	0.62	0.59
Stillborn, no./litter[b]	0.40	0.71	0.49	0.07	0.02	0.03
Mummified, no./litter[b]	0.12	0.21	0.22	0.04	0.07	0.90
Birth weight, kg/pig[b]	1.52	1.55	1.55	0.02	0.18	0.75
Alive on d 3, no./litter	9.92	9.92	9.68	0.11	0.35	0.14
Weight on d 3, kg/pig	1.92	1.98	1.98	0.03	0.06	0.94
Alive at weaning, no./litter[c]	9.31	9.23	9.23	0.08	0.43	0.99
Weaning weight, kg/pig[d]	4.34	4.53	4.52	0.05	0.005	0.85
Average daily gain, g/pig	192.24	202.90	203.53	2.94	0.002	0.88
Weaning age, d	15.7	15.2	15.5	0.2	0.13	0.17
Survival (d 3 to weaning),%[e]	94.8	94.2	93.9	0.9	0.49	0.86

[a]Fat provided as medium-chain triglyceride (C8/C10) or as long-chain triglyceride (choice white grease).
[b]Sow weight on d 90 as covariate.
[c]Pig age at weaning and number of pigs on d 3 as covariates.
[d]Pig age at weaning and pig weight on d 3 as covariates.
[e]Pig weight and number of pigs on d 3 as covariates.

of ME. These daily intakes were exceeded in our experiment, regardless of fat addition. We believe that the high ME intakes in this experiment were due in part to the high feeding frequency (five times per day during the coolest hours (0300 to 1300)). Placing fresh feed in the feeder may have stimulated a behavioral response in the sows, elevating lactation feed intake and thereby allowing them to maintain BW and increase backfat depth by as much as 4.5 mm. However, increasing feeding frequency has not always resulted in significant differences in lactation feed intake (NCR-89, 1990).

Some studies have shown a reduction in feed intake when energy density is increased by adding fat, and other studies have shown no difference between added-fat and control groups. In many cases the energy intake is numerically higher for sows consuming diets with additional fat. In an experiment in which sows consumed a control diet or 10% addition of a dried-fat product, Shurson et al. (1986) did not detect any differences in feed consumption. However, in our experiment feed intake was decreased by 10% in sows consuming the fat-supplemented diets. Thus, sows consumed the same amount of ME and digestible lysine. These intakes are higher than those reported in similar studies (Pettigrew and Moser, 1991; Coffey et al., 1994; Tilton et al., 1999). Results of our study follow the same trend as that observed by Boyd et al. (1978, 1982). They noted that feed intake was lower when fats were added due to the increased caloric density of the diet. In a review of 19 experiments, Pettigrew and Moser (1991) determined that an average decrease in feed intake of 267 g/d occurred when fat (≥ 10%) was added to the lactation diet. They noted, however, a consistent increase (1.24 Mcal ME/d) in the energy intake. This was even greater

Table 3. Effect of dietary medium-chain (MCT) or long-chain triglyceride (LCT) during gestation and lactation on sow variables (least squares means)

	Dietary treatment				Contrast *P*-value	
Sow criterion	0% fat	10% MCT[a]	10% LCT[a]	SEM	0 vs 10% fat	MCT vs LCT
Parity	3.26	3.28	3.87	2.37	0.29	0.09
Daily lactation feed intake, kg[bc]	7.19	6.41	6.54	0.10	0.0001	0.35
Return to estrus, d[b]	6.30	5.84	6.59	0.40	0.86	0.20
Gestation weight change, kg/d[b]	0.66	0.85	0.87	0.03	0.0001	0.38
Lactation weight change, kg/d[b]	0.0	–0.01	0.01	0.07	0.93	0.80
Body condition score (BCS) on d 90	2.76	2.75	2.77	0.03	0.90	0.59
BCS at farrowing[b]	2.72	2.70	2.75	0.03	0.95	0.25
BCS at weaning[b]	2.59	2.63	2.67	0.04	0.19	0.48
BCS, change from d 90 to weaning[b]	–0.18	–0.11	–0.10	0.03	0.07	0.90
BCS, change from d 0 to weaning[b]	–0.15	–0.06	–0.08	0.03	0.05	0.61

[a]Fat provided as medium-chain triglyceride (C8/C10) or as long-chain triglyceride (choice white grease).
[b]Sow weight on d 90 as covariate.
[c]Caloric intakes were 23,619 kcal of ME/d, 23,794 kcal of ME/d, and 23,794 kcal of ME/d, respectively, for the 0% fat, 10% MCT, and the 10% LCT treatments.

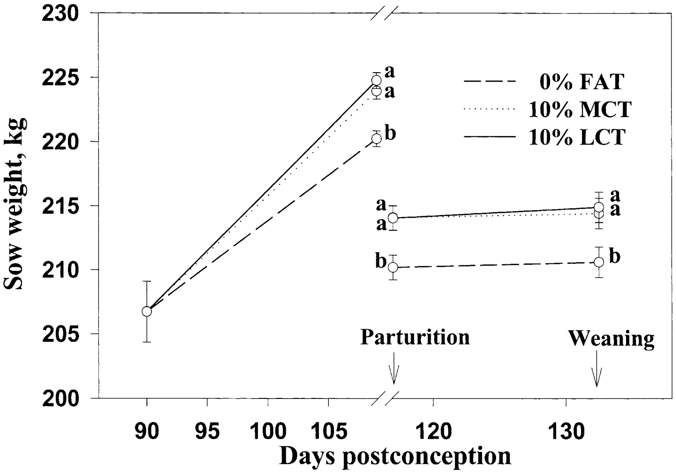

Figure 1. Effect of dietary medium-chain (MCT) or long-chain triglyceride (LCT) during gestation and lactation on sow weights from d 90 of gestation to weaning (least squares means). Sow weight on d 90 was used as a covariate for weights on d 90, d 109, 1 d after farrowing, and at weaning. Unadjusted sow weights on d 90 were 205.4 kg, 203.0 kg, and 211.8 kg for the 0% Fat, 10% MCT, and 10% LCT treatments, respectively. Error bars represent ± SEM.

[a,b]Values with unlike letters differ ($P < 0.01$).

(1.55 Mcal ME/d) when the amount of fat added was 10% of the diet or higher. Because of the high level of feed intake in our study, this effect was not observed. An increase in ME intake with fat supplementation seems to occur only when feed intake is limited due to other causes such as temperature extremes, health challenges, and poor feed quality (O'Grady et al., 1985). The advantage of increasing energy intake by adding dietary fat can be particularly helpful during hot summer months when feed intake is typically depressed (Schoenherr et al., 1989; Azain et al., 1996).

A study by Reese et al. (1982) showed that when sows were fed 16 Mcal of ME/d over lactation, weight loss was reduced by 148% compared to sows fed 8 Mcal of ME/d. In addition, backfat loss was 338% greater in the sows consuming 8 Mcal of ME/d. These changes were associated with a return to estrus by 14 d after weaning by 92.9% of the animals consuming 16 Mcal of ME/d compared to only 41.9% of the animals on the lower-energy diet. The daily energy intake in our study exceeded the 16-Mcal treatment in the study by Reese et al. (1982) by 49.3%, and this likely the reason that no differences were noted in the rebreeding interval. A recent series of studies examined the effects of feeding level and energy source on multiple factors involved in the interaction between nutrition and reproduction (van den Brand et al., 2000a,b,c). They noted an increased weight loss in sows consuming a portion of their energy intake as supplemental fat compared to those fed starch (van den Brand et al., 2000b). Regardless of the fat or energy source in our diets, there were no differences in lactation weight loss. In fact, from 1 d after farrowing to weaning, weight loss was minimal (Table 3).

The number of pigs born alive was not affected by dietary fat in our study. In previous work the percentage of stillbirths was not affected by dietary fat (Stahly et al., 1986; Seerley, 1989). The increase in stillbirths in this study cannot be explained. It is important to note that the increase in stillbirths did not affect the number of pigs born alive. The increase we observed in the number of mummies per litter also was observed by Neal et al. (1994). However, it is not clear why supplementation of fat in the sow diet as late as d 90 of gestation would have any effect on this variable. There was no difference in pig birth weight in this study. Coffey et al. (1994) noted an increase in birth weight due to an increase in the energy fed in gestation. They began feeding the experimental diets 30 d before breeding. In general, birth weights have not been affected by fat supplementation of sows' diets in late gestation (Pettigrew, 1981).

Because of high postnatal death losses in swine (USDA, 1997), improvement in energy status of the pig at birth might improve survival. Improved pig growth and survival have been related to increases in milkfat when sows are fed increased dietary fat (Seerley et al., 1974; Pettigrew, 1981; Averette et al., 1999). Cieslak

Table 4. Effect of dietary medium-chain (MCT) or long-chain triglyceride (LCT) during gestation and lactation on ultrasound measurements of sow backfat depth and longissimus area (least squares means)

	Dietary treatment				Contrast P-value	
Criterion[a]	0% FAT	10% MCT[a]	10% LCT[a]	SEM	0 vs 10% fat	MCT vs LCT
Backfat (BF) depth on gestation d 90, mm[b]	18.72	17.93	18.80	0.47	0.52	0.19
Backfat depth at farrowing (d 0), mm[b]	19.48	19.61	20.40	0.53	0.42	0.30
Change in BF depth (d 90 to 114 of gestation), mm	0.82	1.67	1.68	0.31	0.03	0.98
Backfat depth at weaning (d 15.5), mm[b]	24.17	23.20	24.09	0.86	0.61	0.47
Change in BF depth (d 0 to 15.5 of lactation), mm	4.56	4.39	3.57	0.79	0.55	0.46
Longissimus muscle area on gestation d 90, cm^2 [b]	44.22	44.83	45.06	0.46	0.19	0.75
Longissimus muscle area at farrowing, cm^2 [b]	47.88	44.75	44.86	2.06	0.22	0.97
Longissimus muscle area at weaning, cm^2 [b]	44.96	45.64	46.53	0.46	0.05	0.18

[a]Fat provided as medium-chain triglyceride (C8/C10) or as long-chain triglyceride (choice white grease).
[b]Sow weight on d 90 as covariate.

et al. (1983) found that adding 15% lipid to sows' diets increased the survival of the smaller pigs but had a diminishing effect as the birthweight of the pig increased. Azain (1993) fed MCT to sows in an isocaloric and isonitrogenous comparison to either starch or soybean oil. No improvements in pig growth were observed, but survival of pigs weighing < 900 g at birth was 68%, compared to only 32% in the starch-fed control group. These changes were not likely due to an improvement in the milk composition because the C8 and C10 fatty acids accounted for less than 5% of the total milk fatty acids. Further, total milk lipid content was decreased in sows consuming the medium-chain fat source. However, blood glucose concentration was greater at birth in pigs from sows fed either the soybean oil (80.3 mg/100 mL) or the medium-chain triglyceride (76.8 mg/100 mL) than in those fed starch (61.3 mg/100 mL). Azain (1993) hypothesized that the increase in survival was therefore due to an improvement in the ability of the pig to regulate blood glucose. This suggestion was corroborated by Jean and Chiang (1999), who observed improved survival of pigs from MCT-fed sows associated with increased liver and muscle glycogen content. Although there is limited fatty acid transfer across the porcine uterus and placenta to the fetal tissues (Thulin et al., 1989), ketone bodies produced from the oxidation of lipids may provide carbon to the fetal pig to fuel glycogenic and lipogenic pathways. Medium-chain fatty acid oxidation and its products may alter insulin secretion and glucose metabolism in animals that consume a portion of their energy intake as MCT (Greenberger and Skillman, 1969; Lepine et al., 1989; Odle et al., 1991). Therefore, it is likely that the effects of the medium-chain energy source would occur before parturition. Unfortunately, due to managerial constraints, we were unable to assess effects of MCT on neonatal survival from birth to d 3. We are not ruling out unique and specific effects of MCT, but, due to the constraints of the study, we are unable to make conclusions about MCT effects. Spence et al. (1985) measured the effects of ketogenic diets fed to sows before parturition and observed increased liver glycogen content in pigs. Increased energy storage may improve survivability.

This experiment was conducted on a commercial sow farm where intensive cross-fostering is part of normal farrowing-house management. Cross-fostering is known to have a beneficial effect on pig survival (England, 1986). We detected no effect of feeding dietary fat to sows on pig survival from d 3 to weaning. By d 3 pigs that have not already succumbed due to low energy status have probably developed sufficient ability to regulate their blood glucose concentrations. However, supplementation of sows' diets with fat did improve pigs' weight gains during lactation, as reported recently (Averette et al., 1999; Tilton et al., 1999). Tilton et al. (1999) and van den Brand et al. (2000b) both noted that increased gain was primarily composed of fat when sows were fed diets supplemented with fat. Even modest improvements in pig weaning weights may be beneficial, especially when animals are subjected to weaning stressors at an early age.

Collectively, because the pigs from sows fed supplemental fat had greater ADG and weaning weights, and because the sows consumed the same amount of ME over lactation without significant changes in body mass, we infer that the efficiency of energy utilization was improved with dietary fat supplementation. Fat-supplemented diets have a lower heat increment due to the high efficiency of dietary fat conversion to body or milk fat compared to protein or carbohydrates (O'Grady et al., 1985; Pettigrew and Moser, 1991), and this could explain, in part, the observed response.

Implications

This large-scale field trial conducted on a commercial swine farm shows that supplemental energy from dietary fat can improve body condition of lean-genotype sows during gestation. An intensive lactation feeding protocol (five times per day) resulted in high feed intakes even within control sows and may have obviated effects of supplemental fat on body condition after farrowing. Differences between the medium- and long-chain fat sources were not detected in this study. However, supplemental fat during lactation improved suckling pig growth rates and weaning weights, effects that may benefit early-weaning management programs.

Literature Cited

Averette, L. A., J. Odle, M. H. Monaco, and S. M. Donovan. 1999. Dietary fat during pregnancy and lactation increases milk fat and insulin-like growth factor I concentrations and increases neonatal growth rates in swine. J. Nutr. 129:2123–2129.

Azain, M. J. 1993. Effects of adding medium-chain triglycerides to sow diets during late gestation and early lactation on litter performance. J. Anim. Sci. 71:3011–3019.

Azain, M. J., T. Tomkins, J. S. Sowinski, R. A. Arentson, and D. E. Jewell. 1996. Effect of supplemental pig milk replacer on litter performance: Seasonal variation in response. J. Anim. Sci. 74:2195–2202.

Boyd, R. D., B. D. Moser, E. R. Peo, Jr., and P. J. Cunningham. 1978. Effect of energy source prior to parturition and during lactation on piglet survival and growth and on milk lipids. J. Anim. Sci. 47:883–892.

Boyd, R. D., B. D. Moser, E. R. Peo, Jr., A. J. Lewis, and R. K. Johnson. 1982. Effect of tallow and choline chloride addition to the diet of sows on milk composition, milk yield and preweaning pig performance. J. Anim. Sci. 54:1–7.

Cieslak, D. G., V. D. Leibbrandt, and N. J. Benevenga. 1983. Effect of a high fat supplement in late gestation and lactation on piglet survival and performance. J. Anim. Sci. 57:954–959.

Coffey, M. T., B. G. Diggs, D. L. Handlin, D. A. Knabe, C. V. Maxwell, Jr., P. R. Noland, T. J. Prince, and G. L. Cromwell. 1994. Effects of dietary energy during gestation and lactation on reproductive performance of sows: A cooperative study. J. Anim. Sci. 72:4–9.

Curtis, S. E., C. J. Heidenreich, and C. W. Foley. 1966. Carbohydrate assimilation and utilization by newborn pigs. J. Anim. Sci. 25:655–662.

Doreau, M., and Y. Chilliard. 1997. Digestion and metabolism of dietary fat in farm animals. Br. J. Nutr. 78(Suppl. 1):S15 (Abstr.).

Dourmad, J. Y. 1991. Effect of feeding level in the gilt during pregnancy on voluntary feed intake during lactation and changes in body composition during gestation and lactation. Livest. Prod. Sci. 27:309–320.

England, D. C. 1986. Improving sow efficiency by management to enhance opportunity for nutritional intake by neonatal piglets. J. Anim. Sci. 63:1297–1306.

Greenberger, N. J., and T. G. Skillman. 1969. Medium-chain triglycerides: Physiologic considerations and clinical implications. N. Engl. J. Med. 280:1045–1058.

Jean, K. B., and S. H. Chiang. 1999. Increased survival of neonatal pigs by supplementing medium-chain triglycerides in late-gestating sow diets. Anim. Feed Sci. Technol. 76:241–250.

Kasser, T. R., R. J. Martin, and C. E. Allen. 1981. Effect of gestational alloxan diabetes and fasting on fetal lipogenesis and lipid deposition in pigs. Biol. Neonate 40:105–112.

Lepine, A. J., R. D. Boyd, J. A. Welch, and K. R. Roneker. 1989. Effect of colostrum or medium-chain triglyceride supplementation on the pattern of plasma glucose, non-esterified fatty acids and survival of neonatal pigs. J. Anim. Sci. 67:983–990.

NCR-89. 1990. Feeding frequency and the addition of sugar to the diet for the lactating sow. J. Anim. Sci. 68:3498–3501.

Neal, S. M., K. M. Irvin, and G. C. Shurson. 1994. Lactation dietary fat level: Effects on litter size and piglet growth. J. Anim. Sci. 72(Suppl. 1):333 (Abstr.).

NRC. 1988. Nutrient Requirements of Swine. 9th ed. National Academy Press, Washington, DC.

O'Grady, J. F., P. B. Lynch, and P. A. Kearney. 1985. Voluntary feed intake by lactating sows. Livest. Prod. Sci. 12:355–365.

Odle, J. 1998. Medium-chain triglycerides: A unique energy source for neonatal pigs. Pig News Info. 20:25N–32N.

Odle, J., N. J. Benevenga, and T. D. Crenshaw. 1991. Utilization of medium-chain triglycerides by neonatal piglets: Chain length of even- and odd-carbon fatty acids and apparent digestion/absorption and hepatic metabolism. J. Nutr. 121:605–614.

Patience, J. F., and P. A. Thacker. 1989. Swine Nutrition Guide. pp. 149–171. Prairie Swine Centre, University of Saskatchewan, Saskatoon, Canada.

Pettigrew, J. E. Jr. 1981. Supplemental dietary fat for peripartal sows: A review. J. Anim. Sci. 53:107–117.

Pettigrew, J. E., and R. L. Moser. 1991. Fat in Swine Nutrition. In: E. R. Miller, D. E. Ullrey, and A. J. Lewis (ed.) Swine Nutrition. pp 133–145. Butterworth-Heinemann, Boston, MA.

Reese, D. E., B. D. Moser, E. R. Peo, Jr., A. J. Lewis, D. R. Zimmerman, J. E. Kinder, and W. W. Stroup. 1982. Influence of energy intake during lactation on the interval from weaning to first estrus in sows. J. Anim. Sci. 55:590–598.

Schoenherr, W. D., T. S. Stahly, and G. L. Cromwell. 1989. The effects of dietary fat or fiber addition on yield and composition of milk from sows housed in a warm or hot environment. J. Anim. Sci. 67:482–495.

Seerley, R. W. 1989. Survival and postweaning performance of pigs from sows fed fat during late gestation and lactation. J. Anim. Sci. 67:1889–1894.

Seerley, R. W., T. A. Pace, C. W. Foley, and R. D. Scarth. 1974. Effect of energy intake prior to parturition on milk lipids and survival rate, thermostability and carcass composition of piglets. J. Anim. Sci. 38:64–70.

Shurson, G. C., M. G. Hogberg, N. DeFever, S. V. Radecki, and E. R. Miller. 1986. Effects of adding fat to the sow lactation diet on lactation and rebreeding performance. J. Anim. Sci. 62:672–680.

Spence, C. A., R. D. Boyd, C. D. Wray, and D. M. Whitehead. 1985. Effect of 1,3-Butanediol and short chain acids in sow gestation diets on maternal plasma metabolites and fetal energy storage. J. Anim. Sci. 60:1280–1287.

Stahly, T. S., G. L. Cromwell, and H. J. Monegue. 1986. Effects of dietary additions of 1,3-butanediol or lard for sows on survival of neonatal pigs. J. Anim. Sci. 63:1156–1162.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd ed. McGraw-Hill Publishing Co., New York.

Tilton, S. L., P. S. Miller, A. J. Lewis, D. E. Reese, and P. M. Ermer. 1999. Addition of fat to the diets of lactating sows. I. Effects on milk production and composition and carcass composition of the litter at weaning. J. Anim. Sci. 77:2491–2500.

Thulin, A. J., G. L. Allee, D. L. Harmon, and D. L. Davis. 1989. Utero-placental transfer of octanoic, palmitic and linoleic acids during late gestation in gilts. J. Anim. Sci. 67:738–745.

USDA. 1997. Part III : Changes in the U.S. Pork Industry 1990–1995. National Animal Health Monitoring System, Animal and Plant Health Inspection Service, Veterinary Services, Fort Collins, CO.

van den Brand, H., S. J. Dieleman, N. M. Soede, and B. Kemp. 2000a. Dietary energy source at two feeding levels during lactation of primiparous sows: I. Effects on glucose, insulin, and luteinizing hormone and on follicle development, weaning-to-estrus interval, and ovulation rate. J. Anim. Sci. 78:396–404.

van den Brand, H., M. J. W. Heetkamp, N. M. Soede, J. W. Schrama, and B. Kemp. 2000b. Energy balance of lactating primiparous sows as affected by feeding level and dietary energy source. J. Anim. Sci. 78:1520–1528.

van den Brand, H., N. M. Soede, and B. Kemp. 2000c. Dietary energy source at two feeding levels during lactation of primiparous sows: II. Effects on periestrus hormone profiles and embryonal survival. J. Anim. Sci. 78:405–411.