Effect of Bile Supplementation on Fat Digestion in Early Weaned Pig Diets

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Early weaned pigs are less capable of digesting and utilizing dietary fat than are older pigs (Pettigrew and Moser, 1991; Leibbrandt et al., 1975). Even at 21 days of age, weanling pigs exhibit lower fat digestibility than older pigs (Cera et al., 1988). It has been suggested that there is no benefit from adding fat to diets of weanling pigs until four weeks after weaning (Cline, 1991).

Bile salts function to emulsify lipids and fat solubles to form fat-containing micelles to ease absorption from the intestinal tract. However, in animals, including humans, the production and utilization of bile salts is very limited at birth and during early development stages. In humans, insufficient bile has been associated with lipid malabsorption in premature infants (Watkins et al., 1975). The same malabsorption syndrome has been demonstrated in newly hatched chicks (Serafin and Nesheim, 1967). The addition of bile salts to poultry diets has resulted in an improvement of fat absorption in chicks and hens (Edwards, 1962; Gomez and Polin, 1976; Kussaibati et al., 1982).

There is growing interest in segregated early weaning programs for swine starting as early as 14 days of age. However, one of the limiting factors is the limited abilities of young pigs to digest dietary fat and the subsequent consequences on their performance. In an early study designed primarily to measure the effects of bile on vitamin E absorption, Reinhart et al. (1988) observed that performance of pigs weaned at 21 days increased linearly with increased levels of bile salt in the diet. Bile is harvested from some hog processing plants, but marketed primarily as an export product. The objective of the present study was to determine the effects of bile (desiccated hog bile) supplementation on fat digestibility in weaned pigs as measured in digestion trials.

Materials and Methods

Bile Product and Experimental Diets

Desiccated hog bile (tested negative for *E. coli* and salmonella) containing cholic acid was obtained from American Laboratories, Inc., Omaha. The bile was added to diets at the rate of 0, 0.15, 0.30, and 0.45% of the diet at the expense of corn. The diets (Table 1) were formulated to contain 7% hog fat and 1.45% lysine, and to meet or exceed other nutrient requirements for baby pigs (NRC, 1998).

Swine Nutrient Metabolism Assay

Trial 1. Twenty-four crossbred barrows (Landrace or Yorkshire sows; PIC Line 355 boars), 14 days of age and averaging 10.6 lbs in weight, were sorted by weight and assigned to one of four experimental diets under a completely randomized design. Two pigs were placed per pen in stainless-steel metabolism crates in an environmentally controlled room with temperatures

ranging from 21 to 23°C (69.8 to 73.4°F) under continuous lighting. Two pigs in a pen constituted an experimental unit and were placed together to enhance companionship and curtail the delay in feed intake that could result due to early isolation from the sow. Treatments were randomly assigned to pigs in the crates with three replications per treatment.

The metabolism assay involved a 5 to 6 day total collection of feces. Prior to feeding of experimental diets, the barrows were allowed a 6-day period of acclimation, during which the pigs were provided feed twice a day and allowed to attain a feed intake equivalent to about 5% of their body weight or 1.1 lbs per pen. On day 7, pigs were allowed access to only water and were started on dietary treatments on day 8. To initiate fecal collection, collection trays (stainless steel) with companion screens were placed under pens and a plastic panel was placed directly under each feeder receptacle to collect any waste feed. A non-digestible marker, carmine red (0.5 g), was fed in .22 lbs of morning (9:00 a.m.) ration (.55 lbs) portioned for each pen. The remaining morning ration was fed after pigs had consumed the feed-containing marker, followed by the evening ration of .55 lbs at 6:00 p.m. Appearance of marker in the feces initiated the collection of the first fecal samples. Fecal samples were collected through day 13 when the second marker was fed and terminated when the marker appeared in the feces on day 14. Fecal samples were collected once daily for each pen and frozen after weighing.

Trial 2. Twelve crossbred barrows averaging 13 days of age and weighing 9.5 lbs were used, with one pig placed per pen. During the 6-day acclimation period, each barrow was allowed company with a gilt for four days. The gilts were removed from the pens two days before the barrows were allowed access to only water on day 7. The barrows in Trial 2 were treated similarly as barrows in Trial 1 and experimental procedures of feeding and fecal collection were the same except that there was one pig per pen.

Chemical Analysis of Experimental Diets and Fecal Samples

Dry matter of experimental diets and fecal samples were determined by drying samples at 110°C (230°F) for 24 hours. Nitrogen content of diets and fecal samples was determined using a combustion method which employed a combustion analyzer, Model FP2000 (LECO Corp., St. Joseph, MI). Energy content of diets and fecal samples was determined by bomb calorimetry using an adiabatic calorimeter, Parr 1261 (Parr Instrument Co., Moline, IL). Fat content of diets and fecal samples was determined using a fat analyzer, Model FA-100 (LECO Corp., St. Joseph, MI).

Statistical Analysis

Data from Trials 1 and 2 were combined to increase treatment replications and data in Trial 1 were adjusted by dividing observed values by two to express the data on per pig basis consistent with Trial 2. Data were analyzed using the GLM procedure of SAS (1986).

Results

Chemical Analysis of Experimental Diets and Fecal Samples

The dry matter (91%), fat (9%), gross energy (4 kcal/g), and crude protein (21%) contents of experimental diets are summarized in Table 2. Nutrient content was similar among

diets. The results of the chemical analysis of fecal samples (Table 2) showed that dry matter (97%), gross energy (4 kcal/g), and nitrogen (5%) were similar among treatments. However, the fat content of the fecal samples declined (from 6.5 to 3.8%) with increased level of bile (from 0 to 0.45%) in the diet.

Animal Performance

The presence of bile in the diets of early-weaned pigs did not affect their general performance. Feed intake, weight gain and feed efficiency were similar among pigs fed diets containing the various levels of bile (Table 3). Although palatability was not tested in the present study, it appeared that the addition of bile to diets of early-weaned pigs did not have an adverse effect on animal performance in terms of feed intake and daily weight gain.

Fat Digestibility

The inclusion of desiccated bile product in the diets of early-weaned pigs improved fat digestibility by about 4 percentage units in the present study (Table 3 and Figure 1). The presence of the bile product in the diet resulted in a significant ($P<.01$) linear increase in fat digestibility in relation to increased level of the bile in the diet. The increase in fat digestibility ranged from 93% (0% bile in the diet) to 97% (0.45% bile in the diet). Reinhart et al. (1988) reported a similar response in their study, where fat digestibility increased as bile salt level increased in the diet. In their study, the linear response in fat digestibility appeared to plateau at 0.30% bile. However, in the present study, the linear response of fat digestibility due to bile level in the diet did not plateau, and produced a straight line with an R^2 value of 0.996 when percentage fat digestibility was plotted against bile level in the diet. The highest level of bile used in the present study was 0.45%. It has been suggested that improvement in fat digestibility by addition of bile salt to diets may be due to supplementation of the insufficient bile salt secreted by the animal or the replenishment of the active catabolism of bile salts by the intestinal microflora. Young et al. (1963) also demonstrated that addition of antibiotics to diets of chicks appeared to increase their fat utilization, probably by reducing intestinal microbial populations and thereby reducing their rate of bile salt catabolism. Another possibility is the added advantage of dietary bile salt in enhancing the digestibility of saturated fatty acids with long chains (Gomez and Polin, 1976).

Implications

Segregated early weaning programs, weaning pigs at 14 to 21 days of age, continue to expand rapidly in spite of the limited ability of early-weaned pigs to digest and utilize dietary fat. The results of the present study suggest that the inclusion of desiccated hog bile in the diets of early-weaned pigs may improve their ability to digest and utilize dietary fat. The presence of bile in the diet did not illicit adverse effects on the pigs' live performance or nutrient metabolism. Although more research on the use of this bile product is required, the results obtained in the present study indicate the possible benefits from the use of hog-extracted bile in diets for early weaning pigs.

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Table 1. Percentage composition of experimental diets.

	Bile Diets			
Ingredients	0	0.15	0.3	0.45
Corn	40.11	39.96	39.81	39.66
Soybean meal, 48%	27.2	27.2	27.2	27.2
Whey, dry	15	15	15	15
Pork fat	7	7	7	7
Blood meal	3	3	3	3
Fish meal	3	3	3	3
Meat and bone meal	1	1	1	1
Antibiotic[a]	1	1	1	1
DL methionine	0.14	0.14	0.14	0.14
Dicalcium phosphate	0.9	0.9	0.9	0.9
Limestone	0.6	0.6	0.6	0.6
Salt	0.25	0.25	0.25	0.25
Desiccated hog bile	0	0.15	0.3	0.45
Zinc oxide	0.38	0.38	0.38	0.38
Swine vitamin mix[b]	0.25	0.25	0.25	0.25
Swine trace mineral mix[c]	0.12	0.12	0.12	0.12
Selenium 600 mix[d]	0.05	0.05	0.05	0.05
Calculated composition				
Crude protein, %	22	22	22	22
Lysine, %	1.45	1.45	1.45	1.45
Calcium, %	0.9	0.9	0.9	0.9
Total phosphorus, %	0.77	0.77	0.77	0.77

[a] Supplied 55 mg mecadox/kg of diet.
[b] Provided the following per kilogram of diet: vitamin A, 6,055 IU; vitamin D_3, 605.5 IU; vitamin E, 42.5 IU; menadione sodium bisulfite, 2 mg; vitamin B_{12}, 35.25 ug; riboflavin, 7 mg; calcium pantothenic, 22 mg; niacin, 33 mg.
[c] Provided the following per kilogram of diet: Fe, 116.4 mg; Mn, 14.4 mg; Zn, 116.4 mg; Cu, 10.8 mg; I, 0.402 mg.
[d] Supplied 100 ug Se/kg diet.

Table 2. Chemical analysis of bile diets fed to early-weaned pigs and feces excreted, in trials 1 and 2.

Analysis	Bile levels in diets, %				
	0	0.15	0.3	0.45	SD
Diet samples					
Dry matter, %	91.29	91.13	91.31	91.19	0.46
Fat content, %	8.61	8.85	8.97	9.11	1.39
Gross energy, kcal/g	4.296	4.324	4.319	4.352	0.03
Nitrogen content, %	3.32	3.26	3.31	3.47	0.11
Crude protein, %	20.76	20.38	20.71	21.71	0.67
Fecal samples					
Dry matter, %	96.65	96.34	96.58	96.54	0.61
Fat content, %	6.52	5.81	4.65	3.78	0.88
Gross energy, kcal/g	4.526	4.408	4.437	4.375	0.21
Nitrogen content, %	5.43	5.49	5.56	5.46	0.43

Table 3. Effect of dietary bile on live performance and fat digestion in early-weaned pigs, in trials 1 and 2.

	Bile levels in diets, %				
Criteria	0	0.15	0.3	0.45	SD
Live performance					
Initial weight, lb	9.96	9.84	10.26	10.09	1.27
Final weight, lb	13.71	12.72	13.68	12.93	1.31
Daily gain, lb/day	.626	.481	.573	.472	.137
Daily gain intake, lb/day	.556	.542	.600	.540	.082
Gain:Feed	1.12	0.88	0.95	0.87	0.25
Fat digestion					
Fat content of feces, %	6.52[a]	5.81[a]	4.65[b]	3.8[b]	0.89
Total fat output in feces, lb	.0201[a]	.0166[a]	.0154[a]	.0102[b]	.0037
Fat retained, lb	.269	.271	.309	.284	.046
Fat retention, % of intake	93.04[c]	94.26[b]	95.24[b]	96.54[a]	0.99

Contrasts on bile level	Fecal fat content	Fat output	Fat retention
	----------Probability----------		
0 vs 0.15%	0.203	0.147	0.044
0 vs 0.30%	0.003	0.06	0.001
0 vs 0.45%	<0.001	<0.001	<0.001
0.15 vs 0.30%	0.036	0.617	0.091
0.15 vs 0.45%	<0.001	0.011	<0.001
0.30 vs 0.45%	0.111	0.031	0.028
0 vs All	<0.001	0.006	<0.001

[a, b, c] Means within a row with different superscripts are significantly different (P<.05).

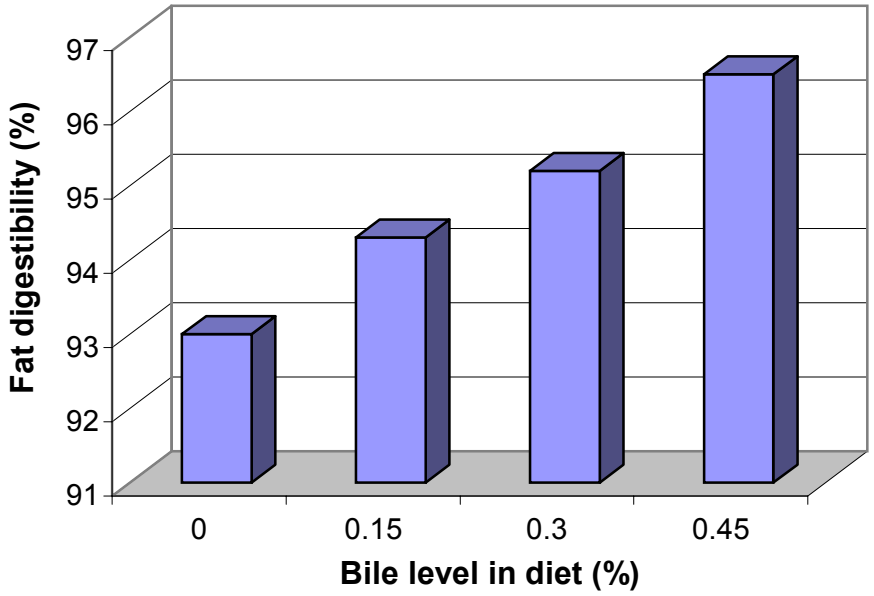

Figure 1. Effect of dessicated hog bile on fat digestibility in early weaned pigs.