Effects on Growth Performance and Pork Quality in Pigs Fed Diets Containing Conjugated Linoleic Acid and High Oil Corn

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Summary and Implications

High oil corn (HOC) is a good source of both energy and protein. In pigs diets, however, it can have a detrimental effect on quality of the carcass. Conjugated linoleic acid (CLA) corrects the fat quality problems that occur from feeding HOC. However, CLA does not consistently act as a growth promotant or as a way to decrease fat when feeding high energy diets.

Introduction

Incorporation of high oil corn (HOC) in the diets of market pigs are beneficial to swine producers in that feed efficiency and dust control are improved and handling and mixing of oil is more user friendly. Because of the added energy in the diet from HOC, feeding HOC is particularly beneficial for young pigs, for lactating sows and for all pigs in hot weather. A potentially detrimental result of feeding HOC, however, is that of producing soft carcass fat and soft bellies because of the high proportion of polyunsaturated fatty acids in HOC diets. Unsaturated fats are susceptible to oxidation, and as a consequence, there is also potential for shorter shelf life of pork products from pigs fed HOC. Soft pork bellies result in reduced sliceability and yield of bacon. Reduced shelf life manifested in undesirable lean color, aroma, and flavor of retail cuts of pork, and decreased sliceability and yield of bacon could cause significant economic loss to the pork industry. Supplementation of the diet with conjugated linoleic acid (CLA) is a possible method of improving shelf life and belly yield of pigs fed HOC. Our earlier results have demonstrated that bellies from pigs fed CLA are firmer than those from pigs fed control diets. These results indicates that CLA could be a valuable addition to pig diets that contain HOC. Therefore, pork quality benefits could be derived from the supplementation of CLA in HOC diets by making pork bellies firmer, and pork cuts more consumer acceptable.

Objective

The objective of our study was to determine if the inclusion of CLA in a HOC diet would improve pork quality and growth performance.

Materials and Methods

Forty-eight barrows weighing about 55 kg were fed one of six experimental diets. Diets contained 1) normal corn (NC), 2) diet 1 + 1.25% CLA oil (oil contained 60% CLA) (NC+CLA), 3) high oil corn (HOC), 4) diet 3 + 1.25% CLA oil (HOC + CLA), 5) diet 1 + choice white grease (NCwCWG), and 6) diet 5 + 1.25% CLA oil (NCwCWG + CLA). Experimental diets were formulated to have equal ratios of metabolizable energy to lysine between the lower-energy diets (diets 1and 2) and higher-energy diets (diets 3, 4, 5, and 6). CLA was replaced by soy oil to make diets 1 and 2 isocaloric and 3, 4, 5, and 6 isocaloric (Tables 1 and 2). Pigs were penned individually and feed intake and weight gain, were measured. Ultrasound measurements of fat thickness and loin muscle area were determined at 55, 90, and 113 kg body weight. Carcass lean was calculated from ultrasound loin muscle area and back fat measurements according to NPPC 1989 formulas. Pigs were slaughtered at 113 kg.

At 24-h post mortem, carcasses were fabricated into primal cuts, including ham, loin, belly, picnic shoulder and Boston butt. Carcasses were cut between the 10th and 11th ribs and loin muscle area and back fat depth at the 10th rib , first rib, last rib, and last lumbar vertebra were measured. Subjective scores for color, marbling, and firmness were taken on each loin at the 10th rib. Loins were boned and cut into chops. Starting at the 10th and 11th rib junction, chops were cut in alternating thickness for samples for specific pork quality measures. The first chop was .63 cm in thickness followed by two 2.54-cm chops. This alternating method was used for all the loin to get representative samples of the entire loin. The 2.54-cm chops were paired and wrapped on styrofoam trays with oxygen permeable polyvinyl overwrap. All chops were held at 2^{o}C for 1, 7, 14, and 21 d. At each representative day, a package of chops was measured for lean color and pH. Bellies were removed and measured for firmness (the distance between ends of a belly suspended over a horizontal bar were measured with both fat and the lean side of the belly in the up position).

Results and Discussion

Growth performance data. Animals fed CLA showed a decline in ADG (P < .05) for the first 28 days, however, by the end of the trial there was no effect (P > .28) of CLA. For the period of 49 to 56 days, when only half of the pigs remained on test, the pigs fed the lower energy diet fed pigs had a greater ADG (P < .02) and ADFI (P < .03) than those fed the higher energy diets. During the second 2-week period, pigs fed NCwCWG had a lower ADFI than pigs fed other treatments, which resulted in pigs fed NCwCWG having a higher GF ratio (P < .05). Also, for the first 42 days, pigs fed diets with higher energy had a greater GF ratio (P < .05) than pigs fed lower energy diets. But the advantage of a higher GF ratio for HOC-fed pigs over NC-fed pigs was not seen in the over all trial. However, pigs fed NCwCWG did have a greater (P < .05) GF than pigs fed HOC diets. CLA main effect showed a reduction (P < .05) in GF, which is a contradiction to our past experiments where GF was increased by CLA. Also, an interaction in GF (P < .01) was seen between corn source and CLA for pigs fed diets with higher energy. HOC-fed pigs showed a benefit for GF from the addition of CLA whereas NCwCWG-fed pigs did not show the same effect from the addition of CLA. (Tables 3-5)

All growth rates were exceptionally good and it is difficult to explain why pigs fed NCwCWG grew at a faster rate throughout the trial than other treatment groups. The lower GF ratio of HOC-fed pigs compared with NC-fed pigs is also difficult to explain. Because of these two results the growth performance data are inconclusive and should be further researched.

Ultrasound data. Initial measurements (55 kg body weight) showed pigs assigned to the lower-energy treatments had a larger LMA (P < .03) but were not different for 10th rib back fat or calculated percent lean (NPPC 1989) than pigs assigned to other treatments. Pigs fed the lower energy treatments had a lower 10th rib back fat (P < .05) and greater LMA at day 28 (P < .05) and just before slaughter (P < .03). The reduced back fat and greater LMA resulted in pigs fed the lower energy diets having the greatest (P < .001) percent lean at day 28 and slaughter (Table 6).

Carcass characteristics. Pigs fed lower energy diets had less back fat at the last lumbar (P < .04) and 10th rib (P < .04) than pigs fed other treatments. An interaction (P < .04) was seen between corn source and CLA for leaf fat weight. The interaction seems to have been caused by an unusual decrease in leaf fat for pigs fed NCwCWG. The decrease in back fat of pigs fed NC is explained by lower energy intake. The decrease in leaf fat was not expected because it would be expected that an increase in energy intake would increase leaf fat. Therefore, the decrease of leaf fat of pigs fed the NCwCWG cannot be explained(Table 7).

Pigs fed the NC diets had higher subjective color loin scores (P < .05) at 24-h post mortem than pigs fed other treatments (Table 7). Pigs fed CLA had greater L* values for loin on day 0 (P < .05), 1 (P < .05), and 2 (P < .05), and b* values were lower for days 0 (P < .05) and 1 (P < .05) for pigs fed CLA than for pigs fed other treatments. No differences were seen in a* values and this was confirmed by the myoglobin values (Table 11).

A trend (P > .11) for CLA-fed pigs to have lighter hot carcasses was seen when weighing intact hot carcasses (Table 7). This trend was found to be significant (P < .05) for the cold halved carcasses (Table 10). CLA-fed pigs also had lighter (P < .05) shoulder weights. CLA-fed pigs had heavier loin (P < .05) when fed with a higher energy diet, whereas there was no effect of CLA for pigs fed the NC (lower-energy) diets. However, CLA did increase (P < .05) the belly weights of pigs fed NC diet and had no effect on belly weights in the pigs fed the higher-energy diets.

Ham weights were not affected by any treatment, but skin weights of the ham were decreased (P < .01) and separable fat weights were increased (P < .01) in pigs fed CLA. These effects may be explained by the harder fat of CLA-fed pigs, resulting in more efficient skin-fat separation by the skinning machine. When fat and skin were added together, there were no effects of CLA (Table 10).

Bellies from pigs fed CLA were firmer (P < .001) than those fed other treatments, as indicated by the belly bar test. The firmness of the bellies is the one measure that has been most consistently affected by feeding CLA. Both left and right side bellies of pigs fed the HOC diet were softer (P < .03) compared with bellies of pigs fed the NC diet, but the HOC+CLA-fed pigs had bellies that were slightly firmer than those fed NC diet but less firm than those fed NC+CLA diet. (Table 7) These results suggest that CLA improves belly quality (firmness) of pigs fed HOC.

Table 1. Diets for days 1 through 28.

	Treatments					
Ingredient	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA
Corn	76.6	76.6	-	-	72.4	72.4
HOC	-	-	76.9	76.9	-	-
SBM	19.6	19.6	19.5	19.5	21.1	21.1
CWG	-	-	-	-	3.0	3.0
Soy oil	1.25	-	1.25	-	1.25	-
CLA	-	1.25	-	1.25	-	1.25
Calculated analysis						
ME kcal/kg	3,318	3,318	3,468	3,468	3,468	3,468
Crude protein, %	15.0	15.0	15.6	15.6	15.6	15.6
Lysine, %	.80	.80	.84	.84	.84	.84
Meth. + Cys., %	.65	.65	.58	.58	.55	.55
Analyzed, %						
Lysine	.73	.72	.75	.73	.75	.73
Meth. + Cys.	.35	.38	.37	.38	.33	.39

Table 2. Diets for days 29 through 56.

	Treatments					
Ingredient	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA
Corn	87.95	87.95	-	-	82.46	82.46
HOC	-	-	87.88	87.88	-	-
SBM	10.75	10.75	8.86	8.86	10.7	10.7
CWG	-	-	-	-	3.59	3.59
Soy oil	1.25	-	1.25	-	1.25	-
CLA	-	1.25	-	1.25	-	1.25
Calculated analysis						
ME kcal/kg	3333	3333	3499	3499	3499	3499
Crude protein, %	10.6	10.6	11.4	11.4	11.1	11.1
Lysine, %	.6	.6	.64	.64	.64	.64
Meth. + Cys., %	.43	.43	.48	.48	.44	.44
Analyzed, %						
Lysine	.58	.54	.62	.60	.59	.59
Meth. + Cys.	.41	.41	.51	.53	.42	.41

Table 3. ADG of pigs fed CLA and HOC.

Item Period, d	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
ADG, kg							
1-14	1.19	1.14	1.25	1.16	1.34	1.23	a
15-28	1.30	1.21	1.23	1.24	1.29	1.25	NS
28-42	1.07	1.03	0.97	1.05	1.02	0.98	NS
42-49	1.10	1.16	1.10	1.25	1.25	1.16	NS
49-56	0.98	0.83	0.66	0.57	0.84	0.71	b, c
Cumulative							
1-28	1.25	1.18	1.24	1.2	1.32	1.24	a
1-42	1.19	1.13	1.15	1.15	1.22	1.14	NS
1-49	1.18	1.13	1.15	1.16	1.22	1.15	NS
Over all	1.17	1.10	1.11	1.13	1.20	1.12	NS

Treatments* (NC through NCwCWG +CLA)

[a] CLA main effect P<.05.
[b] Energy main effect P<.02.
[c] HOC vs. NC P<.01
* NC-normal corn; CLA-conjugated linoleic acid; HOC-high oil corn; NCwCWG-normal corn with Choice white grease

Table 4. ADFI of pigs fed CLA and HOC.

Item Period, d	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
ADFI, kg							
1-14	2.94	2.82	2.94	2.80	2.91	2.91	NS
15-28	3.19	3.11	3.30	3.14	2.90	3.01	a
28-42	3.24	3.26	3.14	3.14	2.95	3.16	NS
42-49	3.45	3.29	3.23	3.60	3.29	3.10	NS
49-56	3.10	3.00	2.80	2.62	2.93	2.64	b
Cumulative							
1-28	3.07	2.96	3.12	2.97	2.91	2.96	NS
1-42	3.12	3.06	3.13	3.03	2.92	3.02	NS
1-49	3.16	3.08	3.14	3.09	2.96	3.03	NS
Over all	3.15	3.08	3.14	3.08	2.98	3.02	NS

Treatments (NC through NCwCWG +CLA)

[a] HOC vs. NCwCWG P<.01.
[b] Energy main effect P<.03.

Table 5. Gain:feed of pigs fed CLA and HOC.

Item Period, d	Treatments						P <
	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	
GF, g/ kg							
1-14	405	404	427	413	462	421	a, b, c
15-28	408	392	372	396	445	415	b, c, d
28-42	330	314	308	335	344	311	NS
42-49	310	347	337	348	379	375	d
49-56	349	346	336	341	388	354	NS
Cumulative							
1-28	407	397	397	404	454	418	a, b, c, d
1-42	380	368	367	380	417	379	a, c, d
1-49	373	366	364	376	413	378	b, c
Over all	370	357	352	367	402	371	c, d

[a] CLA main effect P<.05.
[b] Energy main effect P<.05.
[c] HOC vs. NCwCWG P<.05.
[d] HOC NCwCWG interaction P<.01

Table 6. Ultrasound back fat and loin muscle measurements of pigs fed CLA and HOC.

Item	Treatments						P <
	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	
10th rib BF, cm							
Initial	1.02	0.99	1.04	0.98	0.96	1.02	NS
Day 28	1.49	1.53	1.61	1.73	1.54	1.70	a
Slaughter	2.11	1.98	2.22	2.21	2.03	2.42	b, c
LMA, cm^2							
Initial	22.51	22.99	20.90	22.05	21.44	21.35	b
Day 28	38.34	38.56	35.04	35.60	34.14	37.33	a, b
Slaughter	40.36	40.86	38.13	38.69	36.59	40.46	b, d
% Lean							
Initial	52.54	52.84	51.78	52.51	52.35	52.08	NS
Day 28	55.50	55.42	53.66	53.44	53.56	54.29	e
Slaughter	52.73	53.43	51.37	51.63	51.46	51.28	e

[a] NC vs. HOC P<.05.
[b] Energy main effect P<.03
[c] HOC and NCwCWG interaction P<.04.
[d] CLA main effect P<.06.
[e] Energy main effect P<.001.

Table 7. Carcass measurements of pigs fed CLA and HOC.

Item	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
	Treatments						
Carcass wt., kg	82.8	82.4	82.3	80.8	84.7	82.2	NS
Back fat, cm							
1st Rib	3.78	3.81	4.01	4.11	3.68	3.86	NS
Last rib	2.69	2.44	2.92	2.69	2.67	2.64	NS
Last lumbar	2.21	2.03	2.49	2.44	1.98	2.44	a
10th Rib	2.31	2.16	2.51	2.59	2.08	2.57	a
LMA, cm^2	40.58	42.32	39.42	38.58	39.94	44.32	NS
Leaf fat, kg	1.16	1.17	1.41	1.34	1.10	1.54	b
Loin quality							
Color	2.63	2.38	2.00	2.13	2.38	2.16	c
Marbling	1.88	2.13	1.88	1.88	1.88	1.81	NS
Firmness	2.75	2.25	2.5	2.25	2.38	2.03	NS
45 min pH	6.68	6.54	6.52	6.50	6.55	6.56	NS
120 min pH	6.71	6.43	6.39	6.54	6.42	6.41	NS
24 h pH	5.78	5.75	5.74	5.73	5.77	5.70	NS

[a] NC vs. HOC P<.04.
[b] HOC and NCwCWG interaction P<.04.
[c] Energy main effect P<.05.

Table 8. Belly bar test of pigs fed CLA and HOC.

Item	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
	Treatments						
Belly bar test, cm							
Left side							
Lean down	4.4	7.6	4.2	6.3	3.6	6.9	a
Lean up	7.4	11.2	5.3	8.9	5.0	11.0	a, b
Right side							
Lean down	5.3	7.2	4.6	6.2	4.4	7.8	a
Lean up	7.0	11.3	4.8	8.8	5.0	12.0	a, b

[a] CLA main effect P<.001.
[b] NC vs. HOC P<.03.

Table 9. Ham dissection weights of pigs fed CLA and HOC.

Item	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
	Treatments						
Ham, kg	9.63	9.64	9.66	9.52	10.04	9.57	NS
Lean, kg	6.60	6.70	6.65	6.77	6.66	6.57	NS
Bone, kg	1.35	1.30	1.31	1.17	1.31	1.23	NS
Skin, kg	0.69	0.53	0.68	0.51	0.73	0.58	a
Fat, kg	0.97	1.15	1.03	1.27	1.00	1.21	a
Fat + skin, kg	1.70	1.68	1.70	1.78	1.74	1.79	NS

[a] CLA main effect P<.01.

Table 10. Whole carcass weights of pigs fed CLA and HOC.

	Treatments						
Item	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
Right side	39.5	39.3	39.1	37.8	40.2	38.8	a
Left side	39.9	39.6	39.7	38.7	41.0	39.5	b
Picnic	4.99	5.00	4.98	4.72	5.14	4.83	a
Boston	4.90	4.82	4.92	4.93	4.86	4.57	c
Shoulder	9.90	9.82	9.90	9.65	10.00	9.40	a
Loin	10.97	10.62	10.78	11.33	10.58	11.19	d
Ham	9.70	9.74	9.74	9.84	9.85	9.71	NS
Belly	7.64	8.04	7.81	7.47	7.90	8.08	d

[a] CLA main effect P<.05.
[b] CLA main effect P<.07.
[c] HOC vs. NCwCWG P<.03.
[d] NC and HOC interaction P<.05.

Table 11. Loin quality measurements of pigs fed CLA and HOC.

	Treatments						
Item	NC	NC+CLA	HOC	HOC+CLA	NCwCWG	NCwCWG +CLA	P <
Loin							
% Moisture	73.0	72.9	72.8	72.7	72.8	72.2	NS
% Fat	2.60	2.67	2.78	2.75	3.00	2.78	NS
Myoglobin, mg/g	.660	.677	.739	.620	.685	.666	NS
Day 0							
L*	42.6	45.7	44.3	47.1	44.5	45.6	a
a*	5.8	5.7	5.8	6.4	6.6	6.7	NS
b*	10.3	11.2	10.6	11.4	11.2	11.4	a
Day 1							
L*	42.7	45.7	44.0	46.6	44.4	45.8	a
a*	5.7	6.0	5.9	5.6	6.1	6.2	NS
b*	10.2	11.0	10.7	11.2	11.0	11.4	a
Day 2							
L*	43.3	45.1	43.9	47.7	44.7	46.2	a
a*	6.6	6.3	6.1	6.3	6.4	6.9	NS
b*	10.2	10.6	10.4	10.9	10.6	10.8	NS

[a] CLA main effect P<.05.