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Interactive effects among L-carnitine, paylean (ractopamine•HCl), and dietary energy density on commercial finishing pig growth performance and carcass characteristics

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**INTERACTIVE EFFECTS AMONG L-CARNITINE, PAYLEAN
(RACTOPAMINE·HCl), AND DIETARY ENERGY DENSITY ON COMMERCIAL
FINISHING PIG GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS**

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Summary

Growth performance and carcass characteristics were evaluated on 1,104 pigs fed combinations of L-carnitine, Paylean, and added fat in a $2 \times 2 \times 2$ factorial arrangement. Dietary treatments of L-carnitine (0 or 50 ppm) and fat (0 or 6%) were initiated at approximately 97 lb. Paylean (0 or 9 g/ton) was fed for the last 4 weeks prior to market. Supplementing dietary carnitine did not affect ($P>0.25$) growth performance of pigs between 97 to 203 lb. The addition of 6% dietary fat improved ($P<0.01$) ADG and F/G during this period. During the last 4 weeks of the experiment, when Paylean was fed, a carnitine $\times$ Paylean interaction was observed ($P<0.04$) for ADG and F/G. Both carnitine and Paylean improved growth performance; however, the responses were not additive. Pigs fed added fat had improved ($P<0.05$) feed efficiency during the Paylean supplementation period.

A carnitine $\times$ Paylean interaction ($P<0.03$) was observed for fat thickness and percentage lean. Fat thickness decreased and lean percentage increased in pigs fed carnitine or Paylean, but the responses were not additive. Pigs fed added fat had greater ($P<0.01$) fat thickness and lower percentage lean than pigs not fed added fat. A carnitine $\times$ Paylean $\times$ fat interaction was observed ($P<0.04$) for longissimus muscle area. In general, adding

carnitine, Paylean or fat to the diet increased longissimus muscle area; however, the responses were not fully additive. Carcass weight was greater ($P<0.01$) for pigs fed 6% added fat and tended ($P<0.07$) to be greater for pigs fed carnitine.

Adding Paylean to the diet increased ($P<0.04$) ultimate longissimus pH and reduced drip loss as measured by the filter paper method. Similar to other experiments, adding carnitine to the diet tended to decrease drip loss ($P<0.06$) as measured by the suspension method.

These results suggest that adding L-carnitine and Paylean to the diet increases ADG and that L-carnitine, Paylean, and fat improve feed efficiency when fed to late finishing pigs reared in a commercial facility. These data also support our previous research that demonstrated improvements in carcass characteristics of pigs fed L-carnitine.

(Key Words: Carnitine, Paylean, Meat Quality.)

Introduction

Recent research conducted at Kansas State University has demonstrated beneficial effects of feeding L-carnitine in combination with Paylean in the late finisher phase. Previous

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studies have also shown improvements in drip loss and other meat quality indicators, such as higher longissimus pH. These improvements may be a result of carnitine's affect on either antimortem or postmortem metabolic parameters. Carnitine has been shown to influence the enzymes involved in lactic acid production. However, carnitine may produce a different response in pigs housed in commercial finishing facilities where they have lower levels of feed intake and different metabolic stressors compared to pigs reared in university research facilities. In addition, because of carnitine's known function of transporting fatty acids across the mitochondrial membrane, its affect may differ depending on the energy density of the diet. Therefore, the objective of this experiment was to determine the interactive effects among L-carnitine, Paylean (ractopamine·HCl), and dietary energy density on commercial finishing pig growth performance and carcass characteristics.

Procedures

A total of 1,104 barrows (initially 97 lb, PIC C22 × L326) were allotted by weight in a randomized complete block design to each of the eight experimental treatments arranged in a 2 × 2 × 2 factorial. There were 23 pigs/pen and 6 replicates/treatment. The main effects included dietary carnitine (0 or 50 ppm), Paylean (0 or 9 g/ton), and added fat (0 or 6%).

Pigs were fed a corn-soybean meal diet (Table 1) with or without added L-carnitine and with or without added fat from 92 lb until slaughter (approximately 260 lb). Dietary Paylean treatments (0 or 9 g/ton) were fed for the last 4 weeks of the experiment. The basal diet was formulated on a total lysine:calorie ratio basis with ratios of 3.16 g/Mcal from 97 to 135 lb, 2.70 g/Mcal from 135 to 203 lb, and 3.00 g/Mcal from 203 lb until the end of the experiment. The corresponding lysine levels in the 0 and 6% added fat diets were 1.05 and

1.14%; 0.90 and 0.97%, and 1.00 and 1.08% lysine for the three phases, respectively.

Weights were obtained on every pen and feed disappearance recorded every 14 days during the experiment until the last 4 weeks, at which time measurements were taken weekly to calculate ADG, ADFI, and F/G. At the end of the experiment, eight pigs were randomly selected from each pen and slaughtered at a commercial facility. Standard carcass measurements, visual analyses of longissimus muscle color, marbling, and firmness, longissimus area, color spectrophotometry (L^* , a^* , and b^*), drip loss, and ultimate pH were obtained from each pig at approximately 24 h postmortem.

Data were analyzed as a randomized complete block. Pen was the experimental unit for growth performance data, carcass characteristics, and meat quality measurements. Analysis of variance was performed using the GLM procedure of SAS.

Results and Discussion

Growth Performance. There were no carnitine × Paylean × fat interactions ($P>0.10$) during the entire experiment (Table 2). There were no carnitine × fat interactions ($P>0.73$) observed for growth performance of pigs between 97 and 203 lb (Pre-Paylean period). During this period, supplementing finishing pig diets with L-carnitine did not significantly affect ($P>0.25$) growth performance. As expected, addition of 6% dietary fat improved ($P<0.01$) ADG and F/G during this period.

A carnitine × fat interaction was observed ($P<0.04$) for ADG from d 0 to 14 of the Paylean supplementation period. Carnitine did not affect gain when fat was added to the diet, but improved ADG in pigs fed diets without fat. A carnitine × Paylean interaction ($P<0.02$) was observed for F/G for d 0 to 14. Both carnitine and Paylean improved F/G, but the responses were not additive. Added fat also

improved ($P<0.01$) F/G from d 0 to 14. There were numerical improvements in growth performance from d 14 to 28 of the Paylean supplementation period for pigs fed either carnitine (ADG and F/G improved 3.8 and 4.2%, respectively) or Paylean (ADG and F/G improved 3.0 and 5.5%, respectively), the improvements were not significant ($P>0.13$). This supports other research that indicates that the Paylean growth response is greatest in the first two weeks of administration.

For the overall Paylean supplementation period (d 0 to 28), there were no carnitine $\times$ fat interactions ($P>0.21$). However, a carnitine $\times$ Paylean interaction was observed ($P<0.04$) for ADG and F/G. Carnitine and Paylean both improved ADG and F/G; however, the responses were not additive. Dietary fat decreased ($P<0.01$) ADFI and improved F/G ($P<0.05$).

These results suggest that supplemental carnitine and/or Paylean improve growth performance in late finisher pigs reared in a commercial environment. The marked improvement in gain and efficiency of pigs fed carnitine in the late finisher period has not been well documented in previous research. A notable difference between our experiments with carnitine and Paylean in finisher pigs and previous studies is that our pigs were fed a higher lysine level than would typically be fed in the late finishing period. This was done to assure adequate lysine for pigs consuming Paylean, which required a higher level of lysine to meet increased protein deposition needs. Therefore, one might theorize that a higher level of lysine is also needed for protein deposition to demonstrate a growth response to feeding supplemental L-carnitine. Another difference between this study and others is that these pigs were reared in commercial finishing facility. Feed intakes are typically lower compared to university facilities due to environmental and space allowance differences. In addition, previous studies have not specifically examined the last

4 weeks per se. There may be some metabolic changes that are occurring as the pig becomes heavier, and these may be affected by L-carnitine supplementation.

Carcass Characteristics. A carnitine $\times$ Paylean $\times$ fat interaction was observed ($P<0.04$) for longissimus muscle area. In general, adding Paylean, carnitine, or fat to the diet increased longissimus muscle area; however, the responses were not entirely additive leading to the interaction.

A carnitine $\times$ Paylean interaction ($P<0.03$) was observed for fat thickness and percentage lean. Fat thickness decreased and lean percentage increased in pigs fed carnitine or Paylean; however neither of the responses were additive. Pigs fed added fat had greater ($P<0.01$) fat thickness and lower percentage lean than pigs not fed added fat. A trend for a carnitine $\times$ Paylean interaction ($P<0.06$) also was observed for loin depth measured at the 10th rib. Both carnitine and Paylean increased loin depth, but the response was not as great when carnitine and Paylean were both added to the diet. Pigs fed added fat had decreased ($P<0.01$) loin depth compared to pigs not fed added fat.

Carcass weight was greater ($P<0.01$) for pigs fed 6% added fat and tended ($P<0.07$) to be greater for pigs fed carnitine. A trend for a carnitine $\times$ Paylean interaction ($P<0.09$) was observed for first rib backfat. Pigs fed carnitine or Paylean had decreased fat depth measured at the first rib, but when fed in combination, fat depth was not further decreased. Last lumbar backfat was decreased ($P<0.02$) in pigs fed either carnitine or Paylean. Tenth rib and average backfat were decreased ($P<0.03$) in pigs fed Paylean compared to pigs not fed Paylean. Pigs fed 6% added fat had greater ($P<0.01$) first rib, last lumbar, and average backfat than pigs fed the diet without added fat.

A carnitine $\times$ fat interaction was observed ($P < 0.04$) for visual firmness scores. Visual firmness scores were improved in pigs fed carnitine and no added fat compared to pigs fed carnitine and 6% added fat.

Hunter a^* values (color spectrophotometry) were greater ($P < 0.01$) indicating more redness for pigs fed Paylean and less ($P < 0.01$) redness in pigs fed added fat. As expected, pigs fed 6% added fat also had increased b^* values, which resulted in more yellowness of the longissimus muscle. Saturation index, or vividness, was greater ($P < 0.01$) for pigs fed diets containing 6% added fat and less ($P < 0.01$) for pigs fed Paylean.

In contrast to previous experiments, pigs fed Paylean in this study had higher ($P < 0.04$) ultimate longissimus pH along with pigs fed the diet containing no added fat. In agreement with the pH data, pigs fed Paylean had less drip loss using the filter paper method as did the pigs fed the diet with no added fat. Pigs fed carnitine tended to have decreased drip loss ($P < 0.06$) using the suspension method. The reduction in drip loss with added carnitine

agrees with the results of previous experiments.

These results demonstrate an improvement in meat quality in pigs fed L-carnitine, similar to the results of our previous experiments. However, in this experiment, feeding carnitine also resulted in an increase in growth performance during the last 4 weeks of the experiment. This response was somewhat surprising. Although we have observed trends for improved growth performance in previous experiments, results of this magnitude have not been previously detected. The cause for the response observed in the commercial facility may be related to feed intake, environment, or larger sample population compared with the previous experiments. Two questions are yet to be determined: 1) Do pigs need to be fed a high lysine diet to observe a response to carnitine; and 2) What is the optimum L-carnitine supplementation duration to maximize the growth response and profitability? Further research is needed to determine the most beneficial feeding strategy.

Table 1. Basal Diet Composition (As-Fed Basis)^a

Ingredient, %	97 to 135 lb		135 to 203 lb		203 to 260 lb	
	No Fat	Fat	No Fat	Fat	No Fat	Fat
Corn ^b	73.00	63.30	78.6	69.35	75.10	65.55
Soybean meal (46.5% CP)	24.60	28.25	19.15	22.35	22.75	26.25
Choice white grease	--	6.00	--	6.00	--	6.00
Limestone	0.88	0.84	0.85	0.83	0.84	0.81
Monocalcium phosphate, 21%P	0.85	0.94	0.73	0.80	0.64	0.70
Salt	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine-HCl	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix	0.09	0.09	0.09	0.09	0.09	0.09
Calculated composition						
CP ($N \times 6.25$), %	17.60	18.50	15.60	16.30	17.0	17.80
Lysine, %	1.05	1.14	0.90	0.97	1.00	1.08
Lysine:calorie ratio, g/Mcal	3.16	3.16	2.70	2.70	3.00	3.00
ME, kcal/lb	1,509	1,631	1,513	1,635	1,514	1,636
Ca, %	0.60	0.61	0.55	0.56	0.54	0.55
P, %	0.55	0.57	0.50	0.52	0.50	0.51

^aDiets were formulated to meet or exceed NRC (1998) requirements.

^bL-Carnitine replaced corn to provide either 0, 25, or 50 ppm L-Carnitine and Paylean replaced corn to provide either 0 or 9 g/ton ractopamine-HCl.

Table 2. Interactive Effects of Carnitine, Paylean, and Fat on Growth Performance of Finishing Pigs^a

Item	Fat, %								SEM	Probability (<i>P</i> <)							
	0				6					Carnitine, ppm							
	0		50		0		50			Paylean, g/ton							
	0		50		0		50			Carn*Paylean*Fat							
	0		50		0		50			Carn*Paylean							
	0		50		0		50			Carn*Fat							
0		50		0		50		Paylean*Fat									
0		50		0		50		Carn									
0		50		0		50		Paylean									
0		50		0		50		Fat									
Pre-Paylean ^{b,c}																	
ADG, lb	2.08	2.00	2.05	2.07	2.15	2.17	2.17	2.19	0.04	-	-	0.97	-	0.37	-	0.01	
ADFI, lb	5.55	4.43	5.45	5.52	5.42	5.29	5.38	5.33	0.07	-	-	0.97	-	0.98	-	0.01	
Feed/gain	2.68	2.72	2.66	2.66	2.52	2.44	2.48	2.43	0.04	-	-	0.73	-	0.25	-	0.01	
Day 0 to 14 ^d																	
ADG, lb	1.96	2.23	2.17	2.44	2.02	2.37	2.20	2.28	0.06	0.10	0.10	0.04	0.48	0.01	0.01	0.69	
ADFI, lb	5.76	5.73	6.06	6.11	5.42	5.37	5.47	5.30	0.10	0.50	0.89	0.02	0.42	0.02	0.50	0.01	
Feed/gain	2.95	2.58	2.80	2.50	2.69	2.28	2.49	2.34	0.05	0.20	0.02	0.58	0.46	0.02	0.01	0.01	
Day 14 to 28																	
ADG, lb	1.70	1.89	1.94	1.82	1.80	1.91	1.89	1.93	0.08	0.26	0.08	0.78	0.67	0.22	0.31	0.39	
ADFI, lb	6.02	5.90	5.94	5.75	6.02	5.86	5.91	5.80	0.15	0.81	0.96	0.89	0.91	0.36	0.19	0.95	
Feed/gain	3.56	3.12	3.07	3.29	3.35	3.06	3.19	3.01	0.16	0.22	0.09	0.77	0.59	0.24	0.13	0.34	
Day 0 to 28																	
ADG, lb	1.84	2.07	2.06	2.14	1.91	2.15	2.05	2.11	0.03	0.82	0.04	0.21	0.92	0.02	0.01	0.46	
ADFI, lb	5.89	5.81	6.00	5.94	5.71	5.60	5.68	5.54	0.05	0.86	0.91	0.21	0.71	0.55	0.14	0.01	
Feed/gain	3.21	2.81	2.92	2.79	2.98	2.61	2.78	2.63	0.03	0.81	0.01	0.53	1.0	0.01	0.01	0.05	

^aValues are means of six replications (pens) and 22 to 26 pigs per pen.^bInitial BW of pre-Paylean period, 97 lb.^cGrowth performance for pre-Paylean period was determined for d 0 to 51 prior to initiation of Paylean.^dAverage BW at initiation of Paylean supplementation, 203 lb.

Table 3. Interactive Effects of Carnitine, Paylean, and Fat on Carcass Characteristics and Meat Quality of Finishing Pigs^a

Item	Fat, %								SEM	Probability (<i>P</i> <)						
	0				6					Carn×Paylean×Fat	Carn×Paylean	Carn×Fat	Paylean×Fat	Carn	Paylean	Fat
	Carnitine, ppm															
	0		50		0		50									
	Paylean, g/ton															
	0	9	0	9	0	9	0	9								
Carcass wt, lb	197.96	201.44	200.27	203.44	203.48	207.10	210.06	209.64	2.62	0.64	0.53	0.48	0.67	0.07	0.19	0.01
Fat thickness, mm ^b	16.76	13.92	16.29	14.72	18.83	16.09	16.77	16.25	0.56	0.54	0.03	0.16	0.47	0.32	0.01	0.01
Loin depth, mm ^b	59.28	62.80	60.89	61.52	57.93	61.11	59.16	60.65	0.81	0.68	0.06	0.94	0.91	0.54	0.01	0.01
Lean,% ^b	56.15	59.19	56.82	58.29	54.12	57.03	56.13	56.82	0.59	0.67	0.02	0.23	0.56	0.33	0.01	0.01
Loin eye area, in ²	7.35	7.54	7.51	7.77	7.33	7.96	8.07	7.83	0.17	0.04	0.09	0.69	0.85	0.03	0.07	0.03
Backfat, in																
First rib	1.41	1.37	1.40	1.38	1.54	1.43	1.41	1.44	0.03	0.13	0.09	0.22	0.89	0.19	0.11	0.01
Tenth rib	0.66	0.62	0.67	0.65	0.68	0.65	0.64	0.65	0.02	0.53	0.29	0.12	0.53	0.70	0.03	0.47
Last rib	1.06	1.00	1.06	1.05	1.12	1.09	1.11	1.11	0.03	0.89	0.30	0.49	0.57	0.36	0.18	0.01
Last lumbar	0.61	0.55	0.60	0.55	0.67	0.63	0.60	0.58	0.02	0.93	0.74	0.11	0.54	0.02	0.01	0.01
Average backfat	1.03	0.98	1.02	0.99	1.11	1.05	1.04	1.04	0.02	0.51	0.17	0.09	0.72	0.19	0.01	0.01
Visual color ^c	3.39	3.18	3.48	3.38	3.38	3.48	3.45	3.26	0.09	0.14	0.62	0.09	0.44	0.43	0.26	0.69
Firmness ^c	2.50	2.96	2.86	2.98	2.70	2.76	2.48	2.64	0.13	0.26	0.48	0.04	0.28	0.83	0.03	0.05
Marbling ^c	2.44	2.51	2.45	2.41	2.46	2.43	2.18	2.50	0.15	0.27	0.60	0.78	0.53	0.46	0.47	0.56
L* ^d	45.44	45.73	45.28	46.14	45.29	45.81	46.31	46.45	0.43	0.42	0.78	0.27	0.64	0.10	0.10	0.32
a* ^d	6.07	5.52	6.18	5.48	6.53	5.96	6.41	5.72	0.16	0.96	0.63	0.27	0.88	0.62	0.01	0.01
b* ^d	0.97	0.95	0.92	0.83	1.05	1.12	1.29	1.28	0.16	0.87	0.94	0.29	0.77	0.48	0.91	0.03
a:b	4.64	1.86	-1.43	9.59	7.38	-15.14	3.86	2.52	6.96	0.70	0.06	0.51	0.09	0.39	0.41	0.40
Hue angle	8.88	9.20	7.52	7.03	8.95	9.80	10.64	11.23	1.39	0.99	0.99	0.14	0.78	0.91	0.58	0.06
Saturation index	6.24	5.69	6.34	5.65	6.67	6.16	6.60	5.99	0.18	0.95	0.74	0.46	0.91	0.81	0.01	0.01
Longissimus pH	5.59	5.61	5.62	5.62	5.57	5.60	5.55	5.61	0.02	0.39	0.96	0.34	0.13	0.54	0.04	0.04
Drip loss																
Filter paper	4.51	4.17	4.71	4.75	5.21	4.91	5.64	4.45	0.32	0.13	0.63	0.34	0.16	0.36	0.05	0.02
Suspension	6.92	6.52	5.81	6.07	7.29	6.65	6.98	6.22	0.41	0.48	0.56	0.52	0.27	0.06	0.22	0.12

^aValues are means of six replications (pens) and eight pigs per pen.^bMeasurements were determined with UFOM and collected 7 cm off the midline at the 10th rib, lean percentage was calculated with these values.^cScoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery; 3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, firmness, and marbling, respectively.^dMeasures of dark to light (L*), redness (a*), yellowness (b*).