EFFECT OF DIETARY L-CARNITINE AND RACTOPAMINE-HCL (PAYLEAN) ON THE METABOLIC RESPONSE TO HANDLING IN GROWING-FINISHING PIGS

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Summary

Two experiments (384 pigs) were conducted to determine the interactive effect of dietary L-carnitine and ractopamine·HCl (Paylean) on the metabolic response to handling. Experiments were arranged as split plots, with handling as the main plot and diet as subplots (4 pens/treatment). Dietary L-carnitine (0 or 50 ppm) was fed from 85 lb to the end of the trials (260 lb) and Paylean (0 or 20 ppm) was fed for the last 4 wk of each trial. At the end of each trial, two pigs per pen were assigned to one of two handling treatments. Gentle-handled pigs were moved at a moderate pace three times through a 164-ft course and up and down a 15° loading ramp. Non-gentle-handled pigs were moved at a faster pace, up and down a 30° ramp, and were shocked by an electrical prod. Blood was collected immediately before and after handling in Exp. 1 and immediately after and 1 h after handling in Exp. 2. Feeding Paylean increased (P<0.01) ADG and F/G, but there was no (P>0.10) effect of L-carnitine on growth performance in either trial. In Exp. 1 and 2, non-gentle handling increased (P<0.01) lactate dehydrogenase (LDH), lactate, cortisol, and rectal temperature, and decreased pH. In Exp. 1, a Paylean × handling interaction was observed for pH (P<0.01), temperature (P<0.06), and cortisol (P<0.064). Feeding Paylean decreased pH, increased cortisol, increased temperature, and tended (P<0.09) to increase blood lactate when pigs were non-gentle handled, but not when they were gentle handled. Pigs fed Paylean had increased (P<0.01) LDH compared with that of pigs not fed Paylean. Pigs fed L-carnitine had increased (P<0.03) lactate compared with that of pigs not fed L-carnitine. In Exp. 2, pigs fed Paylean had lower (P<0.02) pH immediately after handling, but pH returned to control levels (P>0.96) by 1 h post-handling. Lactate, LDH, cortisol, and temperature changes from immediately post-handling to 1 h post-handling were not different for pigs fed L-carnitine or Paylean, suggesting that L-carnitine did not decrease recovery time of pigs subjected to non-gentle handling. These results demonstrate the importance of proper handling technique to minimize stressful events during the loading and transporting of pigs, regardless of whether either of these feed additives is being fed. This was evident by the large magnitude of the metabolic changes observed for the handling treatments, whereas in general the magnitude of metabolic changes from the dietary treatments was much smaller. Nonetheless, pigs fed Paylean are more susceptible to stress when handled aggressively, compared with pigs not fed Paylean. Dietary L-carnitine did not alleviate the effects of stress when fed in combination with Paylean.

(Key Words: L-carnitine, Pigs, Ractopamine HCL.)

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Introduction

The increased incidence of downer pigs and metabolic acidosis has been well recognized as a swine industry problem and has resulted in substantial economic losses. A downer pig has been categorized as a pig that becomes fatigued, refuses to get up and walk, or can not keep up with its contemporaries while loading, unloading, or moving through the packing plant. The prevalence of downer pigs has been attributed to several factors, including animal handling, genetics, and muscling. The occurrence of downer pigs may be amplified by the industry trend of producing a more heavily muscled, lean genotype pig.

Non-gentle handling of pigs results in increased concentrations of serum lactate, decreased pH, and increased incidence of downer pigs. Previous research at Kansas State University has suggested that supplemental L-carnitine may improve pork quality in pigs fed Paylean. The improvements in meat quality of pigs fed L-carnitine in combination with Paylean may be the result of L-carnitine's affect on the pigs' metabolic parameters, either antimortem or postmortem.

Because of the known influence of L-carnitine on enzymes involved in lactic acid production, L-carnitine may be able to reduce the number of downer pigs of pigs fed Paylean in commercial production facilities by altering the metabolic response to handling. Our objective was to evaluate the interaction between feeding Paylean and carnitine in gentle- and non-gentle-handled, market-weight finishing pigs.

Procedures

General

Procedures used in these experiments were approved by the Kansas State University Animal Care and Use Committee (Protocol No. 2156) and were conducted at the Kansas State University Swine Teaching and Research Center. Pigs were housed in a modified open-front building with 50% solid concrete and 50% concrete slat flooring. Each 6 × 16-ft pen had a two-hole dry self-feeder and a nipple waterer to allow ad libitum access to feed and water.

A total of 384 pigs (PIC L 42 dams × L327 sire) were used in two experiments. All pigs were used for the growth performance criteria, and a sub-sample of 128 pigs were used for the handling and stress data. In each experiment, 192 pigs were blocked by weight and ancestry (initially 85 lb) in a split-plot design with two handling treatments (whole plot) and four dietary treatments (subplots). There were 12 pigs per pen and 16 pens (four replications) per experiment. The four dietary treatments were arranged as a 2 × 2 factorial. Pigs were fed a corn-soybean meal diet (Table 1) with added L-carnitine (0 or 50 ppm) from 85 lb until the end of each experiment (260 lb). The basal diet was formulated to contain 1.20% total lysine from 85 to 120 lb (phase 1), and 1.00% total lysine from 120 to 190 lb and 190 to 260 lb (phases 2 and 3, respectively). Dietary Paylean treatments (0 or 20 ppm) were fed for the last four weeks of each experiment (approximately 190 to 260 lb). For the remaining nutrients, all diets were formulated to meet or exceed NRC nutrient requirement estimates.

Growth Performance

Weights were obtained on all pigs, and feed added and feeder weights were recorded, every 14 d during the experiment until the last four wk, at which time measurements were recorded at the beginning (190 lb) and the end (260 lb) of the 4-wk period to calculate ADG, ADFI, and F/G. Pigs were only weighed at the beginning and the end of the last 4-wk period (Paylean supplementation) so that they did not become accustomed to the routine of being handled.

Stress Model

The two handling treatments (gentle and non-gentle) were imposed at the end of the experiment (260 lb). Two pigs from each pen in a block were subjected to the gentle handling treatment and two pigs from each pen were subjected to the non-gentle handling treatment so that one pig per pen in a block (one pig from each dietary treatment) would be subjected to the respective handling treatment at the same time (groups of four pigs). Pigs were selected randomly from each pen. The two handling treatments were conducted in random order to avoid circadian and ambient-temperature bias. The handling portion of the study was conducted in a different location than where the pigs were housed for the growth portion of the trial. This was done so that administration of the handling treatments did not bias subsequent groups.

In the gentle handling treatment, the handler moved pigs three times through a 164-ft course , including up and down a 15^{o} loading ramp, using a sorting board at a moderate pace (Figure 1). At the top of the loading ramp, pigs were moved onto a hydraulic pig cart, turned around, and moved back down the loading ramp. The 164-ft course consisted of moving pigs back and forth (3 laps, for a total of 492 ft) to simulate movement in the alleyway of the finishing barn. In the non-gentle handling treatment, pigs were moved at a quicker pace through the course, including up and down a 30^{o} loading ramp. Panels divided the alleyway and narrowed, resulting in crowding, at one end to simulate a single chute to model commercial loading and slaughter facilities. Pigs were subjected to three (one-second) stimulations by an electrical prod (The Green One HS200, Hot-Shot, Savage, MN) per time around the course. The objective was to model the mild and moderate stress that pigs incur as they are loaded and transported to and in slaughter facilities.

Rectal temperature was recorded and blood was collected immediately before and after handling in Exp. 1 and immediately after and 1 h after handling in Exp. 2. The blood was collected via the anterior vena cava by a veterinarian so that samples could be obtained quickly to prevent additional stress. Pigs were restrained for blood collection with a snout snare and were quickly released after blood collection. Pigs were restrained for less than approximately 30 s. Blood samples were immediately placed on ice and transported to the Kansas State University College of Veterinary Medicine to be analyzed for serum LDH, lactate, pH, glucose, urea nitrogen, and cortisol by using an autoanalyzer. The time elapsed from blood collection to arrival at the laboratory was approximately 15 min. In Exp. 1, heart rate was measured during the handling treatments by fitting the pigs with a Polar Vantage NV heart-rate monitor (Polar Electro Oy, Kempele, Finland) to record and store successive interbeat intervals.

Statistical Analyses

Data were analyzed as a split-plot design, with handling (gentle or non-gentle) as the whole plot and diet (L-carnitine, 0 or 50 ppm; and Paylean, 0 or 20 ppm) as the subplot. In each experiment, there were four observations per treatment diet (pens) for growth performance. A sub-sampling of individual pigs (four pigs per pen; two for gentle and two for non-gentle handling) were used for metabolic and physiological response data. Analysis of variance was performed by using the PROC MIXED procedure of SAS.

Results

Combined Growth Performance

The growth performance data from Exp. 1 and 2. were combined (Table 2). There was no effect ($P>0.40$) of feeding pigs L-carnitine on ADG, ADFI, or F/G from 85 to 190 lb (pre-Paylean). These results are similar to previous studies conducted at Kansas State University in which dietary L-carnitine was supplemented during the entire finishing period. From d 0 to 28 of the Paylean supplementa-

tion period, there were no Paylean × L-carnitine interactions (P>0.28) or main effects of L-carnitine (P>0.58) for any of the growth performance criteria. Pigs fed Paylean had improved (P<0.01) ADG and F/G.

For the overall finishing period (85 to 260 lb), there were no Paylean × L-carnitine interactions (P>0.53) observed for ADG, ADFI, or F/G or for main effects of L-carnitine. Pigs fed Paylean had greater (P<0.01) ADG and F/G than did pigs not fed Paylean.

Handling

Experiment 1. There were no pre-handling Paylean × L-carnitine interactions (P>0.20) on any of the pre-handling metabolite measurements (Table 3). There were no Paylean × L-carnitine × handling interactions (P>0.14) or Paylean × L-carnitine interactions (P>0.15) immediately post-handling or for the difference between pre-handling and post-handling for any of the criteria measured.

Pigs that were subjected to the non-gentle handling treatment or fed Paylean had increased (P<0.01) LDH concentration post-handling and had a greater (P<0.01) difference (LDH increase) between pre-handling and post-handling than did pigs that were handled gently or were not fed Paylean.

Pigs fed Paylean had an increased (P<0.01) pre-handling lactate concentration, compared with that of pigs not fed Paylean. A post-handling Paylean × handling interaction trend (P<0.13) was observed for lactate concentration. Pigs that were non-gentle handled or pigs that were fed Paylean had a higher lactate concentration than did pigs that were gentle handled or were not fed Paylean. Lactate concentration was highest post-handling for pigs that were non-gentle handled and fed Paylean. This resulted in a Paylean × handling interaction (P<0.09) for the difference between pre-handling and post-handling lactate concentration. Although pigs fed Paylean had higher (P<0.01) pre-handling lactate concentration than did pigs not fed Paylean, it increased even more post-handling for pigs that were non-gentle handled.

Pigs fed Paylean had a lower (P<0.04) pre-handling pH compared with pigs not fed Paylean. A Paylean × handling interaction (P<0.01) was observed for pH post-handling. Pigs that were subjected to the non-gentle handling treatment had lower post-handling pH than did pigs that were gentle handled, and it was even lower for pigs that were fed Paylean and non-gentle handled. This resulted in a Paylean × handling interaction (P<0.05) for the difference in pH between pre-handling and post-handling. The pH of pigs fed Paylean was initially lower than that of pigs not fed Paylean and pH decreased more for pigs that were non-gentle handled and were fed Paylean.

A trend for an L-carnitine × handling interaction (P<0.09) was observed for glucose concentration post-handling and for the difference between pre-handling and post-handling glucose concentration. Pigs that were non-gentle handled had a higher (P<0.01) post-handling glucose concentration and a greater (P<0.01) difference (increase in glucose) between pre-handling and post-handling. Pigs that were fed L-carnitine also had a slightly higher (P<0.06) post-handling glucose concentration.

There was no effect of dietary treatment (P>0.28) on pre-handling or post-handling urea nitrogen concentration. But pigs that were non-gentle handled had a greater difference (greater increase) in urea nitrogen concentration between pre-handling and post-handling.

A post-handling Paylean × handling interaction (P<0.04) was observed for post-handling cortisol concentration. Pigs that were non-gentle handled had increased post-handling cortisol concentration, compared with pigs that were gentle handled. Pigs that

were fed Paylean and non-gentle handled had the highest post-handling cortisol concentration, compared with that of pigs fed the other treatment diets.

A Paylean × handling interaction ($P<0.06$) trend was observed for the difference in rectal temperature between pre-handling and post-handling. Pigs that that were handled non-gentle had higher post-handling rectal temperature, and the difference between pre-handling and post-handling was greater for pigs that were handled non-gentle than for pigs that were gentle handled. There was a trend ($P<0.06$) for pigs fed Paylean to have a higher post-handling rectal temperature than did pigs that were not fed Paylean. Pigs that were non-gentle handled and fed Paylean had the highest increase in rectal temperature, compared with pigs fed the other treatment diets.

Pigs fed Paylean tended ($P<0.11$) to have faster minimum and average heart rates during the handling treatment than did pigs not fed Paylean (Table 5). Pigs that were non-gentle handled had increased ($P<0.01$) average, maximum, and change in heart rate, compared with pigs that were handled gently.

Experiment 2. A trend ($P < 0.08$) for an L-carnitine × handling interaction was observed for post-handling LDH concentration (Table 5). Pigs fed L-carnitine and handled gentle had a lower LDH concentration than did pigs not fed L-carnitine and handled gentle; but pigs fed L-carnitine and handled non-gentle had a higher LDH concentration than did pigs not fed L-carnitine and handled non-gentle. Pigs fed Paylean had higher ($P<0.01$) post-handling and 1-hr post-handling LDH concentrations than did pigs not fed Paylean. Pigs that were non-gentle handled had a higher ($P<0.01$) post-handling LDH concentration, and the difference between immediately post-handling and 1 hr post-handling was greater ($P<0.01$), for pigs that were non-gentle handled than for pigs that were handled gently.

Pigs that were handled non-gentle or fed Paylean had a higher ($P<0.05$) post-handling lactate concentration than did pigs handled gently or not fed Paylean. There was a trend for a Paylean × handling and a L-carnitine × handling interaction for 1-hr post-handling lactate concentration. Pigs that were handled non-gently had a higher lactate concentration 1 hr post-handling than did pigs handled gently, and it was higher for pigs fed Paylean or L-carnitine than for pigs not fed Paylean or L-carnitine. The difference between post-handling and 1-hr post-handling lactate concentration was greater ($P<0.01$) for pigs that were handled non-gentle than for pigs handled gently. The difference (greater decrease) was greater because post-handling lactate concentration was much higher for pigs that were handled non-gentle than for pigs handled gently, and had further to decrease to approach normal levels as the pig recovered from the non-gentle handling.

Post-handling pH was lower ($P<0.02$) for pigs that were handled non-gentle or fed Paylean than for pigs that were handled gentle or not fed Paylean. The pH of pigs that were handled non-gentle was still lower ($P<0.03$) 1 hr post-handling than for pigs that were handled gentle. A trend was observed for a Paylean × handling interaction ($P<0.08$) for the difference between pH measured post-handling and 1 hr post-handling. Pigs that were non-gentle handled or fed Paylean had a lower post-handling pH; therefore, the difference between post-handling and 1 hr post-handling was greater for pigs that were non-gentle handled or fed Paylean.

Pigs that were handled non-gentle had a higher ($P<0.01$) post-handling glucose concentration than did pigs that were handled gentle. Pigs that were fed Paylean tended to have a lower ($P<0.07$) glucose concentration post-handling than did pigs that were not fed

Paylean. A trend was observed for a Paylean × L-carnitine interaction for glucose concentration 1 hr post-handling. Pigs that were fed Paylean had a lower glucose concentration 1 hr post-handling than did pigs that were not fed Paylean, and pigs that were fed L-carnitine had a lower glucose concentration 1 hr post-handling than did pigs that were not fed L-carnitine. Glucose concentration was lowest 1 hr post-handling for pigs that were fed Paylean and L-carnitine, with that of pigs fed the other treatment diets. A trend was observed for an L-carnitine × handling interaction ($P < 0.09$) for glucose concentration 1 hr post-handling. Pigs that were non-gentle handled had a lower glucose concentration 1 hr post-handling than did pigs that were gentle handled. Pigs fed L-carnitine and handled gently had an increased glucose concentration, compared with that of pigs that were not fed L-carnitine and handled gently; but pigs fed L-carnitine and handled non-gently had a decreased glucose concentration, compared with that of pigs that were not fed L-carnitine and handled non-gentle. The difference between post-handling and 1-hr post-handling glucose concentration was ($P<0.01$) greater (greater decrease) for pigs that were non-gentle handled than for pigs that were handled gently.

A Paylean × L-carnitine × handling interaction ($P<0.04$) was observed for post-handling and 1-hr post-handling urea nitrogen concentration. Pigs that were non-gentle handled had higher post-handling and 1-hr post-handling urea nitrogen concentrations than did pigs that were handled gently. Pigs that were fed Paylean or L-carnitine had a lower urea nitrogen concentration post-handling and 1 hr post-handling than did pigs that were not fed Paylean or L-carnitine. The difference between post-handling and 1-hr post-handling urea nitrogen concentrations was less ($P<0.01$) for pigs that were handled non-gentle than for pigs that were handled gently.

A Paylean × L-carnitine × handling interaction trend ($P<0.07$) was observed for post-handling cortisol concentration. Pigs that were non-gentle handled had a higher post-handling cortisol concentration than did pigs handled gently. Pigs fed Paylean or L-carnitine had an increased cortisol concentration, compared with that of pigs not fed Paylean or L-carnitine, and the post-handling cortisol concentration was highest for pigs fed Paylean and L-carnitine and handled non-gentle, compared with that of pigs fed the other treatment diets. Pigs that were handled non-gentle had ($P<0.01$) higher 1-hr post-handling cortisol concentration and a greater ($P<0.01$) difference (increase) in cortisol concentration between post-handling and 1 hr post-handling, than did pigs that were handled gentle.

Pigs fed L-carnitine had a lower ($P<0.01$) pre-handling rectal temperature than did pigs not fed L-carnitine. A Paylean × L-carnitine interaction ($P<0.02$) was observed for post-handling rectal temperature, and a Paylean × L-carnitine trend ($P<0.06$) was observed for 1-hr post-handling rectal temperature. Pigs fed Paylean had a higher rectal temperature than did pigs not fed Paylean, but it was highest for pigs fed Paylean and L-carnitine, compared with that of pigs fed Paylean and not fed L-carnitine. Pigs that were non-gentle handled had a higher ($P<0.01$) rectal temperature post-handling and 1 hr post-handling than did pigs handled gently.

Discussion

Growth-performance benefits for pigs fed diets containing Paylean were similar to previous experiments conducted at Kansas State University, but a lack of L-carnitine response in the late-finishing period is somewhat different than previous experiments found. Some of the differences may be a result of location of the experiments. Two of the previous experiments that report benefits were conducted in a commercial finishing facility.

Lactate dehydrogenase is a cytoplasmic enzyme that catalyzes a reversible reaction

that converts pyruvate to lactate at the end of anaerobic glycolysis. There are several isoenzymes of LDH. Isoenzyme analysis requires special assays that are not widely available, so in our experiments we analyzed total LDH. An increase in LDH is an indicator of muscle damage and hemolysis. Increased LDH activity may be due to local or diffuse cell damage. Pigs that were non-gentle handled had greater LDH immediately post-handling than did pigs that were handled gently. Although LDH concentrations increased between pre-handling and post-handling for pigs handled gently, the magnitude was minor compared with that of the pigs that were non-gentle handled. This is just one of the criteria involved that demonstrates that the handling course was successful in eliciting differences between pigs that were handled gentle and pigs that were handled non-gentle. Pigs that were fed Paylean were more susceptible to an increase in LDH due to either handling treatment and had greater LDH 1 hr after handling, which indicates that it takes longer for LDH to return to normal levels in pigs fed Paylean than in pigs not fed Paylean. Research at Kansas State University has shown that dietary L-carnitine increased pyruvate carboxylase and decreased LDH in pigs. An increase in pyruvate carboxylase may direct pyruvate away from lactate, thus reducing substrate for lactic acid synthesis. Furthermore, a decrease in LDH may delay the onset of glycolysis. In this experiment, however, added L-carnitine did not alleviate the production of LDH in pigs that were non-gentle handled or fed Paylean.

Serum lactate levels have previously been shown to increase in aggressively handled pigs compared with those being handled gently. Our observations are in agreement with these reports. Within 1 hr post-handling, lactate concentrations were still elevated in pigs handled non-gentle, compared with that in pigs that were handled gentle. This illustrates the importance in allowing ample time for recovery of pigs after delivery to slaughter facilities so that the increased concentration of lactate does not adversely affect meat quality. It is of interest that pigs fed Paylean had increased levels of pre-handling lactate, compared with that of pigs not fed Paylean. This may suggest that pigs fed Paylean were in a partial acidotic state before being handled. Also, pigs that were fed Paylean had greater post-handling lactate concentrations than did pigs not fed Paylean. Pigs that were fed Paylean and non-gentle handled had the greatest lactate concentrations, and it remained greater 1 hr post-handling. Because we did not observe differences in LDH for pigs fed added L-carnitine, it is not surprising that lactate concentrations were not affected by L-carnitine.

Downer pigs have been reported to have decreased blood pH. Pre-handling pH was less in pigs fed Paylean than in pigs not fed Paylean. This supports the observation that pre-handling lactate concentrations were increased for pigs fed Paylean, and may simply be a description of lactate level and acid-base balance. Non-gentle handling of pigs in our experiment decreased post-handling pH, compared with that of pigs handled gently, and it was lowest for pigs fed Paylean, suggesting that Paylean amplifies the effect of non-gentle handling and that pigs were in a state of metabolic acidosis. Pigs fed Paylean did not have a different pH 1 hr post-handling than did pigs not fed Paylean. Although pH was still decreased 1 hr post-handling for pigs handled non-gently, it was near levels of pigs that were handled gently, in comparison to lactate levels, which were still almost 5-fold higher at 1 hr post-handling for pigs handled non-gentle. Although we did observe a trend for a Paylean × L-carnitine interaction for the change in pH between post-handling and 1 hr post-handling, pigs fed L-carnitine in combination with Paylean tended to have an increased pH (better recovery) within 1 hr post-handling, compared with that of pigs not fed L-carnitine.

We observed increased glucose concentrations post-handling in pigs that were handled

non-gentle. In Exp. 2, pigs fed Paylean tended to have a decreased post-handling glucose concentration. Pigs fed Paylean or L-carnitine had decreased 1-hr post-handling glucose concentration, and it was lowest for pigs fed both Paylean and L-carnitine.

In our first experiment, pigs that were non-gentle handled had a greater change (increase) in urea nitrogen concentration between pre-handling and post-handling concentrations. In Exp. 2, pigs that were non-gentle handled had increased urea nitrogen concentrations. This may be the result of increased muscle breakdown occurring from the stress of non-gentle handling. But pigs fed either Paylean or L-carnitine and non-gentle handled had decreased post-handling and 1-hr post-handling urea nitrogen concentrations.

Hypercortisolemia is a result of stress caused by an illness, trauma, or environmental changes that stimulate cortisol releasing hormone, then adrenocorticotrophic hormone (corticotropin), and thus stimulate the adrenal glands to produce more cortisol. Short stressful events (i.e., direct handling, isolation, and transportation) are usually followed by an increase in stress hormones. Research has previously shown that downer pigs have increased cortisol levels, compared with those of non-downer pigs. Pigs that were non-gentle handled in our study had increased levels of cortisol and it was increased further for pigs that were fed Paylean (Exp. 1). Cortisol activity increases blood glucose concentrations by stimulating gluconeogenesis and creating a state of insulin resistance. This may partly explain the increase in glucose concentrations that we observed in pigs that were handled non-gentle.

Rectal temperatures and heart rate have been shown to increase after pigs are subjected to aggressive handling and use of electric prodding. Pigs that were non-gentle handled had an increased rectal temperature immediate post-handling (Exp. 1 and 2) and 1 hr post-handling (Exp. 2), compared with those of pigs that were handled gentle. Pigs that were fed Paylean also had increased post-handling and 1-hr post-handling rectal temperatures (Exp. 2) compared with those of pigs not fed Paylean, and temperatures were highest for pigs fed Paylean in combination with L-carnitine. In our experiment, pre-handling rectal temperature was lower for pigs fed L-carnitine; it is difficult, however, to explain a mechanism for this observation. Paylean tended to increase minimum and average heart rate in our experiment. Non-gentle handling greatly increased average heart rate. These results also indicate that our model was effective in simulating stress-response differences between the two handling treatments and Paylean treatment.

These results demonstrate the importance of proper handling technique to minimize stressful events during the loading and transporting of pigs, regardless of whether either of these feed additives is being fed. This was evident by the large magnitude of the metabolic changes observed for the handling treatments, whereas in general the magnitude of metabolic changes from the dietary treatments was much smaller. Nonetheless, pigs fed diets containing Paylean were more susceptible to adverse effects on metabolic parameters when handled aggressively than were pigs fed diets without Paylean. Finally, dietary L-carnitine did not alleviate the adverse effects, when fed in combination with Paylean.

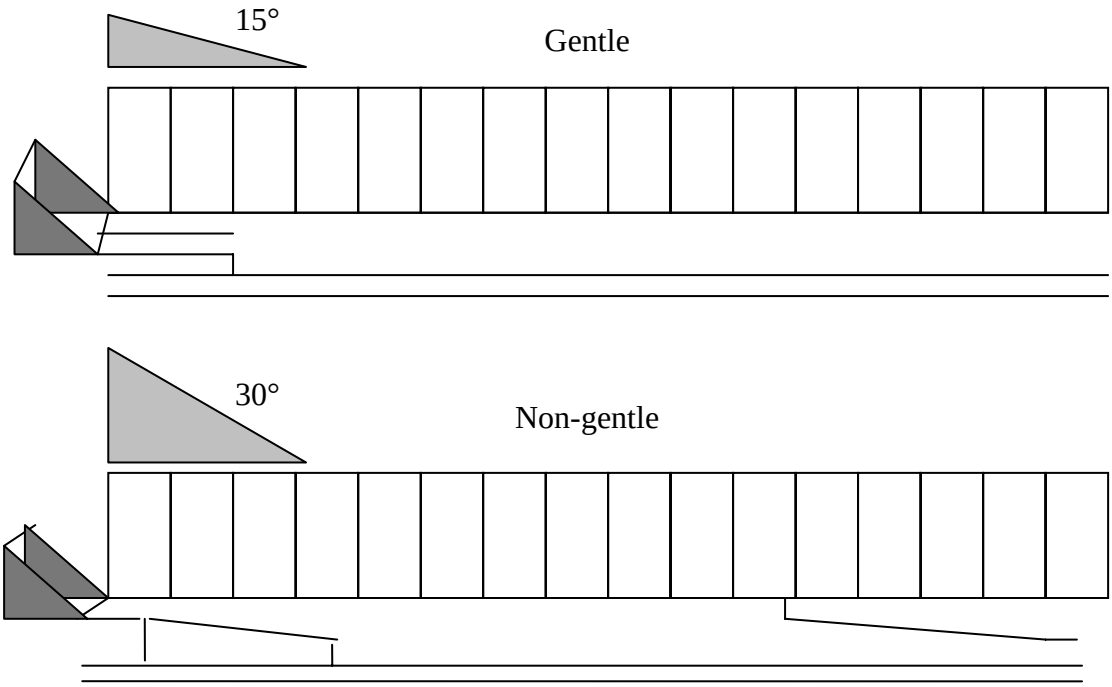

Figure 1. Handling-Course Diagram. Each handling treatment consisted of moving pigs back and forth (3 laps) in the alleyway of the finishing barn. In the gentle handling treatment, the handler moved pigs through the 164-ft course, including a 15^{o} split-race loading ramp, by using a sorting board at a moderate pace. In the non-gentle handling treatment, pigs were moved at a quicker pace through the 164-ft course, including a 30^{o} single-chute loading ramp, and panels were used to narrow the alleyway to stimulate crowding. Pigs were subjected to three (one-second) stimulations by an electrical prod per lap around the course.

Table 1. Basal Diet Composition (Exp. 1 and 2, As-fed Basis)[a]

Ingredient, %	Phase 1 [b]	Phase 2 [b]	Phase 3 [b]
Corn	66.92	74.26	74.45
Soybean meal (46.5% CP)	30.07	22.82	22.80
Monocalcium phosphate, 21% P	1.15	1.10	0.90
Limestone	0.96	0.93	0.90
Salt	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15
Medication[c]	0.05	0.05	-
Corn starch[d]	0.05	0.05	0.15
L-Lysine·HCl	0.15	0.15	0.15
Calculated Analysis			
CP (N × 6.25), %	19.67	16.92	16.92
Lysine, %	1.20	1.00	1.00
Lysine:calorie ratio, g/mcal	3.18	2.65	2.20
ME, kcal/lb	1,505	1,508	1,511
Ca, %	0.70	0.65	0.61
P, %	0.64	0.60	0.55

[a]Diets were formulated to meet or exceed NRC (1998) requirements.
[b]Phase 1 (85 to 120 lb); phase 2 (120 to 190 lb); phase 3 (190 to 260 lb).
[c]Provided 44 mg tylosin per kg diet.
[d]L-carnitine replaced cornstarch to provide either 0 or 50 ppm carnitine in phases 1, 2, and 3. Paylean replaced cornstarch to provide either 0 or 20 ppm ractopamine HCl in phase 3.

Table 2. Combined Interactive Effects between L-carnitine and Paylean on Growth Performance of Finishing Pigs in Exp. 1 and 2[a]

	L-carnitine, ppm							
	0		50					
	Paylean, ppm					Probability ($P <$)		
Item	0	20	0	20	SED	L-carnitine × Paylean	L-carnitine	Paylean
Pre-Paylean								
ADG, lb	2.12	-	2.07	-	0.04	-	0.40	-
ADFI, lb	5.47	-	5.47	-	0.07	-	0.95	-
F/G	2.56	-	2.63	-	0.02	-	0.45	-
Day 0 to 28								
ADG, lb	1.94	2.20	1.92	2.31	0.07	0.28	0.58	0.01
ADFI, lb	5.40	5.25	5.69	5.09	0.35	0.53	0.86	0.31
F/G	2.70	2.33	2.94	2.17	0.07	0.30	0.94	0.01
Overall								
ADG, lb	2.05	2.14	2.05	2.14	0.02	0.83	0.76	0.01
ADFI, lb	5.40	5.31	5.47	5.29	0.13	0.72	0.88	0.36
F/G	2.63	2.50	2.70	2.44	0.02	0.53	0.68	0.01

[a]Values are means of eight observations (pens) and 12 pigs per pen.

Table 3. Interactive Effects of L-carnitine, Paylean, and Handling on Stress Criteria of Finishing Pigs (Exp. 1)[a]

	Gentle Handling				Non-gentle Handling											
	L-carnitine, ppm															
	0		50		0		50									
	Paylean, ppm									Probability ($P <$)						
Item	0	20	0	20	0	20	0	20	SED	L-carnitine × Paylean × Handling	L-carnitine × Paylean	L-carnitine × handling	Paylean× Handling	L-carnitine	Paylean	Handling
LDH, U/L																
Pre-handling	532.50	532.50	537.25	534.40	550.00	604.38	558.00	593.75	25.67	-	0.76	-	-	0.95	0.46	-
Post-handling	487.88	587.50	574.00	600.00	651.13	775.25	647.88	768.75	37.95	0.58	0.55	0.39	0.35	0.48	0.01	0.01
Difference	-44.62	55.00	36.75	65.60	101.13	170.87	89.88	175.00	28.43	0.51	0.69	0.34	0.89	0.41	0.01	0.01
Lactate, mmol/L																
Pre-handling	2.39	3.61	2.23	2.31	2.10	2.85	2.03	2.91	0.26	-	0.35	-	-	0.17	0.01	-
Post-handling	4.70	5.93	5.08	5.85	19.38	21.39	19.16	27.51	1.67	0.21	0.28	0.30	0.13	0.26	0.03	0.01
Difference	2.31	2.32	2.85	3.54	17.28	18.54	17.13	24.60	1.63	0.35	0.99	0.11	0.09	0.03	0.29	0.01
pH																
Pre-handling	7.39	7.37	7.40	7.40	7.41	7.43	7.40	7.39	0.01	-	0.81	-	-	0.20	0.04	-
Post-handling	7.41	7.39	7.41	7.38	7.20	7.11	7.22	7.05	0.02	0.32	0.29	0.71	0.01	0.60	0.01	0.01
Difference	0.02	0.02	0.01	-0.02	-0.21	-0.32	-0.18	-0.34	0.03	0.61	0.37	0.99	0.05	0.33	0.01	0.01
Glucose, mg/dL																
Pre-handling	87.25	88.38	88.50	89.75	87.88	84.25	82.50	88.25	1.82	-	0.20	-	-	0.86	0.54	-
Post-handling	92.00	84.50	90.00	88.13	128.25	122.13	138.13	149.00	5.02	0.57	0.27	0.09	0.49	0.06	0.82	0.01
Difference	4.75	-3.88	1.50	-1.62	40.37	37.88	55.63	60.75	5.37	0.92	0.54	0.08	0.51	0.09	0.67	0.01
Urea nitrogen, mg/dL																
Pre-handling	15.75	13.63	15.13	15.63	15.00	12.38	13.38	12.75	1.13	-	0.31	-	-	0.98	0.29	
Post-handling	15.88	13.63	15.50	15.88	16.38	13.88	14.88	14.13	1.17	0.85	0.36	0.51	0.77	0.89	0.28	0.73
Difference	0.13	0	0.37	0.25	1.38	1.50	1.50	1.38	0.20	0.34	0.75	0.75	1.00	0.11	0.52	0.01
Cortisol, ng/ml																
Pre-handling	12.45	14.81	14.15	9.92	15.99	18.36	12.93	15.11	1.73	-	0.33	-	-	0.18	0.70	-
Post-handling	42.85	46.21	36.20	34.03	49.48	60.86	48.15	61.68	5.07	0.49	0.76	0.10	0.04	0.08	0.02	0.01
Difference	30.40	31.39	22.05	21.98	33.49	42.49	35.22	46.57	4.10	0.83	089	0.13	0.21	0.09	0.15	0.01
Temperature, °C																
Pre-handling	39.17	39.29	38.99	39.04	39.40	39.44	39.16	39.18	0.13	-	0.78	-	-	0.01	0.49	-
Post-handling	40.00	40.08	40.00	40.00	40.99	41.33	40.91	41.24	0.18	0.86	0.80	0.80	0.14	0.50	0.06	0.01
Difference	0.83	0.79	1.01	0.96	1.60	1.89	1.75	2.06	0.17	0.94	1.00	0.94	0.06	0.07	0.16	0.01

[a]Values are means 8 observations (pigs) with 2 pigs/pen (handling group.

Table 4. Interactive Effects of L-carnitine, Paylean, and Handling on Heart Rate of Finishing Pigs (Exp. 1)

	Handling															
	Gentle				Non-gentle											
	L-carnitine, ppm															
	0		50		0		50									
	Paylean, ppm									Probability ($P <$)						
Item	0	20	0	20	0	20	0	20	SED	L-carnitine × Paylean × Handling	L-carnitine × Paylean	L-carnitine × Handling	Paylean × Handling	L-carnitine	Paylean	Handling
Heart rate																
Minimum	118	114	121	132	118	137	118	123	12.53	0.18	0.99	0.11	0.38	0.75	0.11	0.73
Average	192	184	193	200	204	210	230	217	11.14	0.09	0.82	0.19	0.09	0.56	0.11	0.01
Maximum	251	247	258	264	279	281	275	289	10.79	0.93	0.22	0.28	0.42	0.15	0.35	0.01
Change (max-min)	133	133	138	132	164	141	153	167	13.19	0.10	0.20	0.66	0.92	0.46	0.56	0.01
Observations/trt	6	8	5	7	6	6	4	4								

Table 5. Interactive Effects of L-carnitine, Paylean, and Handling on Stress Criteria of Finishing Pigs (Exp. 2)[a]

	Gentle Handling				Non-gentle Handling											
	L-carnitine, ppm															
	0		50		0		50									
	Paylean, ppm									Probability ($P <$)						
Item	0	20	0	20	0	20	0	20	SED	L-carnitine × Paylean × Handling	L-carnitine × Paylean	L-carnitine × Handling	Paylean× Handling	L-carnitine	Paylean	Handling
LDH, U/L																
Post-handling	475.75	621.13	457.13	531.63	509.13	560.25	541.88	637.25	29.53	0.23	0.69	0.08	0.41	0.86	0.01	0.13
1hr Post-handling	462.50	588.25	451.38	528.50	599.88	623.38	594.13	708.13	28.13	0.15	0.66	0.12	0.49	0.93	0.01	0.01
Difference	4.75	-32.88	-5.75	-3.13	90.75	63.13	52.25	70.88	19.74	0.94	0.28	0.53	0.74	0.88	0.58	0.01
Lactate, mmol/L																
Post-handling	2.78	5.94	4.10	5.08	19.38	20.43	18.90	22.24	2.36	0.29	0.98	0.84	0.95	0.67	0.05	0.01
1hr Post-handling	2.61	2.73	2.89	2.29	9.54	10.23	10.25	14.50	1.84	0.13	0.31	0.07	0.06	0.09	0.12	0.01
Difference	-0.16	-3.21	-1.21	-2.79	-9.84	-10.20	-8.65	-7.74	1.99	0.96	0.51	0.31	0.22	0.47	0.33	0.01
pH																
Post-handling	7.46	7.42	7.44	7.43	7.13	7.07	7.10	7.03	0.04	0.56	0.74	0.50	0.33	0.43	0.02	0.01
1hr Post-handling	7.42	7.44	7.43	7.44	7.38	7.40	7.38	7.33	0.02	0.42	0.27	0.25	0.49	0.36	0.96	0.03
Difference	-0.04	0.02	-0.01	0.00	0.25	0.34	0.27	0.30	0.02	0.89	0.08	0.66	0.57	0.98	0.01	0.01
Glucose, mg/dL																
Post-handling	84.25	72.38	86.38	80.88	168.88	149.63	156.63	152.63	10.43	0.70	0.35	0.39	0.80	0.95	0.09	0.01
1hr Post-handling	88.25	78.25	86.25	81.00	100.38	76.63	73.13	75.75	4.21	0.21	0.07	0.09	0.73	0.11	0.04	0.64
Difference	4.00	5.88	-0.13	0.13	-68.50	-73.00	-83.50	-76.88	10.48	0.57	0.67	0.69	1.00	0.20	0.85	0.01
Urea nitrogen, mg/dL																
Post-handling	14.75	13.13	13.50	11.88	20.25	12.25	15.38	13.38	0.87	0.04	0.04	0.65	0.02	0.03	0.01	0.03
1hr Post-handling	15.50	13.75	14.38	12.75	21.00	12.25	14.88	13.50	0.87	0.01	0.01	0.19	0.02	0.01	0.01	0.18
Difference	0.75	0.63	1.38	0.88	0.75	0.00	-0.50	0.13	0.26	0.11	0.35	0.07	0.64	0.81	0.48	0.01
Cortisol, ng/ml																
Post-handling	34.46	38.48	38.42	40.16	42.11	37.92	42.90	56.03	3.85	0.07	0.16	0.21	0.76	0.02	0.17	0.08
1hr Post-handling	20.99	32.12	19.47	25.33	58.74	59.48	61.18	69.49	6.37	0.42	0.89	0.20	0.62	0.80	0.11	0.01
Difference	-13.47	-6.35	-18.95	-14.83	16.63	21.56	18.27	13.46	6.63	0.61	0.34	0.57	0.41	0.13	0.40	0.01
Temperature, °C																
Post-handling	40.30	40.47	40.17	40.63	41.03	41.02	40.88	41.46	0.15	0.42	0.02	0.51	0.87	0.40	0.01	0.01
1hr Post-handling	39.45	39.67	39.31	39.71	40.44	40.30	39.84	40.56	0.21	0.20	0.06	0.67	0.95	0.41	0.03	0.01
Difference	-0.85	-0.79	-0.85	-0.93	-0.60	-0.72	-1.04	-0.90	0.19	0.39	0.76	0.30	0.95	0.10	1.00	0.83

[a]Values are means of 8 observations (pigs) with 2 pigs/pen (handling group).