Effects of L-Carnitine in the Diet of Weanling Pigs
II. Apparent Nutrient Digestibility, Whole Body Composition, and Tissue Accretion

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Story in Brief

An experiment was conducted to determine the effects of supplementing L-carnitine to the diet of weanling pigs on apparent nutrient digestibility, whole body composition, and tissue accretion. Six sets of four littermate barrows (4.9 kg; 18 d) were randomly allotted to four dietary treatments containing 0, 25, 50, or 100 ppm added L-carnitine. Pigs were fed in three dietary phases (P1: d 0-10; P2: d 11-24; and P3: d 25-38 with 1.6, 1.4, and 1.2% Lys, respectively). Pigs were housed individually in metabolism chambers and a 5-d total but separate collection of urine and feces was performed during each phase (P1: d 4-9; P2 d 17-22; and P3 d 29-34). Increasing L-carnitine resulted in a slight improvement in energy digestibility and nitrogen balance with the greatest response observed in pigs fed 25 to 50 ppm L-carnitine. At the conclusion of the experiment, each pig was killed and ground for determination of whole body composition. Additionally, a fifth littermate from each set of pigs was killed at the beginning of the experiment for the determination of initial body composition. Added L-carnitine increased the percentage of protein and decreased the percentage of fat in the weanling pig. Also, the ratio of protein accretion to fat accretion (1.59, 2.07, 2.08, and 2.23) improved with supplemental L-carnitine. These results suggest that the addition of L-carnitine to the diet improves whole body composition, tissue accretion, and to a lesser degree, nutrient digestibility in weanling pigs; however, the greatest response to L-carnitine was observed in pigs fed 50 ppm.

Key Words: Carnitine, Weanling Pigs, Nutrient Digestibility, Accretion

Introduction

Carnitine is a naturally occurring, vitamin B-like compound that is present in muscle and other tissues. The primary metabolic role of carnitine is to facilitate the transfer of long-chain fatty acids across the mitochondrial membrane into the matrix of the mitochondria (Fritz and Yue, 1963; Bray and Briggs, 1980). Due to the fact that carnitine is a cosubstrate of carnitine palmitoyltransferase, a key regulatory enzyme in the pathway of fatty acid oxidation, carnitine status could conceivably affect the utilization of fatty acid stores for the production of adenosine triphosphate (energy). Up-regulation of the transport of long-chain fatty acids results in increased β-oxidation and oxidative phosphorylation in the mitochondrial matrix, in turn, leading to increased energy production. As a consequence of the increased energy yield, a repartitioning of nutrients is possible. Interest in the role of carnitine as a feed additive to improve whole body composition arose from the desire to partition nutrients away from lipid accretion and toward protein deposition in an effort to produce higher yielding animals.

Rincker et al. (2001) and Real et al. (2001) recently reported improvements in growth performance of weanling pigs in response to dietary L-carnitine. However, the question still exists as to the exact mechanisms that elicit the improvements in growth performance, and whether the improvements are the result of a repartitioning of nutrients. Early experiments conducted by Weeden et al. (1990) reported that 1,000 ppm L-carnitine reduced carcass fat and improved feed efficiency. Similar results were also reported by Owen et al. (1996). These authors reported that dietary L-carnitine reduces carcass lipid accretion. As well, Cho et al. (1999) suggested that the supplementation of L-carnitine improved crude fat and gross energy digestibility, resulting in improved ADG. In contrast, Hoffman et al. (1993) reported that added L-carnitine did not improve the performance of young pigs nor metabolizable energy in diets that contained soybean oil. Therefore, the objective of our study was to determine the effects of graded levels of L-carnitine on nutrient digestibility, whole body composition, and tissue accretion in weanling pigs.

Materials and Methods

Six sets of four littermate Yorkshire and crossbred (Yorkshire x Hampshire) barrows (18 ± 2 d), initially averaging 4.9 kg, were individually housed in metabolism chambers and utilized in a 38-d experiment. Pigs were allotted randomly on the basis of weight within litter to the four dietary treatments in a randomized complete block design. There were six pigs per treatment. The four dietary treatments were a control diet supplemented with 0, 25, 50, or 100 ppm L-carnitine. The four dietary treatments are the same as those previously reported by Rincker et al. (2001). Pigs were fed in three dietary phases (P1: d 0-10; P2: d 11-24; and P3: d 25-38 with 1.6, 1.4, and 1.2% Lys, respectively).

Each chamber contained one stainless steel self-feeder and one nipple waterer that allowed *ad libitum* access to feed and water throughout the experiment. The chambers were constructed to allow for the total, but separate collection of urine, feces, and refused feed. A 5-d collection period of urine and feces was performed during each phase (P1: d 5-9; P2: d 17-22; and P3: d 29-34). As well, pig weights and feed consumption were recorded at the start and end of each collection period to be used in the determination of apparent nutrient digestibility. Pigs were also weighed and feed consumption measured at the conclusion of each dietary phase for the determination of average daily gain (ADG), average daily feed intake (ADFI), and gain:feed (G:F). Feed, fecal, and urine samples were then analyzed for DM according to AOAC (1990) procedures, gross energy by bomb calorimetry, and nitrogen content via Kjeldahl methodology. As well, diets were analyzed for L-carnitine concentration by methods described by Parvin and Pande (1977).

At the conclusion of the 38-d feeding experiment, each pig was euthanized for the determination of whole body composition. Additionally, a fifth littermate from each set was euthanized at the onset of the experiment for the determination of initial body composition. After euthanization, whole pigs were placed in boxes and stored in a -20°C freezer for grinding and analysis at a later date.

Whole pigs were ground for composition analysis. Initially, frozen pigs were cut into smaller sections with a band saw and ground three times in a commercial meat grinder equipped with a .64 cm screen. Following grinding, samples were thoroughly mixed and a subsample of approximately 500 g was collected. Whole body subsamples were then freeze-dried and further ground in a Wiley Mill equipped with a 2-mm screen. Whole body samples were then analyzed for DM by AOAC (1990) procedures. Gross energy was measured via bomb calorimetry and protein determinations were performed by Kjeldahl methodology. Lipid content of whole body samples was determined by standard ether extract procedures.

Nutrient digestibility data were analyzed as a randomized complete block design within each period using analysis of variance procedures as described by Steel et al. (1997). There were no treatment by period interactions as trends were similar within periods. Thus, digestibility data were pooled across periods. All data (digestibility, composition, and tissue accretion) were then analyzed in a randomized complete block design using analysis of variance procedures. The model included the effects of block (rep), treatment, and block x treatment (error). The effects of increasing dietary L-carnitine concentration were partitioned into linear, quadratic, and cubic components using orthogonal polynomial contrasts. Pen served as the experimental unit.

Results and Discussion

The chemical analysis of the four dietary treatments is reported in the companion paper (Rincker et al., 2001). The supplemental levels of L-carnitine concentration averaged across periods, were 0, 25, 50, and 89 ppm, respectively. Supplemented levels of L-carnitine were in agreement with calculated levels, signifying proper diet mixing. Because of the inclusion of 5% soybean oil, all diets had a gross energy value between 4,125 and 4,206 kcal/kg.

Data for growth performance are not shown; however, growth performance trends were similar to those previously reported by Rincker et al. (2001). Increasing levels of L-carnitine to the diet of weanling pigs improved ADG and G:F, with the greatest response being observed in pigs fed 50 ppm L-carnitine.

Apparent energy digestibility of weanling pigs is reported in Table 1. An increase (linear, $P<.04$) in GE intake was noted in pigs fed increasing levels of dietary L-carnitine that was associated with a linear increase ($P<.01$) in daily feed consumption. Although fecal GE excretion and urinary GE loss increased (linear, $P<.01$), increasing trends (linear, $P=.13$) in DE and ME (kcal/d), respectively, were still observed due to larger increases in GE intake. Additionally, the inclusion of 25 and 50 ppm L-carnitine had little affect on DE:GE and ME:GE when compared with the control, while 100 ppm L-carnitine decreased (quadratic, $P<.09$) DE:GE and ME:GE in weanling pigs.

Table 1. Apparent energy digestibility of weanling pigs[ab]

	Carnitine, ppm					P >:[c]		
Item:	0	25	50	100	SE	Linear	Quad.	Cubic
ADFI, g/d	415	430	476	479	14	.01	--	--
GE Intake, kcal/d	1,944	2,001	2,147	2,166	77	.04	--	--
Fecal GE, kcal/d	217	214	239	280	8.3	.01	.17	--
DE, kcal/d	1,727	1,788	1,907	1,886	76	.13	--	--
DE, kcal/kg	4,159	4,149	4,162	4,059	24	.01	.13	--
Urine GE, kcal/d	10.2	12.7	10.9	13.9	.68	.01	--	.02

ME, kcal/d	1,717	1,775	1,896	1,872	76	.13	--	--
ME, kcal/kg	4,136	4,121	4,140	4,030	25	.01	.12	--
DE:GE, %	88.8	89.2	88.8	86.8	.52	.01	.09	--
ME:GE, %	88.3	88.6	88.3	86.2	.53	.01	.09	--

[a]Least squares means for six pigs/trt

[b]Data reported on a dry matter basis

[c]Dashes indicate (P>.20).

Trends for nitrogen balance (Table 2) were similar to those reported for energy digestibility. An increase (linear, P<.08) in N intake was observed in pigs fed added L-carnitine that was associated with an increase in ADFI. Although an increase in fecal N excretion (linear, P<.01) was observed, a greater increase in N intake was noted in pigs fed 25 and 50 ppm L-carnitine, resulting in the percentage of N absorbed being improved (quadratic, P<.06) in these two groups. A quadratic response (P<.06) was also observed in the percentage of N retained, as pigs fed 25 and 50 ppm L-carnitine retained more N, while the inclusion of 100 ppm L-carnitine decreased the percentage of N retained when compared with the control.

Table 2. Nitrogen balance of weanling pigs[ab]

	Carnitine, ppm					P >:[c]		
Item:	0	25	50	100	SE	Linear	Quad.	Cubic
N Intake, g/d	14.8	15.7	17.5	17.8	1.5	.08	--	--
N Fecal excr, g/d	2.1	2.0	2.3	2.7	.22	.01	--	--
N Abs, g/d	12.7	13.7	15.2	15.1	1.4	.13	--	--
N Abs, %	86.0	87.2	87.0	84.5	1.0	.12	.06	--
Urine N loss, g/d	1.2	1.3	1.2	1.6	.36	--	--	--
N Ret, g/d	11.5	12.4	14.1	13.5	1.1	.12	--	--
N Ret, %	78.6	79.0	80.7	76.2	1.5	.18	.06	--
Ret:Abs, %	91.4	90.6	92.8	90.2	1.7	--	--	--

[a]Least squares means for six pigs/trt

[b]Data reported on a dry matter basis

[c]Dashes indicate (P>.20).

Whole body percentages of protein and lipid are shown in Table 3. An improvement in whole body composition was observed as the percentage of protein increased (linear, P<.01) and the percentage of lipid decreased (linear, P<.01) in pigs fed increasing concentrations of L-carnitine. Changes in body composition were also observed in the percentage of ash (quadratic, P<.01) and the percentage of water (linear, P<.01), both of which increased with added L-carnitine. Tissue accretion rates are also shown in Table 3. A quadratic increase (P<.05) in the rate of protein (g/d) and energy (kcal/d) accretion was observed with increasing L-carnitine. Although the rate of lipid accretion was unaffected (P>.20) by added L-carnitine, the ratio of protein to lipid accretion improved (linear, P<.01) with increasing L-carnitine. In general, the response to L-carnitine tended to plateau at 50 ppm. These results suggest that the supplementation of L-carnitine improved the rate of protein and energy accretion in weanling pigs. Furthermore, an improvement in whole body composition was observed as the ratio of protein accretion to lipid accretion increased with L-carnitine addition. The increase in the ratio of protein accretion to lipid accretion indicates a repartitioning of nutrients away from lipid deposition and towards the accretion of protein.

Table 3. Whole body composition of weanling pigs[a]

	Carnitine, ppm					P >:[b]		
Item:	0	25	50	100	SE	Linear	Quad.	Cubic
Protein, %	13.4	14.0	14.0	14.1	.14	.01	.05	--
Lipid, %	8.35	7.42	7.17	6.89	.17	.01	.01	--
Ash, %	2.71	2.88	2.79	2.80	.03	--	.01	.01
Water, %	76.4	77.1	77.4	78.1	.32	.01	--	--
Protein accretion, g/d	33.6	42.6	48.5	45.4	2.3	.01	.01	--
Lipid accretion, g/d	21.2	21.1	23.7	20.4	1.4	--	.20	--
Protein:lipid	1.59	2.07	2.08	2.23	.07	.01	.01	.03
Energy gain, kcal/d	379	425	483	426	29	--	.05	--

[a]Least squares means for six pigs/trt

[b]Dashes indicate (P>.20).

Results from our study are in agreement with those reported by Heo et al. (2000). These authors fed diets containing 7% supplemental fat combined with low or high protein levels, so that protein accretion would be limited by ME. Dietary L-carnitine supplementation improved the percentage of absorbed N retained in the body. Similarly, the percentage of fat in the carcass decreased and the protein accretion rate increased in pigs fed L-carnitine.

Implications

This study indicates that the supplementation of L-carnitine improved nitrogen balance and the utilization of gross energy provided in the diet of weanling pigs. However, the greatest improvement in nitrogen balance and energy utilization was observed in pigs fed 25 and 50 ppm L-carnitine. Additionally, pigs fed increasing levels of L-carnitine had improved whole body composition. Supplemental L-carnitine resulted in an increased percentage of protein and a decreased percentage of lipid in weanling pigs. Tissue accretion was also improved due to added L-carnitine, indicated by the increased protein accretion to lipid accretion ratio. We would hypothesize that the supplemental L-carnitine increased the utilization of the soybean oil provided in the diet. The increased fatty acid oxidation of the soybean oil resulted in improved energy utilization, which in turn led to a repartitioning of nutrients away from lipid deposition toward an increase in protein accretion as evident by the improvements in whole body composition.

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