

Effects of L-carnitine, Selenium-enriched Yeast, Jujube Fruit and Hwangto (Red Clay) Supplementation on Performance and Carcass Measurements of Finishing Pigs

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ABSTRACT : Fifty castrated crossbred (Landrace×Yorkshire) pigs, weighing an average of 60.6±3.1 kg were allotted to one of five treatments in a randomized block design to examine the effects of dietary inclusion of 0.1% L-carnitine (50 ppm carnitine), 0.1% selenium-enriched yeast (0.3 ppm selenium), 0.1% Jujube fruit or 0.1% Hwangto (Red clay) on pig performance and carcass quality. All diets were based on corn, wheat, soybean meal and wheat bran and were formulated to supply 13.8 MJ DE/kg. Dietary supplementation did not influence daily gain ($p = 0.57$), feed intake ($p = 0.52$), or feed conversion ($p = 0.32$). Digestibility of dry matter ($p = 0.60$), organic matter ($p = 0.74$), crude protein ($p = 0.76$), crude fibre ($p = 0.70$) and energy ($p = 0.75$) were also unaffected by inclusion of any of the additives. Tissue samples taken from the longissimus muscle showed that the levels of carnitine ($p = 0.0001$) and selenium ($p = 0.0001$) were significantly higher with dietary inclusion of carnitine or selenium-enriched yeast. Dietary treatment did not affect dressing percentage ($p = 0.33$), carcass lean yield ($p = 0.99$) or first, 10th and last rib midline backfat depth ($p = 0.45, 0.82$ and 0.47 , respectively). Dietary treatment also did not affect the percentages of tenderloin ($p = 0.37$), bacon ($p = 0.36$), fat and bone ($p = 0.56$), picnic shoulder ($p = 0.25$), skirt ($p = 0.80$), fresh ham ($p = 0.31$) or ribs ($p = 0.79$). However, pigs fed the diet containing Jujube fruit had a higher percentage of Boston butt than pigs fed the carnitine or selenium supplemented diets ($p = 0.01$). Pigs fed added Hwangto had a higher ($p = 0.04$) percentage of loin compared with pigs fed supplementary selenium or Jujube fruit. Loin muscle from pigs fed carnitine had a significantly lower Hunter colour value for L (whiteness, $p = 0.004$) and a higher value for a* (redness; $p = 0.069$). The overall results indicate that supplementation with L-carnitine and selenium-enriched yeast can produce pork containing higher levels of carnitine and selenium, which could provide health benefits for consumers of pork without detrimental effects on pig performance. (*Asian-Aust. J. Anim. Sci.* 2006. Vol 19, No. 2 : 217-223)

Key Words : Carnitine, Selenium, Jujube Fruit, Red Clay, Pigs, Performance, Carcass Traits

INTRODUCTION

Expanding knowledge of the role of physiologically active components from animal sources has notably changed the role of diet in human health (American Dietetic Association, 2004). Functional foods are usually understood to be any potentially healthful food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains (Wildman, 2001). Functional foods that have been associated with health-related effects include animal products such as eggs with n-3 fatty acids (Farrell, 1998; Lewis et al., 2000), dairy products, and meat from ruminant animals containing conjugated linoleic acid (Belury, 2002).

Carnitine is a vitamin-like compound, which is necessary for the transport of long-chain fatty acids across the inner mitochondrial membrane, thereby facilitating β -oxidation (Fritz and Yue, 1963). Owen et al. (2001a) reported that feeding L-carnitine during the growing-finishing phase had no effect on pig performance, but may

be a means to improve carcass characteristics and tissue carnitine concentration. They reported that 50 ppm added carnitine was sufficient to obtain optimal carcass characteristics and metabolic differences.

Selenium has recognized antioxidant properties. Ku et al. (1972) reported a high correlation between the selenium content of pork loins and the natural selenium content of diets fed to pigs. An organic selenium yeast source resulted in a higher deposition of selenium in muscle than when the inorganic form of the element was provided (Mahan and Parrett, 1996). However, Mahan et al. (1999) reported no benefits in pig performance or carcass traits as a result of altering either the selenium source or the dietary selenium level in pig diets.

Jujube fruit (*Zizyphus jujuba*) is traditionally used for weakness, fatigue, debility, restlessness, and hysteria as well as to assist in the actions of other herbs (Ou, 1989). Jujube seeds are used for medicinal purpose and increase weight gain, muscular strength, and stamina (Yang, 1998). In Chinese medicine, Jujube is prescribed as a *qi* tonic to strengthen liver function. Mildly sedative and anti-allergenic, it is given to reduce irritability and restlessness (Chevallier, 1998). Scientific studies with animals have shown the *Zizyphus jujuba* seed to have anti-anxiety effects, causing a reduction in the speed of conditioned reflexes and

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Table 1. Composition and chemical analysis (% as fed) of the experimental diets

	Control	Carnitine	Selenium	Jujube fruit	Hwangto
Ingredient composition					
Corn	18.00	18.00	18.00	18.00	18.00
Wheat	60.00	60.00	60.00	60.00	60.00
Soybean meal (44% CP)	16.90	16.90	16.90	16.90	16.90
Wheat bran	1.15	1.05	1.05	1.05	1.05
Water	1.00	1.00	1.00	1.00	1.00
Celite-545	1.00	1.00	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35	0.35
Limestone	0.40	0.40	0.40	0.40	0.40
Tri-calcium phosphate	0.70	0.70	0.70	0.70	0.70
Vitamin-trace mineral premix ^a	0.50	0.50	0.50	0.50	0.50
L-carnitine	0.00	0.10	0.00	0.00	0.00
Selenium-enriched yeast	0.00	0.00	0.10	0.00	0.00
Jujube fruit	0.00	0.00	0.00	0.10	0.00
Hwangto	0.00	0.00	0.00	0.00	0.10
Chemical analysis					
Moisture	13.37	13.37	13.37	13.37	13.37
Crude protein	16.06	16.02	16.08	16.05	16.03
Ether extract	1.97	1.97	1.97	1.97	1.97
Acid detergent fibre	6.29	6.14	6.20	6.33	6.13
Ash	5.19	5.20	5.18	5.16	5.21
Calcium	0.56	0.57	0.56	0.56	0.56
Phosphorus	0.49	0.49	0.49	0.49	0.49

^a The vitamin and trace mineral premix provided the following per kilogram of diet: 60 mg Fe; 10 mg Cu; 25 mg Mn; 60 mg Zn; 0.2 mg I; 0.25 µg Se; 8,000 IU Vitamin A; 1,500 IU Vitamin D₃; 40 mg Vitamin E; 1 mg Vitamin K₃; 1 mg Thiamine; 2.5 mg Riboflavin; 2 mg Pyridoxine; 0.01 mg Vitamin B₁₂; 7 mg Pantothenic acid; 15 mg Niacin; 0.05 mg Biotin; 0.5 mg Folic acid and 165 mg Choline.

a reduction in hyperactivity (Park et al., 2000; Han et al., 2001). Because of its stress-reducing effects, the Jujuba can be used as an anti-stress agent.

Hwangto (Red clay) contains SiO₂ (50 to 65%), Al₂O₃ (16 to 24%), Fe₂O₃ (4 to 9%), MgO (0.6% to 2.5%) and K₂O (1 to 3%), respectively (Kang et al., 2002). Hwangto is traditionally used for disease control in livestock (Ryu, 1997). Scientific studies with animals have shown Hwangto to have improved meat quality, but not red meat quantity and feed efficiency in steers (Kang et al., 2002).

The objective of the following experiment was to compare L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto (Red clay) in finishing pig diets in order to determine whether performance or carcass quality are altered by supplementation. The effect of supplementation of L-carnitine and selenium on their deposition in muscle was also determined.

MATERIALS AND METHODS

Growth trial

Fifty castrated, male crossbred (Landrace×Yorkshire) pigs, weighing an average of 60.6±3.1 kg, were allotted to one of five dietary treatments from outcome groups based on initial weight. The control diet was based on corn, wheat, soybean meal and wheat bran while four experimental diets were formulated by supplementing the control diet with either L-carnitine (50 ppm carnitine; Lonza, Basel,

Switzerland), selenium-enriched yeast (0.30 ppm selenium; Easybio, Seoul, Korea), 0.1% Jujuba fruit (Medical Herb Market, Seoul, Korea) or 0.1% Hwangto (Red clay; Greenbio, Incheon, Korea) added at the expense of wheat bran (Table 1).

All diets were formulated to supply 13.8 MJ DE/kg and were supplemented with sufficient vitamins and minerals to meet or exceed the levels recommended by the National Research Council (1998). Celite 545 (1%; Fluka, Switzerland) was added to all diets as a digestibility marker. The diets were fed in meal form.

The pigs were housed in groups of two in concrete floored pens measuring 1.2×2.0 m. Each pen contained a single feeder and a nipple waterer to provide *ad libitum* access to feed and water. There were five replicate pens per treatment. The temperature in the environmentally regulated finishing barn was maintained at 22±2°C. Pigs weights and feed disappearance were recorded every 10 d to determine weight gain, feed intake and feed conversion.

Digestibility trial

On days 11 and 12, fecal samples were collected from each pen with the accumulation of the two-day fecal collection subsequently being pooled. The fecal samples were oven dried for 72 h at 55°C, allowed to equilibrate for 24 h at room temperature and then ground through a 1.0 mm screen with a Cyclotec (Model 1093, FOSS, Denmark). Digestibility coefficients for dry matter, organic matter,

Table 2. Effect of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation on pig performance during the finishing period (60.6-110 kg)^a

	Control	Carnitine	Selenium	Jujube fruit	Hwangto	SEM	p value
Weight gain (kg/day)	1.01	1.06	1.02	1.09	1.10	0.05	0.57
Feed intake (kg/day)	3.17	3.09	2.95	3.21	3.13	0.11	0.52
Feed conversion	3.15	2.94	2.90	2.95	2.84	0.10	0.32

^a Five replicate pens of two pigs per pen for the performance data.

crude protein, crude fibre and gross energy were calculated using the equations for the indicator method described by Schneider and Flatt (1975).

Carcass measurements

The pigs were slaughtered at a commercial abattoir at an average weight of approximately 110 kg. The pigs were weighed, stunned, hoisted by one hind leg, and exsanguinated. Carcass weight was recorded and dressing percentage calculated. Hot carcass measurements were recorded after conventional slaughtering. The carcass was chilled overnight and backfat measurements were made at the 1st, 10th and last rib midline using a ruler. The carcass was then cut into standard wholesale cuts of tenderloin, bacon, Boston butt, Picnic shoulder, skirt, ham, loin, ribs, bone and fat using procedures described by the Korean Rural Development Administration (1997). Weights of each cut were determined. The shoulder was separated from the loin and bacon by a straight cut between the 5th and 6th rib. It was then separated into the Boston butt and Picnic shoulder retail cuts by a straight cut along the inner side of scapula. Each cut contained its corresponding skin and subcutaneous fat. The ham was removed from the loin by a straight cut between the sacral and lumbar vertebrae.

Chemical analysis

Samples of the rations were analyzed in triplicate according to the methods of the Association of Official Analytical Chemists (1990). Analyses were conducted for moisture (AOAC method 930.15), crude protein (AOAC method 984.13), acid detergent fibre (AOAC method 962.09), ash (AOAC method 942.05) and ether extract (AOAC method 920.39). Calcium was determined by an atomic absorption Spectrophotometer (Shimazu, AA625, Japan), and phosphorus was analyzed using a UV-vis. Spectrophotometer (Hitachi, U-1100, Japan). Gross energy value of diets and feces were measured using an Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL). Celite (HCL-Insoluble Ash) analysis was conducted according to the description provided by Prabucki et al. (1975).

A tissue sample was taken from each carcass from the longissimus muscle, between the 11th and 12th rib, for the determination of tissue carnitine concentrations using the method described by Bhuiyan et al. (1992). Muscle tissues were homogenized in 1 mL of ice-cold 1 mol/L HClO₄

using a PowerGen Homogenizer (Model 700; Fisher Scientific; 6×10 s at 30,000 rpm). Three carnitine fractions (free, short-chain and long-chain esters) were assayed the enzymatic radioisotope using the method of McGarry and Foster (1976). The tissues were analyzed for their selenium content with the fluorometric method of the AOAC (1995).

Loin color determination

To determine the color of the loin sections, loin muscles were cut into eight sections according to vertebra location. Samples were taken over the 6th, 8th, 10th, 12th and 14th thoracic vertebra as well as the 2nd, 4th and 6th lumbar vertebra. These fresh cuts were placed on stainless steel trays for approximately 2 h, and then the Hunter L*, a*, and b* values were measured using a Chromometer 50-mm orifice (Minolta Model CR-300, Ramsey, NJ). The average of three readings was utilized. The L* reading is a measure of the whiteness of a sample, the a* reading is a measure of the redness of the sample (the more positive the number, the redder the sample), while the b* reading is a measure of yellowness (the more positive the number, the more yellow the sample).

Statistical analysis

The data were analyzed as a randomized block design using the Analysis of Variance procedures described by Snedecor and Cochran (1980). Pigs were blocked on the basis of initial weight and the pen was considered the experimental unit for analyses of performance and nutrient digestibility. For tissue carnitine and selenium concentration, carcass traits and cut and Hunter measurements, the individual animal data were analyzed. The model included the effects of replication (i.e., block), treatment, and replication×treatment (error). The significance of differences between means was performed by the Least Significant Difference (LSD) method when preceded by a significant F-test. Statistical analyses of Hunter color values measurement was performed with the two-way analysis of variance procedures of Snedecor and Cochran (1980) with the General AOV procedure of STASISTIX (1996). The factors in the model consisted of treatment and location as well as their interaction.

RESULTS

The effects of L-carnitine, selenium-enriched yeast,

Table 3. Effect of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation on nutrient digestibility (%) for finishing pigs

	Control	Carnitine	Selenium	Jujube fruit	Hwangto	SEM	p value
Dry matter	80.6	81.2	80.0	82.8	81.4	3.73	0.60
Organic matter	85.4	85.4	84.4	86.2	85.4	0.91	0.74
Crude protein	76.8	79.6	76.8	80.0	78.4	2.19	0.76
Crude fibre	44.8	42.4	43.6	43.0	45.0	1.52	0.70
Gross energy	81.4	81.6	81.0	83.4	82.0	1.33	0.75

^a Five replicate pens (two castrates per pen) per treatment mean.

Table 4. Effect of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation on tissue carnitine and selenium concentrations at 110 kg body weight*

	Control	Carnitine	Selenium	Jujube fruit	Hwangto	SEM	p value
Carnitine (nM/g DM)	806.1 ^a	1,285.6 ^b	921.3 ^a	897.4 ^a	848.8 ^a	44.5	0.0001
Selenium (µg/kg DM)	631.3 ^a	644.0 ^a	1,250.0 ^b	704.3 ^a	616.3 ^a	63.3	0.0001

^{a,b} Means within a row with different superscripts differ at the p-values indicated.

* Based on five pigs per treatment.

Table 5. Effect of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation on swine carcass traits^a

	Control	Carnitine	Selenium	Jujube fruit	Hwangto	SEM	p value
Slaughter weight (kg)	107.0	109.5	107.1	110.6	111.3	3.15	0.81
Carcass weight (kg)	79.8	81.5	80.0	82.5	83.3	2.36	0.79
Dressing percentage	74.6	74.5	74.7	74.6	74.9	0.14	0.33
Lean yield (%)	66.3	66.8	66.7	66.6	66.5	0.71	0.99
Midline back fat							
First rib (mm)	44.1	38.7	43.8	41.5	41.4	2.22	0.45
10 th rib (mm)	30.5	27.3	28.8	27.5	28.9	2.12	0.82
Last rib (mm)	26.7	21.7	22.6	22.5	23.1	2.04	0.47

^a Based on five pigs per treatment.

Table 6. Effect of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation on the percentage of the carcass comprised of various retail cuts*

	Control	Carnitine	Selenium	Jujube fruit	Hwangto	SEM	p value
Tenderloin	1.48	1.38	1.47	1.46	1.52	0.05	0.37
Bacon	12.67	12.22	12.57	11.68	12.10	0.37	0.36
Boston butt	6.17 ^{ab}	5.93 ^{bc}	5.60 ^c	6.42 ^a	6.18 ^{ab}	0.14	0.01
Fat+bone	33.43	33.03	32.70	33.20	32.02	0.63	0.56
Picnic shoulder	12.35	12.82	13.01	13.40	12.72	0.32	0.25
Skirt	0.48	0.44	0.43	0.44	0.47	0.04	0.80
Fresh ham	19.53	20.50	20.52	20.31	20.46	0.37	0.31
Loin	8.57 ^{ab}	8.48 ^{ab}	7.91 ^b	7.93 ^b	9.06 ^a	0.26	0.04
Ribs	5.12	5.00	5.21	4.89	5.08	0.18	0.79

^{a,b,c} Means within a row with different superscripts differ at the p-values indicated.

* Based on five pigs per treatment.

Jujube fruit and Hwangto on pig performance are shown in Table 2. Dietary supplementation with L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto did not influence weight gain ($p = 0.57$), feed intake ($p = 0.52$) or feed conversion ($p = 0.32$). Digestibility of dry matter ($p = 0.60$), organic matter ($p = 0.74$), crude protein ($p = 0.76$), crude fibre (0.70) and energy ($p = 0.75$) were also unaffected by any of the feed additives (Table 3).

Tissue samples taken from the longissimus muscle showed that the level of carnitine ($p = 0.0001$) or selenium ($p = 0.0001$) present in tissue was significantly higher as dietary carnitine or selenium-enriched yeast was added to the diet (Table 4). For all other treatments, tissue carnitine

and selenium levels did not differ from those of the control treatment.

The effects of feeding diets with L-Carnitine, Selenium-enriched yeast, Jujube fruit and Hwangto supplementation on swine carcass traits are shown in Table 5. Dietary treatment did not affect dressing percentage ($p = 0.33$), carcass lean yield ($p = 0.99$) or middle line backfat depth at the first ($p = 0.45$), 10th ($p = 0.82$) or last rib ($p = 0.47$).

The effects of feeding diets with L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation during the finishing period on the percentage various retail cuts comprise of the total carcass are shown in Table 6. Dietary treatment did not affect percentages of tenderloin (p

Table 7. Effect of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation and loin position on Hunter color values (L*, whiteness; a*, redness; b*, yellowness) of loin^a

Item	Control	Carnitine	Selenium	Jujube fruit	Hwangto	SEM	P-value	
							Treatment	Position
L ^b	59.0 ^a	56.6 ^b	58.7 ^a	58.7 ^a	58.3 ^a	0.45	0.004	0.001
a*	8.1 ^{bc}	8.6 ^a	7.7 ^c	8.4 ^{ab}	8.1 ^{abc}	0.15	0.069	0.006
b*	3.0	2.5	2.9	3.3	2.6	0.24	0.193	0.001

^a Based on six pigs per treatment.

= 0.37), bacon (p = 0.36), fat and bone (p = 0.56), skirt (p = 0.80), fresh ham (p = 0.31), or ribs (p = 0.79). Compared with pigs fed either the control, Jujube fruit or Hwangto diets, pigs fed the diet containing added selenium had a lower (p = 0.01) percentage of Boston butt in the carcass. However, pigs fed diet containing added Jujube fruit had a higher (p = 0.01) percentage of Boston butt in the carcass than pigs fed either the L-carnitine or selenium supplemented diets. Compared with pigs fed the selenium or Jujube fruit diets, pigs fed the diet containing Hwangto had higher (p = 0.04) percentages of loin.

The effects of feeding diets with L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto supplementation during the finishing period on Hunter color values are shown in Table 7. Loin muscle from pigs fed carnitine had significantly lower Hunter colour values of L (whiteness, p = 0.004) and higher values for a* (redness; p = 0.069). The Hunter colour value L* (P = 0.001), a* (p = 0.006) and b* (p = 0.001) decreased as the sampling position of the muscle moved ventrally from the 5th to 14th thoracic vertebra and then increased as the sampling position moved ventrally from the 1st to 6th lumbar vertebra.

DISCUSSION

Dietary supplementation of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto during the finishing period had no effect on pig performance. Similar to our results, Owen et al. (2001b) reported that the addition of L-carnitine did not improve the performance of finishing pigs. These results are also consistent with those of Thomke et al. (1965), Mahan and Parrett (1996) and Mahan et al. (1999), who demonstrated no growth or feed responses when an organic form of selenium was added at various levels to growing-finishing cereal grain-based diets fed to pigs. Similarly, Thacker (2003), failed to demonstrate any performance improvements using Biotite, an aluminosilicate clay similar in composition to that used in the present experiment.

Supplementation of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto in the diet during the finishing period was generally unsuccessful in increasing nutrient digestibility. There is little research with which to compare our findings although Thacker (2003) similarly failed to improve nutrient digestibility with an

aluminosilicate clay (Biotite). However, Chen et al. (2005) found that N digestibility was improved by addition of Biotite V.

Tissue samples taken from the loin showed that the level of carnitine and selenium present in muscle was increased when L-carnitine and selenium-enriched yeast were included in the diet. This result supports that of Owen et al. (2001a), concluding that carnitine is synthesized in the liver and stored to some degree in the heart, but primarily in the muscle. Mahan et al. (1999) reported that dietary selenium affected the selenium concentration in the loin tissues at the end of the finishing (105 kg BW) periods. Mahan and Parrett (1996) and Mahan et al. (2005) reported that more selenium was retained in muscle tissue when a selenium-enriched yeast source was fed. Consequently, as pigs attain market weight (105-110 kg) and are fed either L-carnitine and/or organic selenium, they will have higher carnitine and/or selenium contents in tissue.

There was no significant effect on midline backfat thickness from the addition of the L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto. In contrast, Owen et al. (2001a) reported that increasing dietary L-carnitine reduced average backfat thickness; with 49 to 64 ppm L-carnitine providing the optimum response as determined from break point analysis. Newton and Haydon (1989) also showed a decrease in backfat thickness from finishing pigs fed supplemental L-carnitine.

The failure of selenium to modify backfat levels is consistent with the results of Mahan et al. (1999). Their results and ours indicated that the major carcass characteristics were not significantly affected by dietary selenium. The lack of effect of Hwangto on carcass characteristics supports the work of Thacker (2003) who noted no changes in carcass characteristics as a result of dietary inclusion of an aluminosilicate clay (Biotite).

Feeding diets supplemented with L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto during the finishing period had no effect on the percentage that various retail cuts comprise of the carcass. This is in agreement with other researchers who reported the dietary regimens to have no significant effect on carcass cutability (Unruh et al., 1996).

Supplementation of L-carnitine during the finishing period lowered the Hunter color value L*. These responses seemed to be consistent with fat content. Owen et al. (1993)

reported that feeding L-carnitine during the growing-finishing phase resulted in an 11% reduction in daily lipid accretion rate. Owen et al. (2001b) reported that increasing dietary L-carnitine resulted in a darker color for longissimus muscle.

Interestingly, there was a difference in Hunter color values of loin between positions. These responses seemed to be consistent with the different intramuscular fat content as the sampling position moved from thoracic to lumbar vertebra of loins. Heylen (1999) reported that the intramuscular fat content of the cranial position in longissimus is significantly higher than medial and caudal positions.

In conclusion, it would appear that supplementation of L-carnitine, selenium-enriched yeast, Jujube fruit and Hwangto in the diet during the finishing period had no significant effects on pig performance or carcass traits. However, the level of carnitine and selenium present in muscle was increased as L-carnitine and organic selenium was supplemented in the diet. As a result, it is possible to produce pork containing higher levels of carnitine and selenium, which could provide potential health benefits for consumers of pork, without negative effects on pig performance.

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