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The Effect of Dietary Supplementation of Feather Meal on the Performance and Muscular Taurine Contents in Growing-finishing Pigs

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ABSTRACT : An experiment was conducted to investigate the effects of dietary supplementation of feather meal (FM) on the performance of pigs and taurine content in pork. A total of 135 cross-bred (L×Y×D) pigs, weighing an average 46 kg, were assigned to five dietary treatments; Control, 3% FM supplemented diet (3% FM), 3% FM and 10 ppm pyridoxin supplemented diet (3% FM-pyridoxin), 6% FM supplemented diet (6% FM) and 6% FM and 10 ppm pyridoxine supplemented diet (6% FM-pyridoxin). Each treatment had 3 replications of 9 pigs (4 gilts and 5 barrows) each. Pigs were fed for 11 weeks under a phase feeding program which consisted of grower (0-3 week), grow-finisher (4-8 week) and finisher (9-11 week) periods. During the whole feeding period, ADG and ADFI of pigs fed FM treatments tended to increase in general compared to the control. Feed conversion ratio (feed/gain) of the control was significantly ($p<0.05$) lower than FM treatments. Taurine content of the control was highest in heart muscle (1,393.8 ppm) followed by liver (647.3 ppm), tenderloin (601.2 ppm), ham (462.4 ppm) and loin (375.8 ppm). Taurine contents of heart, tenderloin, ham and loin were significantly ($p<0.05$) increased by FM treatments. Taurine content was highest in the 6% FM-pyridoxin treatment. Taurine content of heart, tenderloin, ham and loin on 6% FM-pyridoxin supplementation were increased by 91%, 23%, 27% and 29%, respectively, compared with the control. Sensory tests of the pork showed that there was no consistent response among the treatments. In conclusion, supplementation of FM and pyridoxin to a pig diet can increase taurine content of the pork. (**Key Words** : Taurine, Feather Meal, Pyridoxin, Pork)

INTRODUCTION

Feather meal (FM) is produced by drying and grinding poultry feathers after heating under a high pressure. It has higher bioavailability and feed value than simple dried feathers. However, it is treated as a kind of polluter in industry due to leachate and strong offensive odor emitted in the FM processing. Despite the amount of feather generation is increasing yearly in proportion to the increase of poultry meat consumption, only 2-3% of FM is used in feed formulation at maximum, which accounts for one third of the total amount of locally generated feathers (about 30,000 MT). Although FM contains 85% or more CP, its digestibility is low (Schor and Krimm, 1961; Moran et al., 1966; Morris and Balloun, 1973) due to keratinous nature and disulfide bonds (Harrap and Woods, 1964).

As a sulfur-containing amino acid, taurine (β-aminoethanesulfonic acid; $HO\text{-}SO_2\text{-}CH_2\text{-}CH_2\text{-}NH_2$) is the end product generated in the metabolic process of amino acids such as methionine or cystine and exists in the form of a free amino acid in body tissues. It is not used for protein synthesis or as an energy source, and is a major free amino acid found in animal tissues.

The most well-known effect of taurine is that it forms taurocholic acid, one of the major bile acids, which improves micelle formation and lipid absorption in the intestinal tract (Gaull, 1983). It is reported that an adequate amount of taurine stimulates the emission of growth hormones which directly involve in the growth of animals (Ikuyama et al., 1988) as well as the emission of prolactin

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which has effects similar to those of growth hormones (Scheibel et al., 1980), and enhances the vitality of insulin by playing the role of an agonist to insulin receptor (Lampson et al., 1983; Maturo and Kulakowski, 1988). In addition, it is also known to have a variety of physiological functions such as brain development (Chesney, 1985; Huxtable, 1992), osmoregulation (Chan and Fishman, 1979), protection of cell membrane (Li et al., 1993; Trachtman et al., 1993) and sperm (Jang et al., 2006, 2008) from oxidation or peroxidation products, protection of cell membrane from damage by exogenous toxic substances (Ding et al., 1993; Waterfield et al., 1993), neuromodulation (Arzate et al., 1986), activation of reproductive function (Alvarez and Storey, 1983), serum cholesterol reduction (Yokogoshi et al., 1999; Lee et al., 2004) and serum glucose reduction (Nakaya et al., 2000). However, as the activities of cysteine dioxygenase (CD) and cysteine sulfinic acid decarboxylase (CSAD) which are enzymes involving in taurine synthesis are too low to trigger taurine biosynthesis in the human body (Rigo and Senterre, 1977; Sturman and Hayes, 1980), taurine should be supplied from outside. It is expected that the production of taurine-enriched pork will be possible if FM rich in cystine content is supplemented in feeds, thereby to supply a precursor of taurine.

In the meantime, pyridoxal-5-phosphate (vitamin B_6 or pyridoxin) is needed as a coenzyme for the activities of various enzymes necessary for the conversion of cystine into taurine such as cysteine dioxygenase (CD), cysteine sulfinic acid decarboxylase (CSAD), etc. Therefore, the present study is carried out to examine the effect of the dietary supplementation of FM as a source of cystine, a precursor of taurine, and pyridoxin on pig performance and taurine content of pork (loin, tenderloin and ham), liver and heart.

MATERIAL AND METHODS

Experimental diet

The composition of the basal diet used as the control is shown in Table 1. The three phase basal diets; Grower, Grow-finisher and Finisher were prepared to contain 3,300 kcal ME/kg and 19.0, 16.0 and 14.0% CP, respectively, in accordance with the NRC requirements (1998). Treated diets were made by adding FM and pyridoxine to the basal diets in non-isonutritive way. FM was obtained from Harim Co. Ltd. (Korea) who produces it by steam cooking and recommends NRC (1998) for its specification.

Experimental animals and design

One hundred thirty five growing-finishing cross-bred pigs (Landrace×Yorkshire×Duroc) with the average weight of 46 kg at the time of starting the experiment were randomly assigned to 5 treatments. Each treatment had 3 replications of 9 pigs (4 gilts and 5 barrows) with a similar weight. The pigs were housed by treatment group in 3×4 m pig pens with a flat floor and scraper system (4 m×3 m) according to a completely randomized placement. Five experimental diets were formulated in each phase: a non-FM group (control); a control+FM 3% supplemented group (3% FM); a control+FM 3%+pyridoxine 10 ppm supplemented group (3% FM-pyridoxin); a control+FM 6% supplemented group (6% FM); and a control+FM6%+ pyridoxin 10 ppm supplemented group (6% FM-pyridoxin).

Table 1. Composition and nutrient content of experimental diets[1]

Ingredients (%)	Grower	Grow-finisher	Finisher
Corn	58.10	66.88	71.79
Soybean meal	30.47	22.44	17.27
Ca- carbonate	0.22	0.31	0.35
Defluorinated-P	1.46	1.41	1.06
Salt	0.15	0.15	0.15
Animal fat	4.47	4.23	3.99
Molasses	4.50	4.00	5.00
Choline-Cl (60%)	0.07	0.03	0.05
$CuSO_4$ (34% Cu)	0.04	0.04	0.03
L-lysine (78%)	0.18	0.21	0.17
DL-methionine (98%)	0.05	0.04	0.01
Antibiotics	0.11	0.06	-
Hog premix[2]	0.20	0.20	0.13
Total	100.00	100.00	100.00
Chemical composition[3]			
ME (kcal/kg)	3,300.00	3,300.00	3,300.00
Crude protein (%)	19.00	16.00	14.00
Lysine (%)	1.13	0.96	0.79
Ca (%)	0.70	0.70	0.60
Phosphorus (%)	0.61	0.57	0.48

[1] As-fed basis. Pigs weighing 46 kg in average were fed grower feed for 3 weeks (0-3 weeks), grow-finisher feed for 5 weeks (4-8 week) and then for 3 weeks (9-11 week).
[2] Provide per kg diet: Vit A, 10,000 IU; Vit D_3, 2,000 IU; Vit E, 42 IU; Vit K, 5 mg; Vit B_2, 9.6 mg; Vit B_6, 2.45 mg; Vit B_{12}, 40 μg; pantothenic acid, 27 mg; niacin, 49 mg; biotin, 0.05 mg; Cu, 140 mg; Fe, 179 mg ; Zn, 179 mg; Mn, 12.5 mg; I, 0.5 mg; Co, 0.25 mg; Se, 0.4 mg.
[3] Calculated values

Feeding

During the experiment period, the pigs were allowed to have water and feed *ad libitum*, and weight gains and feed intake were measured at the time of starting the experiment and in the 3rd week (grower phase), 8th week (grow-finisher phase) and 11th week (finisher phase) to calculate ADG, ADFI and feed/gain by period.

Backfat thickness measurement

Backfat thickness was calculated by averaging the values measured in the 11th and 12th ribs of the carcasss of

slaughtered 60 pigs consisting of 12 pigs from each treatment group.

Sampling

Upon the completion of the experiment, a total of 60 pigs consisting of 6 gilts and 6 barrows from each treatment group were slaughtered according to the standard procedure of the abattoir and loins, tenderloins, hams, hearts and livers were collected. The collected samples were kept in a -50°C freezer until analysis.

Taurine analysis

Pretreatment of samples : After homogenizing the pork samples kept frozen and 0.4 M perchloric acid in the ratio of 1:5, it was centrifuged at 13,000 rpm in 4°C for 20 minutes to collect the supernatant. This process was repeated twice. The supernatant 2 ml was passed through a anion-exchange-column (AG50W-X8, 200-400 mesh, H^+ form, 5×15 mm, Bio-Rad Laboratories) and then washed with 1 ml distilled water three times to produce 5 ml extract in total.

High-performance liquid chromatography (HPLC) : Taurine analysis was basically conducted in accordance with the method used by Paola and Filippo (1999) and obtained results are marked with μg/g and fresh matter.

O-phthalaldehyde (OPA) derivation : The OPA derivation and reagent storage was conducted by the method of Pittaluga et al. (1977).

Sensory testing

Pork loins and bacons were collected from the carcasses and kept frozen until sensory test. Sensory test materials used in this experiment were meats broiled for 20 minutes in an oven with an internal temperature of 200°C. The meats were provided for a sensory evaluation (from 1 for poor to 5 for excellent). Evaluation was conducted in terms of acceptability for overall characteristics considering aroma, flavor, juiciness and tenderness of pork by sex (barrow and gilt) and part (loin and bacon). A sensory test was performed once with an untrained sensory panel consisting of ordinary 20 consumers.

Chemical and statistical analysis

General composition of feeds were analyzed by AOAC (1990) procedure. The data were analyzed by ANOVA using General Linear Models (GLM) procedure of SAS (1995). Significant difference between treatment means were determined at $p<0.05$ using Duncan's new multiple range test (Duncan, 1995).

RESULTS AND DISCUSSION

Performance according to feather meal supplementation

The ADG, ADFI and feed/gain ratio for the period of breeding experiment are shown in Table 2. The ADG of pigs in the grower phase (0-3 weeks) were higher in FM-supplemented groups than in the control group but the

Table 2. The effect of diets supplemented with feather meal on pig performance

Items	Treatments[1]					SEM
	Control	3% FM	3% FM+ pyridoxin	6% FM	6% FM+pyridoxin	
Grower phase (0-3 weeks)						
ADG (g)	683.8	815.7	710.0	770.0	805.2	50.76
ADFI (g)	1,698.6^{b}	1,962.9^{a}	1,754.3^{ab}	1,889.1^{ab}	1,889.1^{ab}	68.80
Feed/gain	2.48	2.41	2.47	2.45	2.35	0.11
Grow-finisher phase (3-8 weeks)						
ADG (g)	728.9	714.6	744.3	725.1	708.9	63.46
ADFI (g)	2,048.3	2,245.1	2,207.4	2,174.0	2,257.4	151.8
Feed/gain	2.81	3.14	2.97	3.00	3.18	0.16
Finisher phase (8-11 weeks)						
ADG (g)	953.8	947.6	1,013.8	935.7	924.3	37.47
ADFI (g)	2,877.1	2,997.1	3,058.6	3,029.1	2,898.6	92.47
Feed/gain	3.02^{b}	3.16^{ab}	3.02^{b}	3.24^{a}	3.14^{ab}	0.06
Overall (0-11 weeks)						
ADG (g)	777.9	805.7	808.4	794.8	793.9	34.99
ADFI (g)	2,179.0	2,373.3	2,316.0	2,329.5	2,331.8	92.16
Feed/gain	2.80^{b}	2.95^{a}	2.86^{ab}	2.93^{a}	2.94^{a}	0.03

[1] Control, 3% FM; Control+3% FM, 3% FM+pyridoxin; Control+3% FM+pyridoxin 10 ppm, 6% FM; Control+6% FM, 6% FM+ pyridoxin; Control+6% FM+pyridoxin 10 ppm.

[a,b] Value with different superscripts in the same row are different ($p<0.05$).

Table 3. Effects of diets supplemented with feather meal on back-fat thickness and carcass grade of pigs

Items	Treatments					SEM
	Control	3% FM	3% FM+pyridoxin	6% FM	6% FM+pyridoxin	
Backfat Thickness (mm)	20.8[b]	22.8[ab]	22.1[ab]	24.3[ab]	25.4[a]	1.27
Carcass grade[1]	1.75	1.75	2.08	1.50	2.25	0.30

[1] Based on scale with 1 = grade A, 2 = grade B, 3 = grade C, 4 = grade D.
[a-b] Values with different superscripts in the same row are different ($p<0.05$).

difference was insignificant. The amount of ADFI was significantly higher in the 3% FM group than in the control group ($p<0.05$). Over the entire period of experiment, ADG and ADFI were higher in the FM-supplemented groups than in the control group but the difference was insignificant. The feed/gain ratio was significantly higher in the FM-supplemented groups than in the control group ($p<0.05$).

According to Smith (1968), the bioavailability of amino acids contained in FM was considerably lower than those of fish meal and soybean meal. In particular, the bioavailability of histidine (0.0%) and lysine (5.3%) in FM was so low that they resulted in degradation of the nutrient value of FM. It is considered that the FM-supplemented groups showed a higher tendency in ADFI and feed conversion ratio than the control group in the present experiment because of the low bioavailability of FM, the poor composition of amino acids in FM and improper calorie/CP due to the simple supplementation of 3% and 6% feather meal.

It is possible to expect that cystein in FM will exert influence on growth by converting into taurine in the body, but according to reports by many researchers, taurine is considered to have an effect on the initial stage of growth. Taurine is reported to play an important role in the growth of neonates (Hayes and Sturman, 1981; Sturman, 1982; Hayes, 1985) and there is also a report that if neonates are not supplied with taurine from outside, they are retarded in growth (Hayes, 1985). Davis and Himwich (1973) reported that taurine concentration in the brain was the highest in the development period of a brain and begins to fall with growth and it was observed commonly in men (Lefauconnier et al., 1976), monkeys (Raizada et al., 1982), mice (Kantro et al., 1984), rabbits (Chandra and Himwich, 1970) and rats (Lieu et al., 1992).

In addition, as the taurine biosynthesis ability varies according to the activities of CD (cysteine dioxygenase) and CSAD (cysteine sulfinic acid decarboxylase) which are two enzymes catalyzing the formation of CSA (cysteine sulfinic acid) according to animal species, growth stage, protein and sulfur-containing amino acid content in diets, it is considered that the addition of feather meal in the grow-finisher phase and finisher phase did not have an effect on the growth rate.

Backfat thickness and pork carcass grading according to FM supplementation

Backfat thickness and pork carcass grade are shown in Table 3. Backfat thickness increased significantly in the FM-supplemented groups than in the control group ($p<0.05$) but no significant differences were shown in pork carcass grading among them. Although it is difficult to logically explain why backfat thickness was increased by FM supplementation, low calorie/CP ratio may be one of the reasons of the present result.

Taurine contents in pork

Taurine contents in hearts, livers, tenderloins, hams and loins according to the level of feather meal supplemented in feed are shown in Table 4. In the control group, taurine content was high in the order of 1,893.8 ppm for heart, 647.3 ppm for liver, 601.2 ppm for tenderloin, 462.4 ppm for ham and 375.8 ppm for loin. Taurine contents showed a significant difference between the treatment groups ($p<0.05$) in the heart, tenderloin, ham and loin but no significant difference in the liver. Taurine content in the heart, tenderloin, ham and loin of the 6% FM-pyridoxin

Table 4. Taurine content in organs and muscles of pigs fed feather meal supplemented diets

Items	Treatments					SEM
	Control	3% FM	3% FM+pyridoxin	6% FM	6% FM+pyridoxin	
	wet tissue (ppm)					
Heart	1,393.8[c]	1,705.9[bc]	2,056.1[b]	2,596.4[a]	2,667.1[a]	129.60
Liver	647.3	781.5	762.0	833.8	859.8	74.91
Tenderloin	601.2[c]	654.8[b]	659.9[b]	728.8[a]	742.2[a]	18.69
Ham	462.4[b]	570.0[ab]	580.4[ab]	561.4[ab]	588.4[a]	38.55
Loin	375.8[b]	417.9[ab]	428.1[ab]	463.5[ab]	483.4[a]	31.15

[a-c] Values with different superscripts in the same row are different ($p<0.05$).

Table 5. Sensory evaluation[1] for acceptability of porks produced by feeding feather meal supplemented diets

Treatments	Barrow		Gilt	
	Loin	Bacon	Loin	Bacon
Control	3.01	2.93	2.75	2.98
3% FM	2.69	2.81	2.88	2.48
3% FM+pyridoxin	2.48	2.88	2.88	2.37
6% FM	2.48	3.17	2.60	3.00
6% FM+pyridoxin	2.54	3.11	2.35	2.73
Mean	2.638	2.977	2.688	2.710
SEM	0.175	0.263	0.167	0.137

Effect of sex (barrow vs. gilt) $p<0.388$. Effect of part (loin vs. bacon) $p<0.148$.
[1] Scale from 1 (poor) to 5 (excellent).

treatment group increased by 91%, 23%, 27% and 29%, respectively when compared with those of the control group. In particular, the increase of taurine content in the heart according to FM supplementation was different from the results of broiler experiment by Lee et al. (2004). In other words, FM-pyridoxin supplementation does not have an effect on the taurine content of heart muscle in broiler meat but it impacts greatly on the taurine content of heart muscle in pigs. Efforts should be made to experiment and clarify the biological significance of this species difference.

Taurine biosynthesis in tissues is derived via the trans-sulfuration pathway and it is a final product of sulfur-containing amino acids. The major pathway is cystine oxidization into cysteine sulfinic acid - decarbonization into hypotaurine - oxidization into taurine. Here, CSAD is an important enzyme, which relies greatly on the coenzyme, pyridoxin together with cystathione synthase, cystathionase, cysteine dioxygenase which are important for sulfur-containing amino acid metabolism. Therefore, pyridoxin deficiency is related with taurine synthesis.

This synthetic system is the major pathway in the liver and brain of many animals but in men, it is not developed so much in premature babies and new-born babies that taurine synthesis is restricted in new-born babies. CD and CSAD, the key enzymes for taurine biosynthesis differ in the ability of taurine biosynthesis according to body tissues or animal species. As CSAD, in particular, is extremely low in the monkey and cat families including men than in rats or dogs, it is reported that taurine biosynthetic ability in these animals are very restricted (Worden and Stipanuk, 1985; Champman and Greenwood, 1988).

When combining all these findings, the dietary supplementation of FM in the grow-finisher phase or finisher phase does not have a significant effect on pig performance but it is considered to increase taurine content in pork significantly.

Sensory evaluation

The results of sensory test are as shown in Table 5. Acceptability was not significantly different among supplementation levels of FM and pyridoxine. Also, there were no significant differences between sex (barrow vs. gilt) or parts (loin vs. bacon).

IMPLICATIONS

As taurine has many important functions, taurine-enriched pork will be viable as a functional animal food. The production of taurine-enriched pork can be produced by supplementing FM, a rich source of cystine, and coenzyme pyridoxine. The result of the experiment showed that taurine content in the heart, tenderloin, ham and loin of the 6% FM-pyridoxin group increased by 91%, 23%, 27% and 29%, respectively when compared with those of the control group. As there were no significant differences among treatment groups in sensory test, it is considered that FM and pyridoxin supplementation does not influence the acceptability of pork. This experiment implicates that supplementation of FM and pyridoxin to pig diet is expected to produce taurine-enriched pork.

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