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Effects of Lacquer (*Rhus verniciflua*) Meal on Carcass Traits, Fatty Acid Composition and Meat Quality of Finishing Pigs

C. H. Song, J. Y. Choi, S. Y. Yoon, Y. X. Yang, P. L. Shinde, I. K. Kwon[1]
S. M. Kang[1], S. K. Lee[1] and B. J. Chae*
Department of Animal Resources Science, College of Animal Life Sciences,
Kangwon National University, Chuncheon 200-701, Korea

ABSTRACT : This experiment was conducted to evaluate the effects of feeding different levels of lacquer (*Rhus verniciflua* Stokes) meal on the growth performance, carcass traits, fatty acid profile and meat quality of *longissmuss dorsi* (LD) muscle in finishing pigs. Pigs (n = 117; Landrace×Yorkshire×Duroc; initial body weight 80±0.4 kg) were allotted to three dietary treatments and fed lacquer at 0, 2 and 4% of the diet for five weeks. Inclusion of lacquer meal in the diets of pigs had no influence on their growth performance, carcass yield, loin eye area and fat free lean; however, pigs fed lacquer diets had lower backfat (linear, p = 0.006; quadratic, p = 0.004). Pigs fed increasing levels of lacquer meal had lower moisture (linear, p<0.001; quadratic, p = 0.008), crude fat (linear, p<0.001) and crude protein (linear, p<0.001; quadratic, p = 0.002) in LD muscle. The LD muscle of pigs fed lacquer meal had lower pH (linear and quadratic, p<0.05) at 6, 8 and 10 days, and linearly lower thio-barbituric acid reactive substances (TBARS, p<0.01) at 8 and 10 days and water holding capacity (WHC, p<0.05) at 3, 6, 8 and 10 days. The fatty acid composition of LD muscle revealed linearly lower stearic (p = 0.034) and total saturated fatty acid (p = 0.049) with increasing dietary lacquer meal levels. In general, higher lightness, redness and yellowness values were observed in LD muscle of pigs fed 2% lacquer meal on day 0 and subsequently on 3, 6, 8 and 10 days of refrigerated storage. The results of the current study suggest that lacquer meal can be incorporated up to 4% in the diet of finishing pigs without any adverse effects on performance; moreover, improvements in the meat quality during refrigerated storage can be obtained by inclusion of lacquer meal in the diet of finishing pigs. (**Key Words :** Carcass Traits, Fatty Acids Profile, Growth Performance, Lacquer (*Rhus verniciflua* Stokes) Meal, Meat Quality, Finishing Pigs)

INTRODUCTION

Lacquer (*Rhus verniciflua*) belongs to Anacardiaceae family and it grows widely in Asian countries. Traditionally lacquer has been used as medicine (Lee et al., 2003) for the treatment of gastritis, stomach cancer and arteriosclerosis (Jung, 1998) and for the protection of antiquities (Kim, 1996) in Japan, China and Korea for thousands of years. The sap of lacquer tree is composed of urushiol (60-65%), glycoprotein (2.1-1.8%), flavonoids (1-2%), gummy substance (6-7%) which contains laccase (0.24%), stellacyanin, polysaccharides, peroxidase and water (Yang et al., 2002). The sap contains three different molecules with laccase enzyme activity and each enzyme has four copper atoms per molecule (Wan et al., 2006).

The stem bark of *Rhus* contains high levels of urushiols, which are responsible for allergic reactions, but its heartwood is devoid of urushiols, and hence this part is being used as a tonic against cancer and for removing the intoxication of smoking or lingering (Park et al., 2004). The ethanol extract of *Rhus verniciflua* Stokes (RVS) had antioxidant effect against hydroxyl radicals (Lee et al., 2001), antiproliferative activity against human cancer cell lines (Kitts and Lim, 2001) and augmented the activity of cell-associated detoxifying enzymes in hepatocytes (Lim et al., 2000).

Improvements in the quality and extended storage life of meat obtained from Hanwoo cattle fed with RVS were reported by Kim et al. (2006). Lacquer supplementation in the diet of broilers had no effect on growth performance, but had a positive impact on fat metabolism by improved

* Corresponding Author: B. J. Chae. Tel: +82-33-250-8616, Fax: +82-33-244-4946, E-mail: bjchae@kangwon.ac.kr
[1] Department of Animal Product and Food Science, College of Animal Life Sciences, Kangwon National University, Chuncheon 200-701, Korea.
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Table 1. Ingredient and chemical composition of experimental diets

Ingredient (%)	Lacquer meal (%)		
	0	2	4
Corn	66.24	62.46	58.27
Ricebran	5.00	5.00	5.00
Dehulled-SBM	20.20	20.90	21.60
Animal fat	2.00	3.40	4.90
Molasses	3.80	3.50	3.50
L-lysine HCl (78%)	0.18	0.16	0.15
DL-methionine (100%)	0.02	0.02	0.03
Choline chloride (25%)	0.04	0.04	0.04
Bactacid	0.10	0.10	0.10
DCP	0.90	0.90	0.91
Limestone	0.80	0.80	0.78
Salt	0.30	0.30	0.30
Mineral premix[1]	0.20	0.20	0.20
Vitamin premix[2]	0.12	0.12	0.12
Probiotic	0.10	0.10	0.10
Lacquer meal[3]	0.00	2.00	4.00
Calculated composition			
ME (kcal/kg)	3,300	3,300	3,300
Crude protein (%)	16.00	16.00	16.00
Lysine (%)	0.95	0.95	0.95
Calcium (%)	0.60	0.60	0.60
Av. phosphorus (%)	0.25	0.25	0.25

[1] Mineral premix supplied per kg diet: 150 mg Fe, 96 mg Cu, 72 mg Zn, 46.5 mg Mn, 0.9 mg I, 0.9 mg Co, 0.3 mg Se.

[2] Vitamin premix supplied per kg diet: 8,000 IU vitamin A, 1,500 IU vitamin D_3, 16 mg vitamin E, 1.0 mg vitamin B_1, 8.0 mg vitamin B_2, 1.6 mg vitamin B_6, 0.03 mg vitamin B_{12}, 1.0 mg vitamin K_3, 16 mg pantothenic acid, 30 mg niacin, 0.06 mg biotin, 0.26 mg folic acid.

[3] Analyzed chemical composition of lacquer meal (as-fed basis): 18.56% moisture, 1.15% crude protein, 4.28% crude fat, 1.55% ash.

fat digestibility and reduced serum cholesterol and triglyceride (Lohakare et al., 2006). However, there is no information on the use of lacquer meal in the diet of pigs. Thus we hypothesized that lacquer meal added to the diet of finishing pigs might affect its carcass and meat quality traits. Hence, the present study was conducted to evaluate the effects of incorporating different levels of lacquer meal in the diet on the performance, carcass characteristics, fatty acid composition and meat quality during refrigerated storage in finishing pigs.

MATERIALS AND METHODS

Lacquer meal

Lacquer meal was obtained from Gapyeong Livestock Company, Gapyeong-gun, Gyeonggi-do, Korea. The stem bark and heartwood of lacquer tree were sun-dried and then processed to sawdust by an electrical mill. This sawdust was then passed through 2-3 mm mesh-screen and the lacquer meal was obtained and added to the diet of finishing pigs.

Animals, their diets and management

In this study, 117 pigs (Landrace×Yorkshire×Duroc; 80 ±0.4 kg average initial body weight) of mixed sex (63 males and 54 females) were randomly allotted to nine pens (comprising 13 pigs per pen; 7 males and 6 females), on the basis of their body weight and sex. Pens were randomly allotted to one of the following dietary treatments: (1) Control (0% lacquer meal), (2) 2% lacquer meal (by weight) and (3) 4% lacquer meal. The experimental feeding was conducted for 5 weeks. Iso-energetic and iso-nitrogenous diets were formulated to contain 3,300 kcal/kg ME and 0.95% lysine (Table 1). All the diets met or exceeded the nutrient requirements as suggested by NRC (1998).

Pigs were housed in partially slotted and concrete floor pens having a pen size of 3.50 m×3.50 m, that were equipped with a self-feeder and nipple waterer to allow *ad libitum* access to feed and water. The study underwent proper ethical standards and was approved by the Institutional Animal Care and Use Committee of Kangwon National University.

Experimental procedures and measurements

Individual pig weight and feed consumption per pen were measured to calculate the average daily gain (ADG), average daily feed intake (ADFI) and feed:gain ratio (F/G) during the experimental period. At the end of the experimental feeding, six pigs (3 males and females, respectively) from each pen reflecting average body weights were slaughtered by electrical stunning and exsanguination at a commercial slaughter house. The carcass traits were obtained from the left side of the carcass after a 24 h chill at 4°C. Hot carcass weight was collected for determination of dressing percentage, and conventional carcass measurements (loin eye area and backfat thickness). Dressing percentage was determined by the following equation: (hot carcass weight/ final live weight)×100. Loin eye area was determined by tracing the longissimus muscle surface area at the 10th rib and by using a compensating polar planimeter. Backfat thickness was determined by measuring the fat thickness at the 10th rib, three-quarters of the lateral length of the longissimus muscle perpendicular to the outer skin surface. Fat free lean percent was estimated using NPPC (1991) equation.

After 24 h chilling of carcass at 4°C, the right *longissmuss dorsi* (LD) muscle was removed and brought to the laboratory to determine the chemical composition, meat quality and fatty acid composition. In the laboratory the LD muscle were trimmed of fat and then sectioned into 2.54 cm chops and packed using polyethylene wrap film (oxygen transmission rate 35.723 cc/m^2·atm, thickness 0.01 mm, 3M Co., Korea). The loins for the analysis of chemical and fatty acid composition were stored at -30°C, while those to be

Table 2. Effect of lacquer meal on performance, carcass characteristics and chemical composition of LD muscle in finishing pigs

Items	Lacquer meal (%)			SEM[1]	p-value[2]	
	0	2	4		Linear	Quadratic
Growth performance						
ADG (g)	626	619	622	23.59	NS[3]	NS
ADFI (g)	2,338	2,246	2,253	35.07	NS	NS
F/G	3.74	3.72	3.64	0.14	NS	NS
Carcass characteristics						
Carcass yield (%)	77.55	78.17	78.80	0.44	NS	NS
Backfat thickness (mm)	24.08	22.17	21.75	0.36	0.006	0.004
Loin eye area (cm^2)	50.56	51.50	51.63	0.23	NS	NS
Fat free lean (%)	57.73	58.44	58.73	0.16	NS	NS
Chemical composition of LD						
Moisture	73.51	74.10	74.12	0.089	<0.001	0.008
Crude protein	23.71	23.05	23.15	0.096	<0.001	0.002
Crude fat	2.70	1.99	1.93	0.137	<0.001	NS
Crude ash	1.07	1.06	1.00	0.011	NS	NS

[1] Standard error of means. [2] Significance of linear and quadratic effects of increasing lacquer meal levels in diet. [3] Not significant (p>0.05).

used for the analysis of meat quality and objective color score were subjected to refrigerated storage at 3±1°C for 3, 6, 8 and 10 days. Also a section of loins were utilized for the analysis of meat quality (pH, TBARS and WHC) and color scores to obtain 0 day values (24 h postmortem).

Minolta CR-310 (Yasuda Seiko Co., Japan) was used to determine the objective color score in terms of lightness (L*), redness (a*) and yellowness (b*) at day 0, 3, 6, 8 and 10 days of refrigerated storage (Park et al., 2007). The surface color of loins was measured through the packaging film following calibration against a white tile covered with the same film. Individual packages were used for repeated measurements and remained intact during the entire storage period. The pH was determined by using a pH meter (F-12, Horiba, Japan). The WHC was measured by the filter-paper press method of Grau and Hamm (1953), while the TBARS assay was performed as described by Sinnhuber and Yu (1977).

Fatty acid composition

Total fat for fatty acid analysis was extracted according to the method of Folch et al. (1957). All samples were then methylated in the presence of sodium methylate (2 N) and 25% boron trifluoride according to the procedure of AOAC (1995). Fatty acid methyl esters were separated and quantified using an Agilent 6890N gas chromatograph (Agilent Technologies, USA) equipped with a flame ionisation detector.

The column used for separation of fatty acid methyl esters was a HP-Innowax column (30 m length×0.32 mm i.d. ×0.25 μm film thickness). Helium was used as carrier gas at a pressure of 30 psi. The oven temperature was initially held at 150°C for 1 min then increased at 3°C/min to 250°C and held for 5 min. The injector (split mode) and detector temperatures were maintained at 260 and 280°C, respectively. Methyl esters were identified by comparison with the retention times of pure standards and reported as percentage of total fatty acids.

Chemical analyses

Representative samples of lacquer meal and LD muscle (minced samples) in triplicates were analyzed by proximate analysis for moisture, crude protein, crude fat, and ash according to AOAC (2000) methods.

Statistical analyses

The data generated was analyzed as randomized complete block using the general linear model procedure of SAS (SAS Inst., Inc., Cary, NC). The treatments were the main effects. Pen was the experimental unit for statistical analysis. The initial and final weights were included in the model as covariates for growth performance data, whereas the final weight was used as a covariate for carcass traits. Orthogonal polynoms were used to evaluate the effect of increasing lacquer meal levels in the diet of finishing pigs. All statements of significance were based on probability $p<0.05$.

RESULTS AND DISCUSSION

Performance, carcass characteristics and chemical composition of LD muscle

There were no differences (p>0.05) in the growth performance when compared among Control and lacquer meal fed pigs (Table 2). These results are consistent with those of Lohakare et al. (2006), who failed to observe any improvements in the growth performance of broilers fed with 2 or 4% lacquer diets. Our findings demonstrate that addition of lacquer meal in the diets of finishing pigs had no detrimental effect and the palatability of diets was comparable with Control diet as there were no differences in the feed intake.

Table 3. Effect of lacquer meal on meat quality during refrigerated storage

Item	Days of storage	Lacquer meal (%)			SEM[1]	P-value[2]	
		0	2	4		Linear	Quadratic
pH	0	5.53	5.53	5.50	0.025	NS[3]	NS
	3	5.59	5.40	5.46	0.035	NS	NS
	6	5.57	5.36	5.41	0.036	0.024	0.029
	8	5.58	5.35	5.39	0.038	<0.001	0.004
	10	5.62	5.35	5.41	0.048	0.028	0.040
TBARS	0	0.13	0.13	0.12	0.005	NS	NS
	3	0.16	0.16	0.14	0.005	NS	NS
	6	0.21	0.19	0.19	0.006	NS	NS
	8	0.26	0.22	0.21	0.008	0.006	NS
	10	0.33	0.26	0.25	0.010	<0.001	NS
WHC	0	39.76	38.97	37.29	0.417	NS	NS
	3	41.83	40.62	39.92	0.361	0.025	NS
	6	50.35	46.33	43.12	1.072	<0.001	NS
	8	55.20	51.19	46.48	1.311	<0.001	NS
	10	59.33	54.28	49.31	1.484	<0.001	NS

[1] Standard error of means. [2] Significance of linear and quadratic effects of increasing lacquer meal levels in diet. [3] Not significant (p>0.05).

The backfat thickness was decreased (linear, p = 0.006; quadratic, p = 0.004) as the level of lacquer meal in the diet was increased; while, carcass yield, loin eye area and fat free lean remained unaffected (Table 2). In line with our findings, Kim et al. (2006) had also noted reductions in the lipid content in longissimus muscle obtained from Hanwoo cattle that were fed diets containing 6% lacquer meal. However, Lohakare et al. (2006) did not observe any changes in the carcass characteristics of broilers fed with lacquer diets, although they had reported non-significant reduction in the abdominal fat.

The compositional analysis of LD muscle revealed an increase in the moisture contents (linear, p<0.001; quadratic, p = 0.008) and decrease in the crude protein (linear, p<0.001; quadratic, p = 0.002) and crude fat (linear, p<0.001) contents in LD muscle of pigs fed with lacquer meal, while no differences were observed in the crude ash contents of LD muscle (Table 2). The lipid content in the longissimus muscle of Hanwoo cattle fed 6% lacquer diet was lower than those fed with Control diets (Kim et al., 2006). These results suggest that addition of lacquer meal was effective in lowering the lipids in muscle. The effects towards lowering backfat thickness and fat content in the LD muscle of lacquer meal added diets might be due to the flavonoid content of these diets. Lee et al. (2002) purified the fraction of ethanol extract of RVS and identified the existence of flavonoid derivatives. Supplementation with flavonoid to the diets resulted in reduced plasma total cholesterol possibly either by inhibition of HMG-CoA reductase activity or increased excretion of fecal bile acid and cholesterol (Yang and Koo, 2000; Zou et al., 2005).

Meat quality and muscle color

Poor color and inadequate WHC were the main quality concerns identified by all members of the pork marketing chain (Cannon et al., 1996). Many factors affect the quality of meat such as genetics, farm handling, slaughter techniques and nutrition. Lipid oxidation is a major cause of deterioration in the quality of muscle foods and can directly affect quality characteristics such as flavor, color, texture, nutritive value and safety of the food (Buckley et al., 1995).

Normally, pH declines gradually from 7.4 in living muscle to roughly 5.6-5.7 within 6-8 h of postmortem and then has an ultimate pH at 24 h of about 5.3-5.7 (Briskey and Wismer-Pedersen, 1961). In our study the 0 day (24 h postmortem) pH values were around 5.5 and were well within the suggested range. The pH values of LD muscle of pigs fed lacquer meal showed no differences at 0 day (24 hours postmortem) and 3 days of refrigerated storage; however, the pH values on day 6, 8 and 10 of refrigerated storage were decreased (linear and quadratic, p<0.05) with an increase in dietary lacquer meal inclusion (Table 3).

The TBARS values of loins showed no differences up to 6 days of refrigerated storage, but on 8 and 10 day of storage, loins from pigs fed with lacquer meal diets showed linearly (p<0.01) lower TBARS values (Table 3). The WHC of loins obtained from finishing pigs fed lacquer meal diets was also linearly lower during 3, 6, 8 and 10 days of refrigerated storage at 3±1°C (Table 3). Similar reductions in the TBARS values during refrigerated storage were reported by Kim et al. (2006) in longissimus muscle of Hanwoo cattle. Thus our results suggest that incorporation of lacquer meal in the diets of finishing pigs improves the meat quality during refrigerated storage at 3±1°C by reducing the pH, lipid oxidation and WHC. A lower pH denatures myofibrillar proteins and consequently, they bind less water (Hamm, 1986). The decreasing pH of loins in pigs fed lacquer diets might partially explain the lower WHC values.

Table 4. Effect of lacquer meal on the color scores of LD muscle during refrigerated storage

Item	Days of storage	Lacquer meal (%)			SEM[1]	p-value[2]	
		0	2	4		Linear	Quadratic
L*	0	54.86	57.17	52.91	0.593	NS[3]	0.005
(Lightness)	3	54.68	58.96	54.11	0.186	NS	NS
	6	55.71	59.68	53.32	0.680	0.001	0.047
	8	55.74	59.97	53.18	0.341	<0.001	0.026
	10	56.26	60.15	54.20	0.667	NS	0.001
a*	0	5.82	7.89	6.32	0.241	NS	0.001
(Redness)	3	6.49	8.00	6.66	0.167	NS	NS
	6	6.15	7.52	6.43	0.22	NS	NS
	8	6.42	6.98	6.23	0.178	NS	NS
	10	4.83	6.26	2.98	0.667	<0.001	<0.001
B*	0	5.70	7.40	5.44	0.246	NS	<0.001
(Yellowness)	3	6.11	7.82	6.33	0.117	NS	NS
	6	6.99	8.31	6.44	0.131	NS	<0.001
	8	6.86	8.29	6.36	0.139	NS	NS
	10	6.65	8.12	5.69	0.287	NS	<0.001

[1] Standard error of means. [2] Significance of linear and quadratic effects of increasing lacquer meal levels in diet. [3] Not significant (p>0.05).

The objective color score of loins is presented is Table 4. Loins obtained from pigs fed with 2% lacquer meal diets were lighter on 0 day (quadratic, p<0.01), and also on 6, 8 and 10 days of refrigerated storage as evidenced by higher L* values. Chops from loins of pigs fed 2% lacquer meal diets were also redder at day 0 (p<0.001) and 10 (linear and quadratic; p<0.001). Similarly, the loins from pigs fed 2% lacquer meal diets were more yellow (p<0.001) at 0, 6 and 10 days of refrigerated storage. In contradiction with the findings of our study, Lokakare et al. (2006) did not notice any changes in the subjective color scores of L*, a* and b* in the breast meat of broilers at 3 and 5 weeks of storage. The loss of redness of meat during storage is caused by oxidation of the bright pinkish-red oxymyoglobin to the brown metmyoglobin. Improved oxidative stability may reduce the rate of that oxidation and preserve the red color for a longer time during storage.

Various researchers have screened the antioxidant activity of *Rhus verniciflua* Stokes by using different solvent extractions. Free phenolic acid fraction (200 ppm) of chloroform extracts from 75% ethanol extract of *Rhus verniciflua* Stoke (RVS) was reported to have strong antioxidant activity and the major active components were found to be gallic acid, butin, and butein (Kim et al., 1999), while Park et al. (2002) had observed ethanol extracts of *Rhus verniciflua* Stoke to have strong antioxidant properties on Yukwa base during storage. The crude ethanol extract from RVS was also found to have inhibitory effects against oxidation of cholesterol and CT-26-induced tumor growth, as well as scavenging ability against reactive oxidants in chemical reaction assay (Lee et al., 1999). The enzyme laccase (benzenediol: oxidoreductase, EC 1.10.3.2) that is present in the sap of lacquer is a copper containing enzyme. Laccase has an affinity to catalyse the reduction of molecular oxygen, and the affinity of strong oxidation directly producing water without hydrogen peroxide as an intermediate of the reaction (Yaropolov et al., 1994). Darker and less yellow loins from pigs fed lacquer meal might also be related to the antioxidant component flavonoid present in lacquer meal. In line with the findings of the present study, significant improvements in a* and lower L* values have been reported in pigs supplemented with α-tocopherol (Dirinck et al., 1996; Mason et al., 2005), whereby suggesting that antioxidants might influence the meat color. Larrain et al. (2008) had also noticed alterations in the time course changes of color measurements in bacon of pigs fed flavonoid rich cranberry diet.

Fatty acid composition

The palmitic acid concentration was found to be lowest (p<0.01) in loins of pigs fed 2% lacquer meal, while there was a linear decrease in the concentrations of stearic acid (p<0.05) and total saturated fatty acid (p<0.05) with an increase in the level of lacquer meal in the diet of finishing pigs (Table 5). However, no differences (p>0.05) in the concentrations of other fatty acids, total mono-unsaturated, unsaturated and MUFA/SFA ratio among dietary lacquer treatments were noted. The reductions in the levels of stearic, palmitic and total saturated fatty acids in our study agree with the findings of Kim et al. (2006). However, Kim et al. (2006) had also reported significantly higher proportions of monounsaturated (C18:1), polyunsaturated fatty acid and ratio of monounsaturated: saturated fatty acids in the meat of lacquer supplemented Hanwoo cattle which differed from the findings of the present study. Yang et al. (2007) had observed decreased palmitoleic acid and increased arachidonic acid in the yolk of layers fed with 1.5 and 3% lacquer meal, while layers fed with 1.5% lacquer meal had higher linolenic and linolenic acid in their yolk. These discrepancies in the findings of fatty acid may be

Table 5. Effect of lacquer meal on the fatty acid composition of LD muscle

Fatty acid (%)	Lacquer meal (%)			SEM[1]	p-value[2]	
	0	2	4		Linear	Quadratic
Myristic acid (C14:0)	1.50	1.48	1.55	0.035	NS[3]	NS
Palmitic acid (C16:0)	23.16	21.82	22.84	0.226	NS	0.003
Palmitoleic acid (C16:1)	4.16	4.09	3.97	0.102	NS	NS
Stearic acid (C18:0)	8.49	7.83	7.26	0.232	0.034	NS
Oleic acid (C18:1)	48.05	49.39	49.41	0.905	NS	NS
Linoleic acid (C18:2)	11.93	12.68	12.38	0.530	NS	NS
Linolenic acid (C18:3)	0.51	0.61	0.50	0.029	NS	NS
Gondoic acid (C20:1)	0.08	0.15	0.07	0.021	NS	NS
Arachidonic acid (C20:4)	1.89	1.95	2.02	0.055	NS	NS
Saturated fatty acid (SFA)	33.15	31.13	31.65	0.369	0.049	NS
Mono-unsaturated fatty acid (MUFA)	52.30	53.63	53.45	0.852	NS	NS
Polyunsaturated fatty acid	14.34	15.24	14.90	0.532	NS	NS
MUFA/SFA	1.58	1.72	1.69	0.065	NS	NS

[1] Standard error of means. [2] Significance of linear and quadratic effects of increasing lacquer meal levels in diet. [3] Not significant (p>0.05).

attributed to species differences.

Conclusively, the results of our study suggest that lacquer meal can be incorporated up to 4% in the diet of finishing pigs without any adverse effects on performance; moreover, reductions in backfat and improvements in the meat quality during refrigerated storage can be obtained by inclusion of lacquer meal in the diet of finishing pigs.

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REFERENCES

AOAC. 1995. Official methods of analysis (15th ed.). Association of Official Analytical Chemists. Arlington, VA.

AOAC. 2000. Official Methods of Analysis. (17th ed.). Association of Official Analytical Chemists. Arlington, VA.

Briskey, E. J. and J. Wismer-Pedersen. 1961. Biochemistry of pork muscle structure. I. Rate of anaerobic glycolysis and temperature change versus the apparent structure of muscle tissue. J. Food Sci. 26:297-305.

Buckley, D. J., P. A. Morrissey and J. I. Gray. 1995. Influence of dietary vitamin E on the oxidative stability and quality of pig meat. J. Anim. Sci. 71:3122-3130.

Cannon, J. E., J. B. Morgan, F. K. McKeith, G. C. Smith, S. Sonka, J. Heavner and D. L. Meeker. 1996. Pork chain quality audit packer survey: Quantification of pork quality characteristics. J. Muscle Foods 7:29-44.

Dirinck, P., A. De Winne, M. Casteels and M. Frigg. 1996. Studies on vitamin E and meat quality. 1. Effect of feeding high vitamin E levels on time related pork quality. J. Agri. Food Chem. 44:65-68.

Folch, J. M., M. Lee and G. H. Sloan. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497-509.

Grau, R. and R. Hamm. 1953. Eine einfache methode zur bestimmung der wasserbindung in muskel. Naturwissenschaften 40:29-30.

Hamm, R. 1986. Current problems in meat research. Fleischwirtschaft 66:1772-1776.

Jung, N. C. 1998. Biological activity of urushiol and flavanoids from Lac tree (*Rhus verniciflua* Stokes). Ph.D. Thesis, Chonnam National University, Kwang-Ju, South Korea.

Kim, I. W., D. H. Shin and N. I. Baek. 1999. Identification of antioxidative components from ethanol extract of *Rhus verniciflua* Stoke. Kor. J. Food Sci. Technol. 31:1654-1660.

Kim, T. J. 1996. Korean Resource Plants, Vol. II. Seoul National University Press, Seoul, Korea. pp. 292-297.

Kim, Y. S., C. Y. Liang, Y. H. Song and S. K. Lee. 2006. Effects of dietary *Rhus verniciflua* Stokes supplementation on meat quality characteristics of Hanwoo (Korean cattle) beef during refrigerated storage. Asian-Aust. J. Anim. Sci. 19:113-118.

Kitts, D. D. and K. T. Lim. 2001. Antitumorigenic and cytotoxic properties of an ethanol extract derived from *Rhus verniciflua* Stokes (RVS). J. Toxicol. Environ. Health Part A. 64:357-371.

Larrain, R. E., C. G. Krueger, M. P. Richards and J. D. Reed. 2008. Color changes and lipid oxidation in pork products made from pigs fed with cranberry juice powder. J. Muscle Foods 19:17-33.

Lee, J. C., H. Y. Jung and K. T. Lim. 1999. Effects of *Rhus verniciflua* Stoke (RVS) on the plasma level of cholesterol and tumor growth in mouse. J. Toxicol. Pub. Health. 15:169-175.

Lee, J. C., J. Kim and Y. S. Jang. 2003. Ethanol eluted extract of *Rhus verniciflua* Stokes inhibits cell growth and induces apotosis in human lymphoma cells. J. Biochem. Mol. Bio. 36:337-343.

Lee, J. C., J. Kim, K. T. Lim, M. S. Yang and Y. S. Jang. 2001. Ethanol eluted extract of *Rhus verniciflua* Stokes showed both antioxidant and cytotoxic effects on mouse thrombocytes depending on the dose and time of the treatment. J. Biochem. Mol. Bio. 34:250-258.

Lee, J. C., K. T. Lim and Y. S. Jang. 2002. Identification of *Rhus verniciflua* Stokes compounds that exhibit free radical scavenging and anti-apoptotic properties. Biochim. Biophys. Acta. 1570:181-191.

Lim, K. T., J. C. Lee, H. Y. Jung and S. K. Jo. 2000. Effects of

Rhus verniciflua Stokes (RVS) on cell associated detoxificant enzymes and glucose oxidase-mediated toxicity in cultured mouse hepatocytes. J. Toxicol. Pub. Health. 16:125-131.

Lohakare, J. D., J. Zheng, J. H. Yun and B. J. Chae. 2006. Effects of lacquer (*Rhus verniciflua*) supplementation on growth performance, nutrient digestibility, carcass traits and serum profile of broiler chickens. Asian-Aust. J. Anim. Sci. 19:418-424.

Mason, L. M., S. A. Hogan, A. Lynch, K. O. Sullivan, P. G. Lawlor and J. P. Kerry. 2005. Effects of restricted feeding and antioxidant supplementation on pig performance and quality characteristics of longissimus dorsi muscle from Landrace and Duroc pigs. Meat Sci. 70:307-317.

NPPC. 1991. Procedures to evaluate market hogs (3rd ed.). National Pork Producers Council, Des Moines, IA, USA.

NRC. 1998. Nutrient Requirements of Swine. (10^{th} ed.) National Academy Press, Washington, DC.

Park, B. Y., J. M. Lee and I. H. Hwang. 2007. Effect of postmortem metabolic rate on meat color. Asian-Aust. J. Anim. Sci. 20:598-604.

Park, K. Y., G. O. Jung, K. T. Lee, J. W. Choi, M. Y. Choi, H. J. Kim and H. J. Park.. 2004. Antimutagenic activity of flavonoids from the heartwood of *Rhus verniciflua*. J. Ethanopharmacol. 90:73-79.

Park, Y. S., Y. S. Kim and D. H. Shin. 2002. Antioxidative effects of ethanol extracts from *Rhus verniciflua* Stoke on Yukwa (oil popped rice snack) base during storage. J. Food Sci. 67:2474-2479.

Sinnhuber, R. O. and T. C. Yu. 1977. The 2-thiobarbituric acid reaction, an objective measure of the oxidative determination occurring in fats and oils. J. Jan. Soc. Fish Sci. 26:259-267.

Wan, Y. Y., Y. M. Du, F. X. Yang, Y. Xu, R. Z. Chen and J. F. Kennedy. 2006. Purification and characterization of hydrosoluble components from the sap of Chinese lacquer tree *Rhus vernicifera*. Int. J. Biol. Macromol. 38:232-240.

Yang, J., Y. Du, R. Huang, Y. Wan and T. Li. 2002. Chemical modification, characterization and structure-anticoagulant activity relationships of Chinese lacquer polysaccharides. Int. J. Biol. Macromol. 31:55-62.

Yang, T. T. C. and M. W. L. Koo. 2000. Chinese green tea lowers cholesterol level through an increase in fecal lipid excretion. Life Sci. 66:411-423.

Yang, Y. X., J. D. Lohakare and B. J. Chae. 2007. Effects of lacquer (*Rhus verniciflua*) meal supplementation on layer performance. Asian-Aust. J. Anim. Sci. 20:82-88.

Yaropolov, A. I., S. S. Skorobogat'ko, S. Vartanov and S. D. Varfolomeyer. 1994. Laccase: property, catalytic mechanism and applicability. App. Biochem. Biotech. 49:257-263.

Zou, Y., Y. Lu and D. Wei. 2005. Hypocholesterolemic effects of a flavonoid-rich extract of *Hypericum perforatum* L. in rats fed a cholesterol-rich diet. J. Agric. Food Chem. 53:2462-2466.