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ARTICLE

Effect of Inclusion of Lacquer (*Rhus verniciflua* Stokes) Meal on Carcass Traits and Meat Quality in Growing-finishing Pigs

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Abstract

In this study, pigs [n=117; (Landrace × Yorkshire) × Duroc; 64±0.5 kg initial body weight] were used to investigate the effect of feeding different levels of lacquer (*Rhus verniciflua* Stokes) meal on performance, carcass traits and quality of meat kept under refrigeration at 3±1°C. The pigs were randomly allotted to 3 treatments on the basis of body weight and sex and each treatment was replicated 3 times (13 pigs in each replicate). Lacquer meal in sawdust form obtained from the stem bark and heartwood of sun-dried lacquer trees was added to the grower and finisher diets at 0, 20 and 40 g/kg diet. The experimental diets were fed for 8 wk. Inclusion of lacquer meal had no influence (p>0.05) on growth performance of pigs. Improvement in carcass traits and decreased back fat thickness were noticed in pigs fed diets added with 20 and 40 g/kg lacquer meal. *Longissimus muscle* obtained from pigs fed lacquer meal had higher moisture and lower fat content, thiobarbituric acid reactive substances and water holding capacity. Meat from lacquer fed pigs was also darker and redder. The data indicates that lacquer meal can be incorporated up to 40 g/kg in the diet of fattening pigs without affecting growth performance. Also, lacquer meal increases carcass lean content and improves the oxidative stability of the meat.

Key words: carcass traits, lacquer (*Rhus verniciflua* Stokes) meal, meat quality, growing-finishing pig

Introduction

In recent years, there has been a trend towards the use of natural substances present in fruits, vegetables and herbs as antioxidants and functional foods (Farr, 1997). An increasing number of plant sources and by-products are being explored and studied for their phytochemicals and their potential benefits on animal productivity.

Lacquer (*Rhus verniciflua*) a plant of Anacardiaceae family, grows widely in Japan, China and Korea. It has been used as traditional medicine (Lee *et al*., 2003) and for the protection of antiquities (Kim, 1996). The sap of the lacquer tree is composed of urushiol (600 to 650 g/kg), glycoprotein (21 to 18 g/kg), flavonoids (10 to 20 g/kg) and gummy substance (60 to 70 g/kg) (Yang *et al*., 2002).

Supplementation of lacquer meal in the diet of Hanwoo cattle improved meat color stability and water holding capacity, retarded lipid oxidation and extended storage life of meat (Kim *et al*., 2006). In broilers, inclusion of lacquer meal did not have any effect on growth performance, but improved fat digestibility and reduced serum levels of cholesterol and triglyceride (Lohakare *et al*., 2006). In our previous study, lacquer meal added to the finisher diets of pigs at 20 and 40 g/kg reduced back fat and improved oxidative stability of meat but there was no effect on the growth performance and carcass traits (Song *et al*., 2008). Thus, the present study was conducted to further evaluate the effects of including lacquer meal in grower and finisher diets of fattening pigs on their performance, carcass characteristics and meat quality during refrigerated storage.

Materials and Methods

Lacquer meal

The lacquer meal used in the present study was obtained from Gapyeong Livestock Company (Gapyeong-gun, Gyeonggi-do, Korea). The stem bark and heartwood of the lacquer trees were sun-dried and then reduced to sawdust by an electrical mill. The sawdust was then passed

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through 2 to 3 mm mesh-screen and added as such to the grower and finisher diets.

Animals and diets

The study underwent proper ethical guidelines and was approved by the Animal Care and Use Committee of Kangwon National University. One hundred and seventeen growing pigs [(Landrace × Yorkshire) × Duroc; 64± 0.5 kg average initial body weight; 120±10 days of age] of mixed sex (63 boars and 54 gilts) were randomly allotted to three dietary treatments with three replicate pens in each (comprising 13 pigs per pen), on the basis of their body weights and sex (7 boars and 6 gilts). These pigs were housed in partially slotted and concrete floor pens having a pen size of 3.5 m × 3.5 m. Pens were equipped with a self-feeder and nipple waterer to allow *ad libitum* access to feed and water.

Lacquer meal was incorporated at 0, 20, and 40 g/kg of the diet and isocaloric and isonitrogenous grower and finisher diets were formulated. The experimental feeding was conducted for 8 wk: 0 to 3 wk (grower diet) and 4 to 8 wk (finisher diet). Grower diets were formulated to contain 13.81 MJ/kg ME and 1.10% lysine and finisher diets were formulated to contain 13.81 MJ/kg ME and 0.95% lysine (Table 1). All the diets met or exceeded the nutrient requirements as suggested by NRC (1998).

Table 1. Formula and chemical composition of the experimental diets

Item	Grower (0 to 3 wk)			Finisher (4 to 8 wk)		
Lacquer meal (g/kg)	0	20	40	0	20	40
Ingredient (g/kg)						
Maize	588.9	551.5	508.0	662.4	624.6	582.7
Ricebran	50.0	50.0	50.0	50.0	50.0	50.0
Dehulled-SBM	274.0	278.5	285.0	202.0	209.0	216.0
Animal fat	22.0	35.0	52.0	20.0	34.0	49.0
Molasses	35.0	35.0	35.0	38.0	35.0	35.0
L-lysine	1.2	1.1	1.0	1.8	1.6	1.5
DL-methionine	0.3	0.3	0.4	0.2	0.2	0.3
Choline chloride	0.4	0.4	0.4	0.4	0.4	0.4
Bactacid[1)]	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	11.5	11.5	11.5	9.0	9.0	9.1
Limestone	8.5	8.5	8.5	8.0	8.0	7.8
Salt	3.0	3.0	3.0	3.0	3.0	3.0
Mineral premix[2)]	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin premix[3)]	1.2	1.2	1.2	1.2	1.2	1.2
Probiotic product[1)]	1.0	1.0	1.0	1.0	1.0	1.0
Lacquer meal	0.0	20.0	40.0	0.0	20.0	40.0
Chemical composition (%)						
ME (MJ/kg)[4)]	13.81	13.81	13.81	13.81	13.81	13.81
CP[5)]	18.77	18.70	18.68	16.00	16.34	16.27
Ether extract[5)]	5.40	6.53	8.06	5.33	6.60	7.92
Crude fiber[5)]	4.24	5.27	6.29	4.10	5.08	6.11
Total ash[5)]	5.40	5.76	6.13	4.75	5.10	5.47
Calcium[4)]	0.70	0.70	0.70	0.60	0.60	0.60
Available phosphorus[4)]	0.30	0.30	0.30	0.25	0.25	0.25
Lysine[4)]	1.10	1.10	1.10	0.95	0.95	0.95
Methionine + Cystine[4)]	0.65	0.65	0.65	0.57	0.57	0.57

[1)]Bactacid: organic acid product obtained from Koren Milk Product Inc. (Gyeonggi-do, Korea). Probiotic product: Worldlab (CTC BIO, Seoul, Korea).

[2)]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.

[3)]Supplied per kg diet: For grower diets: 8,960 IU vitamin A, 1,680 IU vitamin D3, 22.4 mg vitamin E, 1.4 mg vitamin B1, 11.2 mg vitamin B2, 2.2 mg vitamin B6, 0.042 mg vitamin B12, 1.4 mg vitamin K3, 22.4 mg pantothenic acid, 42 mg niacin, 0.084 mg biotin, 0.364 mg folic acid. For finisher diets: 8,000 IU vitamin A, 1,500 IU vitamin D3, 16 mg vitamin E, 1.0 mg vitamin B1, 8.0 mg vitamin B2, 1.6 mg vitamin B6, 0.03 mg vitamin B12, 1.0 mg vitamin K3, 16 mg pantothenic acid, 30 mg niacin, 0.06 mg biotin, 0.26 mg folic acid.

[4)]Calculated values.

[5)]Analyzed values.

Experimental procedures and measurements

The pigs were weighed individually and feed consumption per pen was measured at the end of each phase. The overall average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (F/G) were calculated.

At the end of the experiment, six pigs (3 boars and gilts) from each replicate weighing 110 kg were transported 60 km to a commercial slaughter house after overnight fasting. After resting for 3 h, pigs were electrically stunned, slaughtered by bleeding and eviscerated. The hot carcass weights were taken immediately after the final wash and before the carcasses were moved to the chill cooler. The carcasses were then dissected and placed in the chiller (4°C). The carcass traits were obtained from the left side of each carcass, following 24 h chilling. Loin eye area was determined immediately after excision by tracing the *longissimus muscle* surface area at the 10th rib and by using a compensating polar planimeter. Backfat thickness was measured at the 10th rib, three-quarters of the lateral length of the *longissimus muscle* (LM) perpendicular to the outer skin surface using a vernier caliper (Mitutoyo Co., Kawasaki, Japan). Fat free lean percent was estimated using NPPC (1991) equation and adjusted to lean containing 0% fat.

After 24 h chilling of carcass at 4°C, the right LM was removed and the chemical composition and meat quality was measured. The LM was trimmed of all external fat and sectioned into 2.54 cm chops and packed using polyethylene wrap film (oxygen transmission rate 35.723 cc/ $m^2 \cdot$ atm, thickness 0.01 mm, 3M Co., Seoul, Korea). The samples for the analysis of chemical composition were stored at -30°C, whereas those used for the analysis of meat quality were stored at 3±1°C for 5 or 10 d. Also, a section of loins were utilized for the analysis of CIE color score, pH, thiobarbituric acid reactive substances (TBARS) and water holding capacity (WHC) to obtain 0 day values (24 h postmortem).

A color difference meter (Co., CR-310 Minolta, Japan) was used to determine CIE L (lightness), a (redness) and b (yellowness) values at day 0, 5 and 10 d of refrigerated storage. 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. One part of loin sample was homogenized in 9 parts of distilled deionized water and used for measuring pH (F-12, Horiba, Japan). The pH was measured immediately after sectioning of loins on d 0, and after 10 min bloom on 5 and 10 d of refrigerated storage. The WHC was measured by the filter-paper press method as indicated by Grau and Hamm (1953). TBARS assay was performed as described by Sinnhuber and Yu (1977) and values were expressed as mg malonaldehyde/ kg sample.

Chemical analyses

Representative samples of lacquer meal and minced LM chops were analyzed for crude protein (954.01), crude fat (954.02), moisture (934.01) and ash (942.05) according to Association of Official Analytical Chemists (1995) methods. Total flavonoids present in crude ethanol extract of lacquer meal were determined by aluminium nitrate colorimetric method as described by Mohammadzadeh *et al*. (2007). Quercetin was used as a standard compound in the range of 5 to 100 μg/mL concentration to construct a standard curve and the amount of total flavonoids expressed as quercetin equivalent.

Statistical analyses

The data was subjected to one-way ANOVA to determine significant differences among treatments by using SAS software (SAS Inst., Inc., Cary, NC, 1998). The pen was the experimental unit for the analysis of all traits. When significant differences were noted ($p<0.05$), means were separated using Duncan's multiple range tests.

Results

The lacquer meal used in this study had 14.9 MJ gross energy, 13.9 g crude protein, 53.1 g ether extract, 545.0 g crude fiber and 817.0 g neutral detergent fiber per kg (Table 2). The flavonoids present was 41.2 g quercetin equivalent per kg of lacquer meal.

There were no effects of lacquer meal inclusion on the overall growth performance of pigs (data not shown). The

Table 2. Chemical composition of lacquer meal (on dry matter basis) used during the feeding trial

Item	g/kg
Dry matter	814.0
Gross energy (MJ/kg)	14.9
Crude protein	13.9
Ether extract	53.1
Crude fiber	545.0
Neutral detergent fiber	817.0
Total Ash	188.0
Calcium	4.4
Phosphorus	1.2
Total flavonoid	41.2

inclusion of lacquer increased ($p<0.05$) the dressing percentage, loin eye area and fat free lean percent and decreased backfat thickness (Table 3).

The LM of pigs fed lacquer diets had higher ($p<0.05$) moisture and lower ($p<0.05$) crude fat content, while the crude protein remained unaffected (Table 4).

Table 3. Effect of lacquer meal on carcass characteristics of *longissimus muscle*

Items	Lacquer meal (g/kg)			S.E.M.[1)]
	0	20	40	
Carcass characteristics				
Dressing percentage	77.37[b]	78.52[a]	78.79[a]	0.15
Backfat thickness (mm)	25.00[a]	22.67[b]	21.83[b]	0.32
Loin eye area (cm^2)	52.32[b]	53.37[ab]	54.00[a]	0.34
Fat free lean percentage	57.25[b]	58.23[a]	58.61[a]	0.14

[a,b]Means with different superscripts in the same row differ significantly ($p<0.05$).
[1)]S.E.M., standard error of the mean.

Table 4. Effect of lacquer meal on chemical composition of *longissimus muscle*

Items	Lacquer meal (g/kg)			S.E.M.[1)]
	0	20	40	
Composition of longissimus muscle (g/kg)				
Moisture	735.3[b]	740.6[a]	741.0[a]	1.24
Crude protein	231.0	231.3	232.0	1.56
Crude fat	27.1[a]	18.6[b]	17.3[b]	1.56
Crude ash	10.5[a]	10.0[b]	10.3[ab]	0.52

[a,b]Means with different superscripts in the same row differ significantly ($p<0.05$).
[1)]S.E.M., standard error of the mean.

Table 5. Effect of lacquer meal on meat color during storage at 3 ± 1°C

Items	Storage day	Lacquer meal (g/kg)			S.E.M.[1)]
		0	20	40	
Color (CIE)					
L	0	53.95	52.78	53.66	0.26
	5	54.25	54.07	53.62	0.21
	10	54.89[a]	53.93[b]	53.32[b]	0.21
a*	0	5.95[b]	8.31[a]	7.69[a]	0.26
	5	5.58[b]	7.41[a]	6.99[a]	0.20
	10	3.31[b]	4.30[a]	4.14[a]	0.17
b*	0	6.80[a]	5.15[c]	5.92[b]	0.16
	5	7.19[a]	5.97[b]	6.28[b]	0.10
	10	6.81[a]	4.95[ab]	5.73[b]	0.19
	5	46.58[a]	43.91[b]	42.16[b]	1.45
	10	55.69[a]	50.31[b]	49.28[b]	0.94

[a, b, c]Means with different superscripts in the same row differ significantly ($p<0.05$).
[1)]S.E.M., standard error of the mean.

Table 6. Effect of lacquer meal on pH, TBARS and WHC during refrigerated storage at 3 ± 1°C

Items	Storage day	Lacquer meal (g/kg)			S.E.M.[1)]
		0	20	40	
pH	0	5.50	5.43	5.49	0.04
	5	5.59	5.44	5.53	0.05
	10	5.60	5.51	5.58	0.05
TBARS (mg MA/kg)	0	0.14[a]	0.10[b]	0.09[b]	0.01
	5	0.24	0.22	0.23	0.01
	10	0.35[a]	0.30[b]	0.27[b]	0.01
WHC (%)	0	35.97[a]	33.97[b]	31.22[c]	0.43
	5	46.58[a]	43.91[b]	42.16[b]	1.45
	10	55.69[a]	50.31[b]	49.28[b]	0.94

[a, b, c]Means with different superscripts in the same row differ significantly ($p<0.05$).
[1)]S.E.M., standard error of the mean.

The CIE L values of LM after refrigeration remained unaffected at 0 d and 5, while at 10 d of storage, LM of pigs fed lacquer diets had lower ($p<0.05$) CIE L values (Table 5). Pigs fed lacquer diets had higher CIE a ($p<0.05$) and lower CIE b values at 0, 5, and 10 d of refrigerated storage.

The TBARS (day 0, and 10) and WHC (day 0, 5, and 10) were lower in the LM obtained from pigs fed lacquer diet, however the TBARS at d 5 and the pH values at d 0, 5, and 10 of refrigerated storage were not influenced by incorporation of lacquer in the diet (Table 6).

Discussion

Lacquer meal was supplemented in the diet of pigs to study its effects on performance, carcass characteristics and meat quality. The experimental diets were made isoenergetic by replacing parts of maize by animal fat in diets incorporated with lacquer meal and thus the ether extract was higher in these diets than control diets. Similar to the findings of the current study, no growth performance benefits were reported in broilers (Lohakare *et al*., 2006) and finisher pigs (Song *et al*., 2008) when their diets were supplemented with lacquer meal at 20 and 40 g/kg diet.

In the current study, addition of lacquer meal improved dressing percent, loin eye area and fat free lean percent; moreover the lipid content of LM was decreased in pigs fed lacquer diets. In contrast, Lohakare *et al*. (2006) did not find any changes in the carcass characteristics of broilers supplemented with lacquer meal. However, Kim *et al*. (2006) reported reductions in the lipid content of

LM in Hanwoo cattle that were fed with 60 g/kg lacquer added diet which is in agreement with the findings of the current study. The changes towards lower back fat thickness and fat content in the muscle of pigs fed lacquer meal might be due to the flavonoid content of these diets. Flavonoids are known to reduce body fat mass (Tominaga *et al*., 2006) and abdominal fat accumulation (Nakagawa *et al*., 2004).

The pH values observed in our study at 24 h postmortem were within the range of 5.4-5.5 reported by Briskey and Wiser-Pedersen (1961). The ability of muscle cells to entrap water is directly effected by pH, ionic strength, and the oxidation of myofibrillar protein and myofibrils (Huff-Lonergan and Lonergan, 2005). In the current study, LM of pigs fed lacquer diets had lower TBARS and WHC during refrigerated storage. A lower pH denatures myofibrillar proteins and consequently, they bind less water (Hamm, 1986). The pH of loins obtained from pigs fed lacquer was numerically lower which might partially explain their lower WHC values.

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). The loss of redness of meat during storage is caused by oxidation of the bright pinkish-red oxymyoglobin to the brown metmyoglobin (Faustman and Cassens, 1990). Improved oxidative stability may reduce the rate of such oxidation and preserve the red color for a longer time during storage which might explain the higher CIE a values in loins of pigs fed lacquer diets. Similar reductions in the TBARS values during refrigerated storage were reported by Kim *et al*. (2006) and Kang *et al*. (2008) in LM of Hanwoo cattle. Lower L values observed on d 10 of refrigerated storage indicate that meat of pigs fed lacquer is dark in color which is a desirable color based on consumer preference (Bates *et al*., 2005). The LM of pigs fed lacquer had lower yellow (CIE b) values during all storage days. Darker and less yellow loins from pigs fed lacquer might also be related to the antioxidant component flavonoid present in lacquer. The changes in the color, TBARS and WHC were similar to those noticed in our previous study in finishing pigs (Song *et al*., 2008). In line with the findings of the present study, significant improvements in a and lower L values have been reported in pigs supplemented with á-tocopherol (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.

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