Effect of Beta-agonists on Composition of Pork Longissimus Muscle

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SUMMARY: Seventy pigs were randomly assigned to five treatments by litter and sex (male castrate and female). Four groups received beta-agonist compounds in their diet. Pigs were slaughtered at approximately 100 kilograms live weight. Beta-agonist treated pigs had larger longissimus muscle areas and less subcutaneous fat than control pigs. Longissimus muscle from beta-agonist treated pigs contained less ether extractable constituents, cholesterol, insoluble hydroxyproline and total hydroxyproline and more moisture than muscle from control pigs. Female pigs had less subcutaneous fat, larger areas of longissimus muscle than male castrates. Muscle from females contained more moisture, less ether extractable constituents and less cholesterol than muscle from male castrates. Results from this study showed beneficial improvements in increased muscle, less subcutaneous and intramuscular fat and lower cholesterol levels for beta-agonist treated pigs compared to litter mate non-treated pigs.

INTRODUCTION: An important question of diet composition in relation to human health is the need to reduce the fat and cholesterol content of red meat. Production of red meat with minimum amount of separable fat can be achieved through live animal selection and production practices, and by physical removal of fat from the various cuts during carcass processing. Beta-adrenergic agonist compounds have been shown to decrease fat deposition and increase muscle accretion in finishing pigs by partitioning dietary nutrients away from fat tissue and preferentially toward lean tissue (HANRAHAN, 1987; YEN et al., 1990). A major question is whether an increase in lean tissue affects cholesterol level of muscle. Additionally, reported levels of cholesterol in pork vary considerably, ranging from approximately 29 to 139 mg/100 g of fresh lean (SWEENEY and WEIHRAUCH, 1976; FENNEWALD, 1991). Therefore, the objective of this study was to evaluate the effect of beta-adrenergic compounds on the levels of cholesterol and intramuscular fat in the longissimus muscle of pigs.

MATERIALS and METHODS: Seventy pigs (45 gilts and 25 barrows) were randomly assigned to five treatment groups by sex and litter. A standard corn and soybean meal diet fortified with vitamins and minerals was provided ad libitum during the growing and finishing period. During the final five weeks of the finishing period four treatment groups received beta-agonist compounds in their diet. Treatment groups 2, 3 and 4 received 1, 4 and 10 ppm, respectively, of an unnamed beta-agonist compound and group 5 received 1 ppm of the beta-agonist L-644,969 in their diet. Treatment group 1 served as the control.

The pigs were slaughtered at approximately 100 kg live weight. A sample of blood was collected during exsanguination and subsequently analyzed for serum cholesterol. After chilling overnight at 2°C, the longissimus muscle area and 3/4 backfat measurements at the 10th rib were determined. A 15 cm portion of the left loin posterior to the 10th rib was removed and stored at 2-4°C for an additional four days. At five days postmortem, two 2.5 cm thick chops were cut from the 10-13th rib area of the loin for subsequent shear value determinations. An adjacent 2.5 cm thick chop was removed and the longissimus muscle analyzed for hydroxyproline. The remaining 7.5 cm section of the longissimus muscle was passed twice through a grinder

equipped with a plate containing 3 mm openings. Three ground samples were obtained from each loin and randomly assigned as follows: two samples for cholesterol analyses by two independent laboratories and one sample for moisture, fat and protein analyses.

The designated chops for shear determinations were cooked in a convection oven at 177°C to an internal temperature of 74°C. The chops were cooled to room temperature and six 1.27 cm cores were taken from the longissimus muscle of each chop. Each core was sheared once on an Instron Universal Testing Machine equipped with a Warner-Bratzler attachment and a 100 kg load cell. Cooking yield was determined for each chop.

Hydroxyproline analysis was performed using the preparation method of HILL (1966) and the analytical method of NEUMANN and LOGAN (1950). Ether extractable constituents and crude protein were determined by AOAC (1984) procedures. Cholesterol levels of muscle and blood plasma were determined by Laboratory A using the procedure of ADAMS et al. (1986) and muscle by Laboratory B using the procedure of KOVACS et al. (1979).

Data were analyzed using the SAS General Linear Models Procedure (SAS, 1985). A two-way analysis of variance was applied with treatment and sex included as sources of variation. When the analysis of variance indicated a significant treatment effect, the Least Significant Difference was determined between means. The cholesterol values determined by the independent laboratories were compared using the Paired Comparison T-test.

RESULTS and DISCUSSION: Pigs that received beta-agonist compounds in their diet for five weeks prior to slaughter had larger longissimus muscles ($P<.05$) and 10th rib fat depth tended to be less than control pigs (Table 1). Longissimus muscle of the beta-agonist treated pigs had less ether extractable fat and less cholesterol ($P<.05$) than muscle from the control pigs. Although there was a significant difference in cholesterol levels obtained by the two independent laboratories, results from each laboratory indicated similar differences in cholesterol levels among the five treatment groups.

Table 1. Comparison of chemical and physical characteristics of longissimus muscle, subcutaneous fat depth and serum cholesterol from control and beta-agonist treated pigs

Item	Treatment group (ppm beta-agonist)				
	1 (0)	2 (1)	3 (4)	4 (10)	5 (1)
Longissimus muscle area, cm^2	30.39^{a}	35.10^{b}	37.68^{bc}	38.13^{c}	35.17^{b}
10^{th} rib fat depth, cm	2.95^{a}	2.59^{ab}	2.29^{b}	2.29^{b}	2.74^{a}
Protein, %	21.84	22.33	22.51	22.57	22.24
Moisture, %	72.86	73.11	72.93	72.57	73.36
Ether extract, %	4.64^{a}	3.99^{ab}	3.79^{b}	4.21^{ab}	3.71^{b}
Cholesterol, mg/100 g					
Laboratory A	55.56^{a}	50.78^{bc}	50.20^{c}	50.24^{c}	52.73^{b}
Laboratory B	51.79^{a}	47.86^{bc}	47.26^{c}	47.36^{c}	49.07^{b}
Hydroxyproline, mg/g					
Insoluble	0.84^{a}	0.71^{b}	0.73^{b}	0.68^{b}	0.73^{b}
Soluble	0.67^{a}	0.65^{a}	0.69^{a}	0.62^{ab}	0.53^{b}
Total	1.52^{a}	1.36^{ab}	1.42^{ab}	1.31^{b}	1.26^{b}
Warner-Bratzler shear value, kg/1.27 cm	4.37^{a}	4.74^{ab}	5.24^{c}	4.85^{abc}	5.18^{bc}
Serum cholesterol, mg/dl	151.17	149.56	132.71	139.49	141.69

^{abc}Means in the same row with different superscripts are different ($P<.05$).

The observed reduction in intramuscular fat with beta-agonist treatments agrees with data reported for pigs by MERKEL et al. (1990). MCKEITH et al. (1990) reported a reduction in cholesterol content in the longissimus muscle of ractopamine treated pigs. RHEE et al. (1982) observed no differences in cholesterol content of beef muscle with different marbling scores for percent of lipid. It is postulated that the lower cholesterol in the beta-agonist treated pigs compared to the controls in the present study was related to the reduced cell membrane content of muscle associated with the increase in muscle of the beta-agonist treated pigs.

Warner-Bratzler shear values were lower for the control group than for treatment groups 3 and 5 ($P<.05$), but did not differ from shear values of groups 2 and 4. Thus, beta-agonist treatments did not consistently increase shear values of cooked longissimus muscle. RICKES et al. (1990) reported shear force values were unchanged due to beta-agonist treatment (L-668-488), while JONES et al. (1985) reported increased shear values for cimaterol treated pigs.

Insoluble hydroxyproline was less for the four beta-agonist treated groups than for the control group. Except for group 5, soluble hydroxyproline was similar for the control and treated groups. Total hydroxyproline tended to be less for muscle of all beta-agonist treated pigs compared to the control pigs. MORGAN et al. (1989) reported no relationship between various parameters of collagen analyses and increased shear values of beta-agonist treated broiler chickens.

Serum cholesterol levels did not differ among the five treatment groups nor among the four sire of two sex groups. ROTHSCHILD and CHAPMAN (1976) reported significant differences in blood serum cholesterol for pigs that differed genetically.

Female pigs had larger longissimus muscles and less 10th rib fat depth ($P<.05$) than male castrate pigs. Longissimus muscles from female pigs had more moisture, less fat, less cholesterol and lower shear values than muscles from male castrate pigs (Table 2).

Table 2. Comparison of chemical and physical characteristics of longissimus muscle, subcutaneous fat depth and blood serum cholesterol from male castrates and female pigs

Item	Male castrate	Female
Longissimus muscle area, cm^2	33.75^{c}	36.13^{d}
10^{th} rib fat depth, cm	2.95^{a}	2.36^{b}
Protein, %	22.30	22.30
Moisture, %	72.56^{a}	73.19^{b}
Ether extract, %	4.46^{a}	3.85^{b}
Cholesterol, mg/100 g		
Laboratory A	53.32^{a}	51.12^{b}
Laboratory B	49.26^{c}	48.34^{d}
Hydroxyproline, mg/g		
Insoluble	0.73	0.75
Soluble	0.61	0.64
Total	1.34	1.39
Warner-Bratzler shear value, kg/1.27 cm	5.15^{a}	4.72^{b}
Serum cholesterol, mg/dl	147.16	140.75

[a,b]Means in the same row with different superscripts differ ($P<.01$).
[c,d]Means in the same row with different superscripts differ ($P<.05$).

The mean 10th rib fat depth for male castrate pigs in the control group was 3.68 cm and 2.52 cm for females in the control group. In beta-agonist treated groups the mean 10th rib fat depth was 2.75 cm for male castrates and 2.34 for the females. The beta-agonist treatments were more effective in reducing the 10th rib fat of male castrates (0.93 cm) compared to females (0.18 cm).

Data presented in Table 3 indicate that cholesterol content of the longissimus muscle was negatively correlated with longissimus muscle area ($P<.001$) and positively correlated with percent ether extractable fat in the longissimus muscle ($P<.001$). The relationship between serum cholesterol and muscle cholesterol or muscle fat was inconsistent. Shear values were not significantly related to any of the criteria evaluated in this study.

CONCLUSIONS: Under the conditions of this investigation, beta-agonist treated pigs, compared to controls, had less 10th rib fat depth, larger area of longissimus muscle, and less ether extractable fat and cholesterol in the longissimus muscle. Likewise, female pigs compared to castrate male pigs had less 10th rib fat depth, larger area of the longissimus muscle and less ether extractable fat and cholesterol in the longissimus muscle.

Table 3. Correlation coefficients for chemical and physical attributes of longissimus muscle and carcass characteristics of beta-agonist treated and control pigs

Item	Shear Value	Water %	Protein %	Ether extract %	Cholesterol[a]	Cholesterol[b]
Protein, %	.01	.30*	-	-	-	-
Ether extract, %	-.22	-.77***	-.25*	-	-	-
Backfat, cm	-.22	-.31**	-.02	.39***	.26*	.37**
Longissimus area, cm^2	.16	.60***	.23	-.53***	-.47***	-.58***
Cholesterol[a]	-.03	-.38**	-.21	.55***	-	-
Cholesterol[b]	-.05	-.26*	-.39***	.59***	.73***	-
Hydroxyproline						
Insoluble	-.06	.12	-.05	.01	.19	.30*
Soluble	-.07	.06	-.03	-.03	.01	.11
Total	-.08	.10	-.05	-.01	.11	.24*
Serum cholesterol	-	-.12	-.06	.18	.01	.25*

*P<.05
**P<.01
***P<.001
[a]Laboratory A
[b]Laboratory B

REFERENCES:

ADAMS, M.L., SULLIVAN, D.M., SMITH, R.L. and RICHTER, E.F. (1986): Evaluation of direct saponification method. J. AOAC 69: 638.

AOAC (1984): "Official Methods of Analysis" 14th edition. Association of Official Analytical Chemists, Washington, D.C.

FENNEWALD, K.J. (1991): Chemical and physical characteristics of longissimus msucle from beta-agonist treated and control pigs. M.S. Thesis, University of Missouri. 59 pages.

HANRAHAN, J.P., FITZSIMONS, J.M., MCEWAN, J.C., ALLEN, P. and QUIRKE, J.F. (1987): Effects of the beta-agonist cimaterol on growth, food efficiency and carcass quality in sheep. In: "Beta-Agonists and Their Effects on Animal Growth and Carcass Quality" (J.P. HANRAHAN, ed.). Elsevier, London. pp. 106-118.

HILL, F. (1966): The solubility of intramuscular collagen in meat animals of various ages. J. Food Sci. 31: 161-166.

JONES, R.W., EASTER, R.A., MCKEITH, F.K., DALRYMPLE, R.H., MADDOCK, H.M. and BECHTEL, P.J. (1985): Effect of the beta-adrenergic agonist cimaterol on the growth and carcass characteristics of finishing swine. J. Anim. Sci. 61: 905-913.

KOVACS, M.P., ANDERSON, W.E. and ACKMAN, R.G. (1979): A simple method for the determination of cholesterol and some plant sterols in fishery-based food products. J. Food Sci. 44: 1299-1305.

MCKEITH, F.K., PERKINS, E.G., JONES, D.J. and MOWRY, D.H. (1990): Effect of ractopamine on the fatty acid composition and cholesterol content of pork longissimus muscle. J. Anim. Sci. 68(Suppl. 1): 336.

MERKEL, R.A., BABIKER, A.S., SCHROEDER, A.L., BURNETT, R.J. and BERGEN, W.G. (1990): The effect of ractopamine on qualitative properties of porcine longissimus muscle. J. Anim. Sci. 68(Suppl. 1): 336.

MORGAN, J.B., JONES, S.J. and CALKINS, C.R. (1989): Muscle protein turnover and tenderness in broiler chickens fed cimaterol. J. Anim. Sci. 67: 2646-2654.

NEUMANN, R.E. and LOGAN, M.A. (1950): The determination of collagen and elastin in tissues. J. Biol. Chem. 184: 299-306.

RHEE, K.S., DUTSON, T.R., SMITH, G.C., HOSTETLER, R.L. and REISER, R. (1982): Cholesterol content of raw and cooked beef longissimus muscles with different degrees of marbling. J. Food Sci. 47: 716-719.

RICKES, E.L., CHANG, C.H., WALLACE, D.H., TRIMBOLI, W.A., SEWARD, R.L. and HEDRICK, H.B. (1990): Effect of the beta-agonist L-668,488 on performance, carcass composition and carcass characteristics in swine. J. Anim. Sci. 68(Suppl. 1): 296.

ROTHSCHILD, M.F. and CHAPMAN, A.B. (1976): Factors influencing serum cholesterol levels in swine. J. Heredity 67: 47-48.

SAS (1985): "SAS User's Guide: Statistics". SAS Institute, Inc., Cary, NC.

SWEENEY, J.P. and WEIHRAUCH, J.L. (1976): Summary of available data for cholesterol in foods and methods for its determination. Critical Reviews in Food Science and Nutrition 8: 131-159.

YEN, J.T., MERSMANN, H.J., NIENABER, J.A., HILL, D.A. and POND, W.G. (1990): Responses to cimaterol in genetically obese and lean pigs. J. Anim. Sci. 68: 2698-2706.