Is Meat Quality Affected by the Use of Repartitioning Agents?

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Introduction

The effects of the β-adrenergic agonists (BAA) and somatotropin on livestock species are well documented and have been the topic of discussion at previous conferences (see RMC proceedings 1984, 1985, 1987). These agents markedly alter carcass composition, i.e., they decrease fat deposition and increase muscle mass. The BAA appear to have their greatest effect on muscle hypertrophy, while somatotropin appears to have its greatest effect on fat deposition. Because of the reduction in fat and increased muscle content of carcasses from animals treated with these agents, concerns have been raised about their effects on qualitative properties of the meat. The objective of this review is to summarize the published literature, including abstracts, on the effects of BAA and somatotropin on meat quality of beef, pork and lamb. The data are presented by qualitative trait, species and BAA.

Questions such as the following have been asked: Do these agents predispose carcasses to cold-induced shortening? Does the decrease in fat and presumably marbling affect the palatability factors? Because catecholamines stimulate glycogenolysis, do their analogs, the β-agonists, cause DFD or PSE conditions in postmortem muscle? Does the change in muscle protein turnover accounting for the marked hypertrophy affect the enzymes involved in postmortem proteolysis? The connective tissue proteins? These are some important questions, but few answers have been reported in the scientific literature to date.

Beta-Adrenergic Agonists

Marbling

Feeding .25, .5 or 1 ppm of cimaterol to pigs did not affect *longissimus* muscle marbling scores in a study by Jones et al. (1985) as shown in Table 1 (see next page). The ND under the observation heading in this and subsequent tables indicates that the respective trait for treated animals did not differ from untreated controls. In contrast, Moser et al. (1986) observed a linear increase ($P<.05$) in marbling scores with these same levels of cimaterol fed to pigs (Table 1). Ricks et al. (1984a) likewise observed a linear increase in marbling in pigs fed .05, .1 or 1 ppm clenbuterol. However, Wallace et al. (1987) reported a nonsignificant trend toward a decrease in marbling in pigs fed 4 ppm of the agonist L-644,969. Hancock et al. (1987) fed pigs 2.5, 5, 10, 20 or 30 ppm ractopamine and observed no difference from control in marbling scores for any level of agonist. Merkel et al. (1988) also found no difference in *longissimus* muscle marbling score of pigs fed 20 ppm ractopamine for either 2, 4 or 6 wk.

In carcasses of lambs fed 2 ppm clenbuterol, Hamby et al. (1986) observed a decrease ($P<.05$) in flank streaking (Table 2). Marbling score also was decreased ($P<.05$) in cattle fed 10 mg.head^{-1}.d^{-1} clenbuterol (Miller et al., 1988), while Ricks et al. (1983, 1984b) found that marbling scores of cattle fed 10 or 500 ppm clenbuterol did not differ from controls. These data for the effects of BAA on marbling are inconsistent. Even though significant differences were observed in some instances (Tables 1 and 2), the magnitude of change in degree of marbling (flank streaking in one study) was relatively small and probably of little practical significance.

Ether-Extractable Lipid

Feeding 5, 10 or 20 ppm ractopamine to pigs did not affect ether-extractable lipid content of the *longissimus* muscle (McKeith et al., 1988, Table 3). Similarly 4 ppm of the agonist, salbutamol, did not affect ether-extractable lipid content of porcine *longissimus* muscles (Cole et al., 1987; Wood et al., 1987). Merkel et al. (1988) observed that *longissimus* muscles of pigs fed 20 ppm ractopamine for 2 or 4 wk did not differ from controls, whereas at 6 wk muscle lipid content was decreased ($P<.05$).

Ether-extractable lipid content of the *longissimus* muscle of lambs was unaffected by 4 ppm cimaterol 6d after withdrawal (Table 4). Hanrahan et al. (1987) observed a decrease in extractable lipid in *longissimus* muscles of cattle fed either 33, 49.5 or 66 mg.head^{-1}.d^{-1} cimaterol. Like marbling, these data for ether-extractable lipid are inconsistent and the small decreases in lipid in the BAA-treated animals probably are of little practical significance.

Muscle Color

The data presented in Table 5 indicate that none of the five BAA at any of the levels fed affected color of *longissimus* muscle. McKeith et al. (1988) conducted a 4d retail display

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Table 1. Effect of Beta-Adrenergic Agonists on Marbling in Porcine Longissimus Muscle.

Agonist	*Level fed, ppm*	*Observation*	*Source*
Cimaterol	.25, .5, 1	ND	Jones et al., 1985
	.25, .5, 1	linear increase[a]	Moser et al., 1986
Clenbuterol	.05, .1, 1	increase[a]	Ricks et al., 1984a
L-644,969	4	NS trend toward decrease	Wallace et al., 1987
Ractopamine	2.5, 5, 10, 20, 30	ND	Hancock et al., 1987
	20	ND	Merkel et al., 1988

[a]P<.05.

Table 2. Effect of Beta-Adreneregic Agonists on Marbling in Ovine and Bovine Longissimus Muscles.

Species and Agonist	*Level fed, ppm*	*Observation*	*Source*
Lambs – Clenbuterol	2 ppm	decreased flank streaking[a]	Hamby et al., 1986
Cattle – Clenbuterol	10, 500	ND	Ricks et al., 1983, 1984b
	10mg/hd/d	decrease[a]	Miller et al., 1988

[a]P<.05.

Table 3. Effect of Beta-Adrenergic Agonists on Ether-Extractable Lipid of Porcine Longissimus Muscle.

Agonist	*Level fed, ppm*	*Observation*	*Source*
Ractopamine	5, 10, 20	ND	McKeith et al., 1988
	20	ND at 2 & 4 wk decrease at 6 wk[a]	Merkel et al., 1988
Salbutamol	4	ND	Cole et al., 1987
	4	ND	Wood et al., 1987

[a]P<.05.

Table 4. Effect of Beta-Adrenergic Agonists on Ether-Extractable Lipid of Ovine and Bovine Longissimus Muscle.

Species and Agonist	*Level fed, ppm*	*Observation*	*Source*
Lambs – Cimaterol	4	ND after 6d withdrawal	Boucque et al. 1987
Cattle – Cimaterol	33, 49.5, 66 mg/hd/d	decrease[a]	Allen et al., 1987
	.57, 2.29, 11.42	ND	Hanrahan et al., 1987

[a]P<.001.

study utilizing loin chops from pigs fed either 0, 5, 10 or 20 ppm ractopamine to observe lean color, surface discoloration and overall appearance. These data are presented in Table 6. The subjective score system used appears in the footnotes to the table. Neither the linear effect of dose level, nor the contrast of control vs BAA-treated samples differed for any of the traits scored. There was a nonsignificant trend for all subjective scores to increase with retail storage time, indicating that color and appearance had deteriorated, but treatment had no effect on these muscle color observations.

In lambs fed 10 ppm cimaterol, Beermann et al. (1985) observed increased (P<.001) Hunter "Rd" and "a" values, indicating darker *longissimus* muscles but stated that the increased values were in the normal range (Table 7). They also stated that no visual differences in color of muscle were detected. Allen et al. (1985) also reported darker (P<.05) *longissimus* muscles from lambs fed 2.29 or 11.42 ppm cimaterol than from controls. In a study with cattle fed either

Table 5. Effect of Beta-Adrenergic Agonists on Porcine Longissimus Muscle Color.

Agonist	*Level fed, ppm*	*Observation*	*Source*
Cimaterol	1	ND	Bebaert et al., 1987
	.25, .5, 1	ND	Jones et al., 1985
	25, .5, 1	ND	Moser et al., 1986
Clenbuterol	.05, .1, 1	ND	Ricks et al., 1984a
L 644,969	.25, 1, 4	ND	Wallace et al., 1987
Ractopamine	2.5, 5, 10, 20, 30	ND	Hancock et al., 1987
Salbutamol	2, 4, 8	ND	Cole et al., 1987
	4	ND	Wood et al., 1987

Table 6. Longissimus Visual Characteristics During Four Days of Retail Display.[a,b]

		Ractopamine level, ppm			
Trait	*Day*	*0*	*5*	*10*	*20*
Number Obs.		22	11	11	11
Lean Color[c]	1	2.85	2.82	2.76	2.75
	2	2.91	2.86	2.87	2.97
	3	2.89	3.01	2.84	2.89
	4	3.23	3.15	3.01	3.13
Surface discoloration[d]	1	1.35	1.18	1.31	1.15
	2	1.39	1.35	1.54	1.21
	3	1.66	1.67	1.76	1.56
	4	3.12	2.66	2.88	2.58
Overall appearance[e]	1	3.69	3.47	3.96	3.47
	2	3.34	3.25	3.42	3.04
	3	4.37	4.20	4.56	4.11
	4	6.35	5.71	5.94	5.95

[a]Data courtesy of Floyd K. McKeith et al., University of Illinois.
[b]Nonsignificant linear effect, and the contrast control vs treated.
[c]Score of 1 = pale; 5 = dark.
[d]Score of 1 = no surface discoloration; 7 = complete discoloration.
[e]Score of 1 = extremely desirable; 9 = extremely undesirable.

Table 7. Effect of Beta-Adrenergic Agonists on Ovine and Bovine Longissimus Muscle Color.

Species and Agonist	*Level fed, ppm*	*Observation*	*Source*
Lambs – Cimaterol	10	increased Rd and a values (but normal range)[a]	Beermann et al., 1985
	2.29, 11.42	darker[b]	Allen et al., 1985
Cattle – Cimaterol	33, 49.5, 66 mg/hd/d	ND	Allen et al., 1987

[a]$P<.001$.
[b]$P<.01$.

33, 49.5 or 66 mg.head^{-1}.d^{-1} cimaterol, Allen et al. (1987) observed no differences in color of muscles. These data indicate that feeding BAA to livestock species has little effect on color of *longissimus* muscles, and the small differences probably are of no practical significance.

Muscle Firmness/Wateriness

Feeding BAA to pigs had no effect on *longissimus* muscle subjective scores for firmness and/or wateriness (Table 8). These observations were made irrespective of agonist or the

Table 8. Effect of Beta-Adrenergic Agonists on Porcine Longissimus Muscle Firmness/Wateriness.

Agonist	*Level fed, ppm*	*Observation*[a,b]	*Source*
Cimaterol	.25, .5, 1	ND	Jones et al., 1985
Clenbuterol	.05, .1, 1	ND	Ricks et al., 1984a
Ractopamine	2.5, 5, 10, 20, 30	ND	Hancock et al., 1987
	20	ND	Merkel et al., 1988
Salbutamol	4	ND	Wood et al., 1987

Table 9. Effect of Beta-Adrenergic Agonists on Porcine Longissimus Muscle pH, Water-Holding Capacity and Cooking Losses.

Agonist	*Level fed, ppm*	*Observation*[a,b]	*Source*
Clenbuterol	1	ND pH_1, pH_u ND WHC	Bekaert et al., 1987
	1	ND, pH_{45}, pH_u ND WHC ND cooking losses	VanWeerden, 1987
Ractopamine	5, 10, 20	ND pH_u	McKeith et al., 1988
Salbutamol	2, 4, 8	ND, pH_{45}, pH_u	Cole et al., 1987

[a]pH at 45 min, 1h or ultimate pH as indicated by pH_{45}, pH_1, pH_u.
[b]WHC = water-holding capacity.

Table 10. Effect of Beta-Adrenergic Agonists on Ovine and Bovine Longissimus Muscle pH and Drip Losses.

Species and Agonist	*Level fed, ppm*	*Observation*[a,b]	Source
Lambs – Cimaterol	2.29, 11.42	increased pH (.3)	Allen et al., 1985a
		ND if slaughtered immediately	1985b
	10	ND pH 15 min increased pH_2 to pH_u	Beermann et al., 1985
	.55, 2.29, 11.42	increased pH_u	Hanrahan et al., 1986
Cattle – Cimaterol	33,49.5, 66 mg/hd/d	ND in pH increased drip losses 2&6d PM	Allen et al., 1987

[a]pH at 2h or ultimate pH as indicated by pH_2 or pH_u
[b]PM = postmortem.

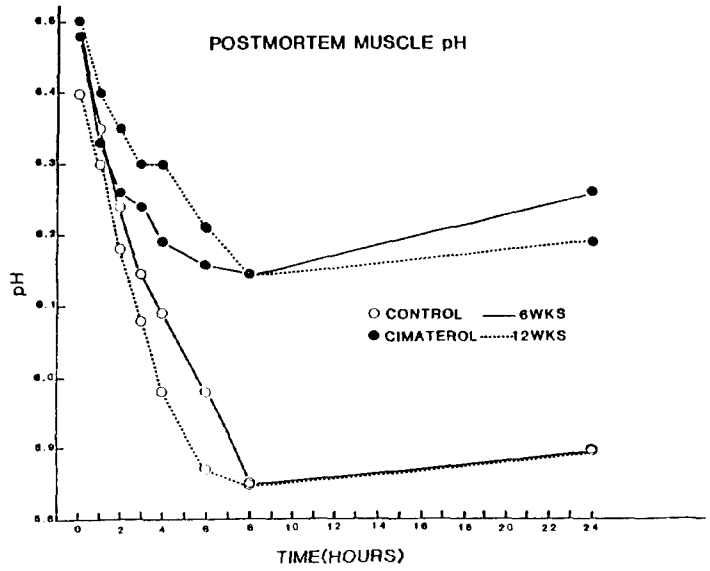
level fed. No data on muscle firmness and/or wateriness subjective scores were available for either beef or lambs fed BAA.

Muscle pH, Water-Holding Capacity, Cooking Losses

Longissimus muscle pH at either 45 min or 1h postmortem as well as ultimate pH was not affected by feeding BAA to pigs (Table 9). In addition, 1 ppm of clenbuterol did not significantly affect water-holding capacity (Bekaert et al., 1987; VanWeerden, 1987) or cooking losses (VanWeerden, 1987) in pork. Cole et al. (1987) reported that *longissimus* muscles of pigs fed either 2, 4 or 8 ppm salbutamol did not differ from controls in pH at either 45 min postmortem or in ultimate pH.

Allen et al. (1985a) observed that in lambs fed either 2.29 or 11.42 ppm cimaterol, *longissimus* muscle ultimate pH was increased .3 units compared to controls (Table 10). In a second study, they observed no difference in ultimate pH of muscles from lambs fed 1 ppm cimaterol compared to controls when lambs were killed immediately upon arrival at the slaughter plant (Allen et al., 1985b). Beermann et al. (1985) found no effect of 10 ppm cimaterol on muscle pH 15 min after slaughter, but from 2H postmortem to ultimate pH, the agonist-treated lambs had higher pH values (Figure 1). Muscle pH of control lambs did not differ at 6 or 12 wk, nor did

Figure 1



Postmortem pH decline of control lambs and those fed 10 ppm cimaterol for either 6 or 12 wk.

lambs fed 10 ppm cimeratol for either 6 or 12 wk. However, the data in Figure 1 show that BAA-treated lambs had approximately .3 unit higher pH from 8h through 24h postmortem, which is similar to the observations of Allen et al. (1986a, Table 10) and those of Lee et al. (1988) shown in Table 18. Hanrahan et al. (1986) also observed an increase in ultimate pH in *longissimus* muscles of lambs fed either .55, 2.29 or 11.42 ppm cimaterol. Allen et al. (1987) reported no difference in muscle pH of cattle fed either 33, 49.5 or 66 mg.head^{-1}.d^{-1} cimaterol. However, they did observe increased drip losses from the *longissimus* muscles of these cattle 2 and 6d postmortem (Table 10). While the data for lambs fed BAA indicate that muscle pH was increased, the effect of pH on muscle color did not adversely affect visual color scores.

Tenderness

Jones et al. (1985) reported that pork loin chops of pigs fed 1 ppm cimaterol had greater Warner-Bratzler shear values ($P<.05$) than those fed .25, .5 ppm or the controls (Table 11). After 7d of withdrawal, shear values for none of the agonist-fed pigs differed from controls. VanWeerden (1987) observed no difference from controls for shear values of pigs fed 1 ppm clenbuterol. Yen and Mersman (1988) observed increased shear values in loin chops of lean and obese pigs fed either .69 or 1.38 ppm cimaterol compared to controls. They found no difference between level of BAA fed or between lean and obese pigs in tenderness (Table 12).

Loin chops from lambs fed 10 ppm cimaterol did not differ in shear value from untreated controls (Beerman et al., 1985; Table 11). In contrast, Hamby et al. (1986) reported that shear values of lambs fed 2 ppm clenbuterol were greater ($P<.05$) than controls. Allen et al. (1986) also observed increased shear values in muscles of cattle fed either 33, 49.5 or 66 mg.head^{-1}.d^{-1} cimaterol compared to controls. Schiavetta et al. (1988) reported that shear values of loin steaks from cattle fed 7 mg.head^{-1}.d^{-1} clenbuterol for 50d were increased by 19% but decreased after 90d of withdrawal of the agonist (Table 11).

Table 11. Effect of Beta-Adrenergic Agonists on Longissimus Tenderness.

Species and Agonist	*Level fed, ppm*	*Observation*	*Source*
Pork – Cimaterol	.25, .5, 1	increased shear for 1 ppm	Jones et al., 1985
Clenbuterol	1	ND	vanWeerden, 1987
Lambs – Cimaterol	10	ND	Beermann, et al., 1985
Clenbuterol	2	increased shear	Hamby et al., 1986
Cattle – Cimaterol	33, 49.5, 66 mg/hd/d	increased shear	Allen et al., 1986
Clenbuterol	7 mg/hd/d	increased shear 19%	Schiavetta et al., 1988

Table 12. Shear Values of Loin Chops From Lean and Obese Pigs Fed Cimaterol for 10 Weeks.[a,b,c]

		Cimaterol, ppm	
Phenotype	*Control*	*.69*	*1.38*
Obese	3.45[d]	4.54[e]	4.64[e]
Lean	3.84[d]	4.92[e]	5.29[e]

[a] Data courtesy of J-T Yen and H.J. Mersman, USDA-ARS, Clay Center, NE.
[b] Pooled SE = .45.
[c] Kilograms force to shear 1.27 cm diameter cores.
[d,e] Means in a row with different superscripts differ ($P<.05$).

Lee et al. (1988) indicated that BAA did not affect tenderness of muscles equally. They fed 5 ppm cimaterol to lambs to study the effects of stress and withdrawal of the agonist on meat tenderness as assessed by Warner-Bratzler shear (Table 13). The *longissimus* muscle of lambs fed cimaterol for 8 wk had greater ($P<.05$) shear values than controls or those fed the agonist for 7 wk and after 1 wk of withdrawal. Shear values of the *semimembranosus* muscles of BAA-treated lambs were greater than controls, while those of the *semitendinosus* muscles did not differ between treatments. Neither stress nor withdrawal affected shear force values in these lambs fed cimaterol.

Table 13. Effects of Cimaterol, Its Withdrawal and Imposed Stress on Shear Values of Lambs.[a].

Trait	*Control*	*7 wk Cim.[b] 1 wk WD[c]*	*8 wk Cim.[b] min. stress[d]*	*8 wk Cim.[b] mod. stress[e]*
Warner-Bratzler shear, kg				
Longissimus	6.7[f]	7.9[f]	9.3[g]	8.2[g]
Semimembranosus	6.8[f]	8.9[g]	10.9[g]	10.1[g]
Semitendinosus	5.9	6.6	7.0	6.1

[a] Data courtesy of Yu B. Lee, University of California.
[b] Cim = cimaterol (5 ppm).
[c] WD = withdrawal of cimaterol from feed.
[d] min = minimum stress (attempt to minimize stressful conditions).
[e] mod = moderate stress (solitary isolation for 6h).
[f,g] means within a row without common superscripts differ ($P<.05$).

Table 14. Warner-Bratzler Shear Values and Total Calcium-Dependent Proteinase (CDP) Activity.[a]

Characteristic	*WK*	*Control*	*Ractopamine, 20 ppm*
Warner-Bratzler shear, kg[b]			
	4	2.60 ± .21	2.84 ± .28
	6	3.00 ± .12	3.09 ± .25
Total CDP activity[c]			
	2	.54 ± .17	.56 ± .12
	4	.51 ± .14	.63 ± .05
	6	.60 ± .15	.34 ± .22

[a]Michigan State University data from pigs.
[b]Kilograms per 1.27 diameter core.
[c]Absorbance at 278 nm per g muscle.

Table 15. Catheptic Enzyme Activities.[a,b,c]

Enzyme	*Wk*	*Control*	*Ractopamine, 20 ppm*
Cathepsin B			
	2	28.8 ± 1.27	26.2 ± 2.24
	4	19.4 ± 1.26	22.4 ± .90
	6	22.8 ± 1.18	23.1 ± 1.51
Cathepsin H			
	2	149.2 ± 3.19	132.5 ± 2.42
	4	106.6 ± 1.94	125.0 ± 1.68
	6	170.6 ± 3.77	222.4 ± 3.83
Cathepsin L			
	2	60.1 ± 1.54	68.5 ± 2.36
	4	46.1 ± 1.26	64.3 ± 1.77
	6	54.4 ± 1.72	73.8 ± 2.26

[a]Michigan State University data from pigs.
[b]Catheptic enzyme activities are the total of the sedimentable and unsedimentable fractions for each enzyme.
[c]Activities expressed as units·mg protein^{-1}min^{-1} (1 unit is the release of 1 mol of product/min).

Table 16. Instron Shear Force of Longissimus Muscle as Influenced by Cimaterol.[a]

	Treatment[b]			
Interval	*Control*	*Cimaterol*[c]	*% Change*	*P-Value*
3 wk, kg	5.43	6.22	14.5%	P<.02
6 wk, kg	4.49	6.47	44.1%	P<.001

[a]Data courtesy of Don H. Beermann et al., Cornell University.
[b]Cimaterol added as a premix at 10 ppm.
[c]Numbers of lambs per treatment group = 6, except Cimaterol at 6 wk = 5.

Table 17. Effect of Cimaterol Administration on Specific Activity of Calcium-Dependent Proteinase in Longissimus Muscle of Lambs Treated for 3 and 6 weeks.[a,b]

	Treatment	*Treatment*		*Percentage*		
Item	*Period*	*Control*	*Cimaterol*[c]	*Change*	*P-Value*	*Sem*[d]
CDP-I[e,f]	3 wk	0.96	0.43	−55.2%		
	6 wk	.078	.023	−70.5%		
	Mean	.087	0.33	−62.1%	P<.001	.0099
Total CDP[e,f]	3 wk	.377	.426	+13.0%		
	6 wk	.344	.426	+23.8%		
	Mean	.35	.429	+20.8%	NS	.0285

[a]Data courtesy of Don H. Beermann et al., Cornell University.
[b]Values are least square means.
[c]Cimaterol added as a premix at 10 ppm.
[d]SEM = Standard error of the means.
[e]Specific activity of CDP is expressed as absorbance units.mg protein^{-1}. 30 min^{-1}.
[f]Number of animals per smallest subclass: N = 8 (3 wk); = 6 (6 wk).

Table 18. Effect of L-644,969 on Cathepsin B and Calcium-Dependent Proteinase Activity in Lambs.[a,b]

Item	*% Change from Control*
Cathepsin B	36% decrease (P<.05)
CDP-II	48% increase (P<.05)
Calpastatin	68% increase (P<.01)

[a]Data courtesy of William R. Dayton et al., University of Minnesota.
[b]Fed 4 ppm L-644,969.

Merkel et al. (1988) observed no difference in shear values of pork loin chops of pigs fed 20 ppm ractopamine for either 4 or 6 wk (Table 14). McKeith et al. (1988) also reported no difference in shear force values of pork loin chops from control pigs for those fed either 5, 10 or 20 ppm ractopamine (Table 20). Merkel et al. (1988) found no differences in total calcium-dependent proteinase (CDP) activity (Table 14) or cathepsin B, H or L activities (Table 15) between ractopamine-fed pigs and controls at either 2, 4 or 6 wk of treatment.

Wang et al. (1988) observed that Instron shear force of *longissimus* muscles of lambs fed 10 ppm cimaterol was increased 14.5% and 44% after 3 and 6 wk of treatment, respectively (Table 16). To assess the contribution of proteolytic activity on these differences in tenderness, they measured the micromolar calcium-dependent proteinase (CDP-I) and total CDP activities. In lambs fed cimaterol for 3 and 6 wk, CDP-I activity was decreased by 55% and 62%, respectively (Table 17). Interestingly, total CDP activity was increased by 13% and 24% at 3 and 6 wk, respectively. This indicates that CDP-II (millimolar calcium requiring form) activity was increased markedly to account for the increase in total CDP activity. Since CDP-I is undoubtedly contributing significantly more to postmortem proteolysis than CDP-II and the former activity is decreased, these authors suggest that this observation may account for the decreased tenderness in BAA-treated lambs. Kretchmar et al. (1988) also reported increased CDP-II activity (48%) as well as increased

calpastatin activity (68%) in lambs fed 4 ppm L-644,969 compared to untreated controls (Table 18). While they did not report CDP-I activity, they observed that cathepsin B activity was decreased in lambs fed BAA, which they indicated may play a role in the decreased tenderness. To determine the cause(s) of the decreased tenderness in BAA-treated lambs, Lee et al. (1988) measured sarcomere lengths in the *longissimus* and *semitendinosus* muscles (Table 19). Sarcomere length did not differ in either muscle between controls and lambs fed 5 ppm cimaterol.

These data indicate that tenderness (shear force values) of pork loin chops are not adversely affected by feeding BAA to pigs in most studies reported to date. In the several studies in which shear force values were significantly increased, the values are well within the acceptable tenderness range reported for pork loin chops by DeVol et al. (1988). The effect of BAA on tenderness of lamb and beef *longissimus* muscle appears to be related to the agonist, the length of time it is fed and the level at which it is fed.

Palatability Traits

McKeith et al. (1988) reported the effects of 0, 5, 10 or 20 ppm ractopamine on panel juiciness, tenderness, flavor intensity, off-flavor intensity and overall desirability scores of fresh pork loin chops (Table 20). They observed no significant linear effect (ractopamine dose) or in the contrast of treated vs control for any of the palatability traits. These authors also compared these same palatability traits on the *semitendinosus* muscles of cured ham from these pigs (Table 21). Ractopamine at no level affected palatability scores of cured hams compared to controls. Both the linear effect and the contrast of treated samples vs controls were nonsignificant. These data indicate that the palatability scores of fresh pork loin chops and cured hams from pigs fed 5, 10 or 20 ppm ractopamine were similar to untreated controls.

Processing Yields

McKeith et al. (1988) reported various yields obtained during the curing process for hams and bellies from pigs fed 0, 5, 10 or 20 ppm ractopamine (Table 22). They observed a significant linear effect ($P<.05$) for all ham yield data and for the contrast of treated vs control for all data except percent ham yield. Neither the linear effect nor the treated vs control contrast was significant for any of the yields of the pork belly during processing. These data suggest that the muscle hypertrophy characteristics of BAA-treated pigs resulted in greater processed yield of hams compared to controls. These yield observations were not apparent in the fatter belly even though the bellies of the treated pigs were leaner than those of controls.

Table 19. Effect of Cimaterol on Sarcomere Length and Longissimus Muscle of pH.[a]

Trait	*Control*	*Cimaterol, 5ppm*
Sarcomere length, μm		
Longissimus	1.91 ± .16	1.72 ± .30
Semitendinosus	2.05 ± .10	1.92 ± .21
Longissimus pH_{24}	5.6[b]	5.8 -6.0[c]

[a] Data courtesy of Yu B. Lee, University of California.
[b,c]Means within a row without common superscripts differ ($p<.05$).

Table 20. Palatability Characteristics of Pork Loin Chops.[a,b]

	Ractopamine level, ppm			
Trait	*0*	*5*	*10*	*20*
Number obs.	23	12	11	12
Juiciness[c]	4.82	4.93	5.03	5.13
Tenderness[c]	5.72	5.44	5.61	5.69
Flavor intensity[c]	6.42	6.26	6.34	6.18
Off-flavor intensity[c]	7.30	7.30	7.04	7.16
Over desirability[c]	5.77	5.43	5.68	5.80
Warner-Bratzler shear force[d]	2.84	3.15	3.76	2.78

[a]Data courtesy Floyd K. McKeith et al., University of Illinois.
[b]Nonsignificant linear effect, and the contrast control vs treated.
[c]Eight point scale, 8 most desirable and 1 least desirable for each trait.
[d]Kg force required through a 1.27 cm diameter core.

Table 21. Palatability Scores and Shear Values of Cured Ham (Semimembranosus) from Pigs Fed Ractopamine for 48 Days.[a,b]

	Ractopamine Level, ppm			
Trait	*0*	*5*	*10*	*20*
Number obs.	22	12	10	12
Moistness[c]	5.01	4.65	4.73	5.12
Off-flavor intensity[c]	7.46	6.98	6.86	6.97
Textural mouth feel[c]	5.48	5.58	5.61	5.73
Tenderness[c]	6.08	6.07	6.23	6.19
Overall desirability[c]	5.80	6.01	6.08	6.07
Warner-Bratzler shear value[d]	1.20	1.31	1.29	1.32

[a]Data courtesy of Floyd K. McKeith et al., University of Illinois.
[b]Nonsignificant linear effect and the contrast control vs treated.
[c]Scores of 8 most desirable and 1 least desirable for each trait.
[d]*Kilograms force to shear 1.27 cm diameter cores.*

Table 22. Processing Yields of Hams and Bellies From Pigs Fed Ractopamine.[a]

	Ractopamine level, ppm					
Trait	*0*	*5*	*10*	*20*	*Linear effect[b]*	*Control vs Treated[b]*
Number obs.	22	12	11	12		
Ham weight, kg	6.41	6.86	6.72	7.21	*	*
Ham pumped weight, kg	7.12	7.59	7.51	8.10	*	*
Ham cooked weight, kg	6.13	6.73	6.46	7.26	*	*
Ham yield, %	95.67	97.91	96.64	100.64	*	–
Belly weight, kg	5.88	5.68	6.04	6.18	–	–
Belly pumped weight, kg	6.26	5.98	6.40	6.57	–	–
Belly cooked weight, kg	5.60	5.33	5.66	5.89	–	–
Belly yield, %	95.18	93.89	93.48	95.02	–	–

[a]Data courtesy of Floyd K. McKeith et al., University of Illinois.
[b]* $P<.05$ linear effect, and control vs treated for ham data *except* NS % ham yield for latter contrast.
[c]Ham yield = cooked ham wt/boneless ham green wt.
[d]Belly yield = cooked belly wt/belly green wt.

Table 23. Effect of Porcine Somatotropin on Pork Quality Characteristics of Longissimus Muscle.[a,b]

	Somatotropin, μg/kg BW					
Observation	*0*	*30*	*60*	*120*	*200*	S_X
24-h pH	5.33[c]	5.43[d]	5.44[d]	5.47[d]	5.53[d]	.034
Gardner Rd-Value	26.24[c,d]	27.05[c]	23.94[d,e]	24.46[d]	22.87[e]	.52
Gardner a-Value	13.32[c]	12.74[c,d,e]	12.38[d,e]	12.18[e]	11.10[f]	.20
Cooking loss, %	20.25	23.74	23.34	21.77	20.96	1.37
Instron shear value, kg	3.17	2.89	3.59	3.03	3.76	.28

[a]Data courtesy Don H. Beermann et al., Cornell University.
[b]N = 16 per treatment group.
[c,d,e,f]Means within a row without a common superscript differ ($P<.05$).

Porcine Somatotropin

Few published data are available on the effects of somatotropin on the qualitative properties of meat, and none is available for beef or lamb. The most extensive studies are those of Beermann and co-workers for porcine somatotropin, and they are summarized here.

Daily injections of pituitary-derived porcine somatotropin (pSTH) at 0, 30, 60, 120 or 200 ug/kg body weight increased ($P<.05$) *longissimus* 24h pH from .1 (30 ug/kg) to .2 (200 ug/kg) units (Table 23). Gardner "Rd" values were also in-

Table 24. Effects of Recombinantly-Derived Porcine Somatotropin on Rib Chop Quality Characteristics.[a,b]

Characteristic	Control	22 Kd Form Somatotropin, μg/kg			21 Kd Form Somatotropin, μg/kg			S_x
	0	30	60	90	30	60	90	
Juiciness	4.58[c,d]	5.03[c]	4.23[d]	4.86[c]	4.75[c]	4.77[c]	4.54[c,d]	.40
Tenderness	4.77[c,d,e]	4.62[d,e]	4.49[e]	5.23[c]	4.72[d,e]	5.05[c,d]	4.61[d,e]	.42
Flavor Intensity	5.25[c]	5.06[c,d]	4.70[d]	5.26[c]	5.13[c,d]	5.03[c,d]	5.06[c,d]	.36
Meat Aroma	5.06[c]	4.51[d]	4.97[c,d]	5.02[c,d]	5.11[c]	5.03[c]	4.97[c,d]	.41
Cooking Loss, %	25.9	24.8	26.5	25.1	24.1	25.4	25.6	1.30
Instron Shear Value, kg	5.19	5.35	5.46	5.25	5.41	4.70	5.19	.33

[a]Data courtesy Don H. Beermann et al., Cornell University.
[b]N = 10 per treatment group.
[c,d,e]Means which do not share a common superscript differ (P<.05).

creased (P<.05) indicating darker color while "a" values were decreased (P<.05), i.e., less red in pSTH-treated pigs. The authors stated that color of muscle was visually not perceptibly altered by pSTH-treatment. Neither cooking losses nor Instron shear values were significantly altered by pSTH.

These authors (Beermann et al., 1988) also studied the effects of two (21 vs 22 Kd) forms of recombinantly-derived pSTH (0, 30, 60 and 90 ug/kg body weight) on palatability traits as well as percent cooking losses and Instron shear values (Table 24). Panel juiciness, tenderness, flavor intensity and meat aroma of pork rib chops essentially did not differ between control pigs and those injected daily with either form of pSTH. Cooking losses and Instron shear values also were not affected by pSTH treatment. These data indicate that even though carcass fat content was dramatically reduced, pork quality and palatability traits were not adversely affected by treatment with pSTH.

Summary

Feeding beta-adrenergic agonists to pigs has little or no effect on marbling, color, firmness/wateriness, pH, water-holding capacity, tenderness or postmortem proteolysis of porcine muscles. The BAA either cause no change or they decrease marbling and/or ether-extractable lipid of lamb and beef *longissimus* muscles. They increase muscle pH with either no change (visual scores) or slight increases in darkness (objective measurements) of beef and lamb muscles. Shear force values of beef and lamb muscles are increased by feeding BAA and tend to reflect level of agonist fed, length of feeding the agonist or whether a withdrawal period follows BAA treatment. Feeding BAA to lambs decreased CDP-I and cathepsin B activity and increased CDP-II and calpastatin activities in postmortem muscles.

Pituitary-derived porcine somatotropin (pSTH) had no effect on shear values, cooking losses or on marbling and firmness/wateriness scores of porcine muscle. Even though pSTH increased ultimate pH and decreased Gardner "Rd" and "a" values, visually muscle color did not differ between treated and controls. Recombinantly-derived porcine somatotropin decreased intramuscular lipid but had no effect on Instron shear values, nor did it affect cooking losses or panel scores for flavor, aroma, juiciness, tenderness and amount of connective tissue.

Conclusions

Although several of the beta-adrenergic agonists have been shown to markedly improve growth performance and carcass composition, they have little or no effect on qualitative properties and palatability of pork muscles. The slightly darker color of muscles from beef and lambs fed BAA does not appear to be of any practical significance. That BAA decrease tenderness of beef and lamb muscles is apparent, but the extent of the decrease appears to be associated with specific agonists, the level fed and the length of feeding the agonist. Other qualitative properties of beef and lamb muscle do not appear to be significantly affected by BAA. Somatotropin dramatically improves growth performance and composition of gain without adversely affecting quality or palatability traits of pork.

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