THE EFFECT OF REPARTITIONING AGENTS ON CARCASS AND MEAT QUALITY

Floyd K. McKeith
*Department of Animal Sciences,
University of Illinois,
Urbana, Illinois, 61801,
United States*

Summary

The use of repartitioning agents has been discussed extensively during the last decade. Numerous studies have been conducted to evaluate the efficacy and safety of these products. Somatotropin (SM) has been evaluated extensively in swine. However, limited information is available on other meat animals. Somatotropin is very effective in improving the composition of carcasses and yet has limited effects on the sensory and processing characteristics of pork. Several beta-adrenergic agonists (BA) are being evaluated for safety and efficacy as repartitioning agents in a wide variety of meat animals. These compounds improve carcass composition and have limited, or no, effect on colour and intramuscular fat content of muscle. Some BA affect tenderness more than others. Improvements in the composition of meat animals and the efficiency of growth obtained through the use of repartitioning agents will be beneficial to the livestock and meat industry.

Introduction

Repartitioning agents have been evaluated extensively during the last decade. Somatotropin (SM) and beta-adrenergic agonists (BA) have been shown to have dramatic effects on carcass composition (increasing muscle mass and reducing fat content). Although these compounds have different modes of action, they have a similar effect on the growth and composition of meat animals. Repartitioning agents have been evaluated on a variety of species of livestock. However, more information is currently available on swine than the other species.

To clearly characterize the effects of repartitioning agents on carcass and meat quality, we must define quality. In this review, carcass quality will refer to slaughter characteristics, carcass cutting yields and composition. Meat quality will refer to the appearances of fresh muscle and the sensory properties of fresh and processed meats.

The purpose of this review is to discuss the efficacy of repartitioning agents and their impact on the quality and acceptability of meat and meat products.

Somatotropin

Somatotropin has a consistent effect of reducing dressing percentage 2 to 3% in swine and cattle (Table 1). This reduction in dressing percentage is directly related to the increase in size, or yield, of by-products. McKeith *et al.* (1989) reported increase in the weights of livers, kidneys, hearts and stomachs in swine. The increase in by-product yields have limited economic value in the pork industry.

McKeith *et al.* (1989) discussed implications of somatotropin to the pork processing industry. The slaughter segment of the industry would require few alterations. However, the fabrication and processing segment may require some changes. The reduction of subcutaneous fat may require changes in the procedures used to remove fat and skin from the loin. Belly thickness may be reduced and ultimately make bellies too thin for traditional bacon production.

Table 1. Effect of somatotropin on dressing percentage of beef and swine.

Pigs	
Machlin, 1972	up to 3.4% ↓
Baile *et al.*, 1983	≈ 1% ↓
Chung *et al.*, 1985	ND[a]
Bryan *et al.*, 1989	up to 2.1% ↓
Knight *et al.*, 1991	up to 1.5% ↓
Bidanel *et al.*, 1991	up to 3% ↓
Clark *et al.*, 1992	2.8% ↓
Lefaucheur *et al.*, 1992	up to 3.6% ↓
Goodband *et al.*, 1993	up to 4% ↓
Cattle	
Dalke *et al.*, 1992	ND
Moseley *et al.*, 1992	up to 4% ↓

[a] ND = not different

Table 2. Effects of somatotropin on carcass composition.

Swine		
Chung *et al.*, 1985	% muscle	4.2 ↑
	% fat	.ND
Etherton *et al.*, 1986	% protein	1.2% ↑
	% fat	5.3% ↓
Etherton *et al.*, 1987	% protein	1.9% ↑
	% fat	7.1% ↓
Campbell *et al.*, 1989a	% protein	2.8% ↑
	% fat	11.3% ↓
Campbell *et al.*, 1989b	% protein	.ND
	% fat	5.6% ↓
McLaughlin *et al.*, 1989	% protein	1.4% ↑
	% fat	4.8% ↓
Bidanel *et al.*, 1991	% protein	11.8% ↑
	% fat	12.7% ↓
Knight *et al.*, 1991	% protein	1.0% ↑
	% fat	4.6% ↓
Cattle [a]		
Dalke *et al.*, 1992	% protein	1.3% ↑
	% fat	4.7% ↓
Moseley *et al.*, 1992	% protein	1.4% ↑
	% fat	5.6% ↓

[a] Composition of 9-10-11th ribs.

Treatment of swine with somatotropin can reduce fat content up to 10 to 15% and increase lean content up to 10 to 15%(Table 2). The changes in composition for cattle were smaller, 5.6% and 1.4% for protein and fat respectively. These changes will reduce subcutaneous fat thickness 20 to 40% and will also have an effect on the intermuscular fat of most cuts. Reducing intermuscular fat is important to the meat industry because of the difficulty of trimming and/or removing intermuscular fat from fresh cuts of meat. Contemporary consumers are conscious of the fat that they are consuming and cuts with high levels of intermuscular fat are difficult to merchandise. Improvements in the percentage of muscle protein translate into larger muscles which is a positive attribute for the fresh and processed pork industries. The magnitude of the compositional changes for beef were smaller than those observed for pork, but reducing fat and increasing lean in feedlot animals is an asset to the beef industry. Limited information is available on the effects of somatotropin on sheep and poultry.

Changes in composition will result in changes in the carcass cutting yield of meat animals. The yield of cuts from pigs treated with somatotropin (4mg/d) is presented in Table 3. The yield of the untrimmed and trimmed major wholesale cuts did not differ dramatically between the control and SM treatments. However, boneless cut yields from somatotropin-treated carcasses were higher for all major cuts, with the exception of the picnic shoulder. Changes in the composition of cuts was the most dramatic result of this comparison. SM reduced the fat content of boneless trimmed cuts by 25 to 50%. This change was a result of reducing intermuscular and intramuscular fat. As stated previously, the reduction of intermuscular fat enhances the appearance of meat. However, reduction of intramuscular fat in pork and beef may not be desirable. Research has suggested that intramuscular fat contents of 2 to 2.5% for pork and 3 to 3.5% for beef are the thresholds of acceptability.

Somatotropin has limited effects on the colour of pork (Table 4) and reduces the intramuscular fat content in the *longissimus* of beef and pork by 20 to 40%. The reduction in intramuscular fat content has a direct effect (based on the current grading program) on the value of beef animals in the United States. Intramuscular fat content of pork has no direct economic effect on the value of pork. Sensory properties of pork *longissimus* muscle are presented in Table 5. Somatotropin increases shear force of pork in most cases, although it has limited effects on sensory ratings for tenderness and juiciness. The values reported for most of the studies were less than 4 kg of force for shears and the sensory responses were above the midpoint of the scale which suggests that the products had acceptable palatability ratings.

The processing properties of pork treated with somatotropin have been evaluated on sausage and cured meat products. Lonergan *et al.* (1992) evaluated the processing properties of pepperoni, boneless ham and bacon from somatotropin-treated pork and found few economically important differences. McKeith and Merkel (1991) reported that the processing yields of thin bellies were lower than traditional bellies but that no difference were observed in the sensory properties of the product. Boles *et al.* (1991) found no differences in the processing and sensory properties of hams from somatotropin and control hams. Halloran *et al.* (1991) reported that cured hams, loins and bellies from somatotropin-treated animals had characteristics beneficial to both processors and consumers.

Table 3. Effect of somatotropin on the carcass yield and composition of major wholesale cuts[a].

		Control	*Somatotropin*
Side weight (kg)		34.56	33.79
Wholesale cuts (kg)	*Ham*	9.24	9.36
	Loin	8.49	8.28
	Belly	5.39	5.03
	Shoulder	7.36	7.22
Trimmed wholesale cuts (kg)	*Ham*	8.21	8.51
	Loin	6.75	7.07
	Picnic Shoulder	3.85	3.84
	Boston butt	2.58	2.75
Boneless trimmed	*Ham* (kg)	6.16	6.57
	Water (%)	68.34	71.67
	Lipid (%)	12.48	8.96
	Loin (kg)	4.50	4.99
	Water (%)	56.74	66.95
	Lipid (%)	27.18	14.05
	Boston butt (kg)	2.43	2.55
	Water (%)	62.70	70.92
	Lipid (%)	20.99	10.00
	Picnic shoulder	2.94	2.89
	Water (%)	67.35	71.67
	Lipid (%)	15.00	9.34

[a] McKeith *et al.*, 1989.

Beta-adrenergic agonists

A variety of beta-adrenergic agonists have been evaluated in meat animals (Figure 1). The structures of these compounds differ and suggest that the effects of the compounds may vary. BA consistently increase the dressing percentage in pork, beef, lamb and poultry (Table 6). The increase in dressing percentage may be related to increasing muscle mass, decreasing fat and limited effects on by-products.

Numerous studies have evaluated the efficacy of BA on growth and composition of meat animals. In this review, I selected papers that presented composition changes in percentage muscle, protein and/or fat (Table 7). Most studies suggest that BA will reduce the fat content of the carcass by 5 to 10% and will increase muscle mass to the same extent. The magnitude of the response for poultry is not as large as that found in pork or beef.

Table 4. Effects of somatotropin on the colour, firmness and marbling of the *longissimus* muscle.

Swine		
Chung *et al.*, 1985[a]	marbling	0.8 ↑
	% lipid	0.6% ↑
Novakofski *et al.*, 1987[a]	colour	N.D
	firmness	0.4 ↓
	marbling	0.4 ↓
	% lipid	0.7% ↓
		1.4% ↓
McLaughlin *et al.*, 1989[a]	colour	N.D
Beermann *et al.*, 1990[a]	colour	0.1 ↓
	firmness	0.2 ↓
	marbling	0.5 ↓
Bidanel *et al.*, 1991	% lipid	1.3% ↓
Miller *et al.*, 1991[a]	colour	0.7 ↑
	firmness	0.2 ↓
	marbling	1.0 ↓
Clark *et al.*, 1992[a]	colour	N.D
	marbling	0.3 ↓
Goodband *et al.*, 1993[a]	colour	0.4 ↓
	firmness	0.2 ↓
	marbling	0.9 ↓
Cattle		
Dalke *et al.*, 1992	marbling	0.7 degree ↓
	quality grade	2/3 grade ↓

[a] = Using a 5-point scale.

Table 5. Effects of somatotropin on the sensory properties of pork *longissimus*.

Novakofski *et al.*, 1987[a]	tenderness	up to 0.6 ↓
	juiciness	N D
	shear force	up to 0.3kg ↑
Solomon *et al.*, 1988	shear force	up to 1.1kg ↑
Prusa *et al.*, 1989[b]	tenderness	up to 31.8 ↓
	juiciness	N D
	shear force	N D
Beerman *et al.*, 1990	shear force	up to 0.6kg ↑
Boles *et al.*, 1991[b]	tenderness	up to 7.0 ↓
	juiciness	up to 12.0 ↓
Solomon et al., 1991	shear force	up to 1.6kg ↑
Goodband *et al.*, 1993[c]	tenderness	up to 0.7 ↓
	juiciness	up to 0.8 ↓
	shear force	up to 1.0kg ↑

[a] = 14-point scale; [b] = 150-point scale; [c] = 10-point scale.

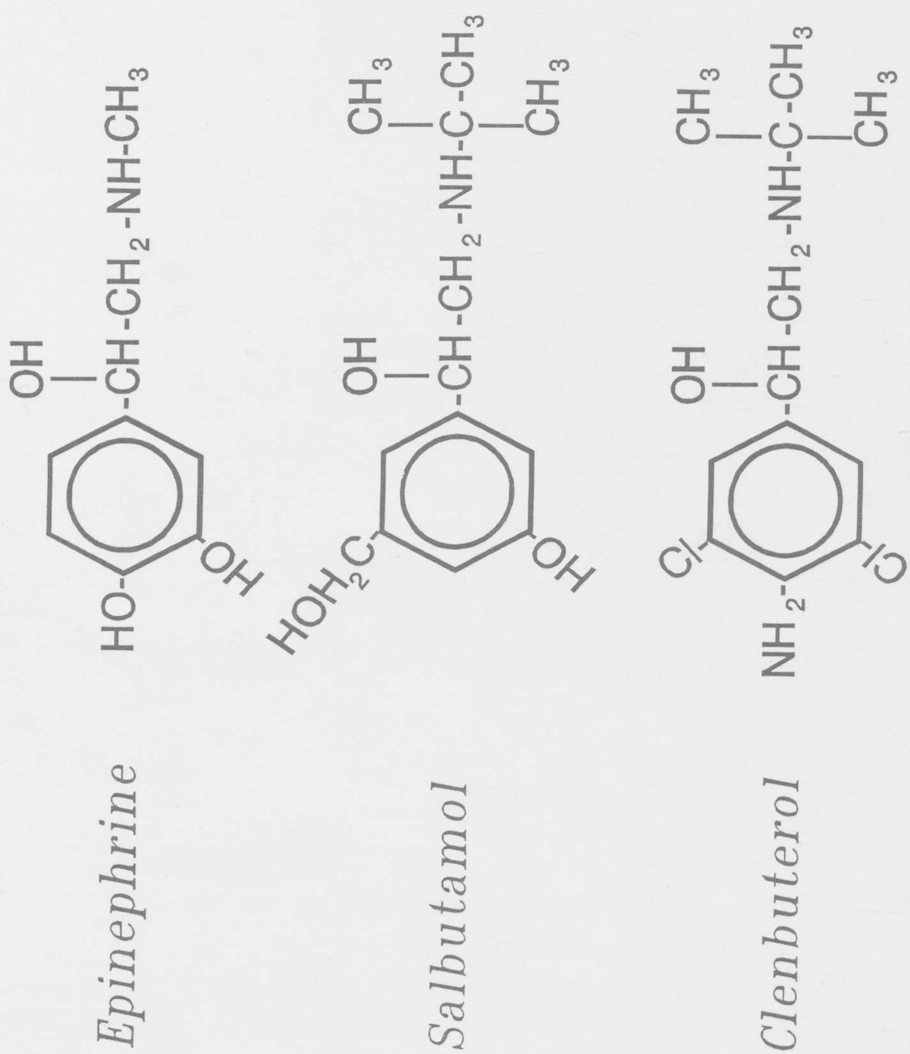
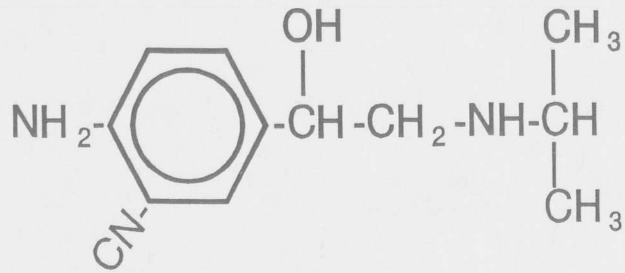
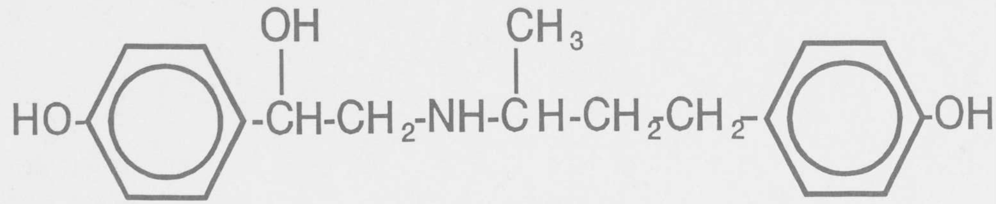


Figure 1. Beta-adrenergic agonists.

Cimaterol



Ractopamine



L-644,969

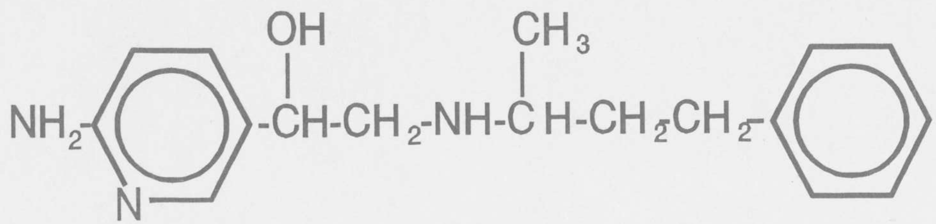


Figure 1 (cont.). Beta-adrenergic agonists.

Table 6. Effects of beta agonists on dressing percentage.

Swine		
Dalrymple *et al.*, 1984a	CL	0.9% ↑
Dalrymple, 1984	CM	0.7% ↑
Jones *et al.*, 1985	CM	1.0% ↑
Moser *et al.*, 1986	CM	0.3% ↑
Stites *et al.*, 1991	RAC	2.0% ↑
Bark *et al.*, 1992	RAC	N D
Cole *et al.*, 1987	SL	2.2% ↑
Warriss *et al.*, 1990a	SL	2.0% ↑
Warriss *et al.*, 1990b	SL	1.6% ↑
Beef		
Ricks *et al.*, 1987	CL	0.8% ↑
Hanrahan *et al.*, 1986	CM	4.6% ↑
Carroll *et al.*, 1990	RAC	0.3% ↑
Chikhou *et al.*, 1993	CM	up to 3.5% ↑
Sheep		
Dalrymple *et al.*, 1984a	CL	2.6% ↑
Kim *et al.*, 1987	CM	4.9% ↑
Shackelford *et al.*, 1992	$L_{644,969}$	N D
Poultry		
Dalrymple *et al.*, 1984b	CL	1.1% ↑
Dalrymple and Ingle, 1987	CM	1.0% ↑
Wellemreiter and Tonkinson, 1990	RAC	1.1% ↑

CL = Clenbuterol
CM = Cimaterol
RAC = Ractopamine
SL = Salbutamol

Table 7. Effect of beta adrenergic agonists on carcass composition.

Swine			
Moser *et al.*, 1986	CM	% muscle	2.6% ↑
Watkins *et al.*, 1990	RAC	% muscle	up to 6.0% ↑
		% fat	up to 4.3% ↓
Stites *et al.*, 1991	RAC	% muscle	3.0% ↑
Bark *et al.*, 1992	RAC	% muscle	10.8% ↑
		%fat	9.9% ↓
Cattle[a]			
Ricks *et al.*, 1984	CL	% protein	up to 2.2% ↑
		% fat	up to 10.6% ↓
Hanrahan *et al.*, 1987	CM	% fat	up to 8.3% ↓

Table 7 (cont.). Effect of beta adrenergic agonists on carcass composition.

Cattle (cont.)			
Convey *et al.*, 1987	$L_{644,969}$	% muscle	up to 8.0% ↑
		% fat	up to 6.0% ↓
Anderson *et al.*, 1989	RAC	% protein	up to 1.3% ↑
		% fat	up to 4.2% ↓
Sheep			
Baker *et al.*, 1984[b]	CL	% protein	up to 2.2% ↑
		% fat	up to 4.8% ↓
Kim *et al.*, 1987	CM	% protein	0.2% ↑
		% fat	1.5% ↓
Poultry			
Dalrymple & Ingle, 1987	CM	% fat	0.8% ↓
Gwartney *et al.*, 1991	CM	% protein	up to 1.0% ↑
		% fat	up to 1.5% ↓

[a] Composition of the 9-10-11th rib section.
[b] Hindsaddle analysis.

Table 8. Effects of diet and ractopamine on the carcass cutting yield[a] of market pigs[b].

	Protein %:	***14.00***	***16.00***	***16.00***
	Lysine %:	***0.15***	***0.00***	***0.00***
Cuts	***Ractopamine, ppm:***	***20.00***	***20.00***	***0.00***
Carcass weight, kg		77.9	77.5	77.0
Boneless Picnic, kg		2.97	2.99	2.85
Boston Butt, kg		2.67[cd]	2.82[c]	2.55[d]
Boneless Loin, kg		5.25	5.20	5.01
Skinless Belly, kg		5.19	5.08	5.19
Boneless Ham, kg		7.15[c]	7.21[c]	6.59[d]
Inside, kg		1.86[c]	1.88[c]	1.73[d]
Outside, kg		2.95[c]	3.04[c]	2.52[d]
Knuckle, kg		1.37	1.44	1.34

[a] Cut weights from one side of the carcass.
[b] Adapted from Stites *et al.*, 1989.
[c,d] Means in the same row with common superscripts do not differ (P>0.05).

Carcass cutting yields (Table 8) are improved with the use of ractopamine (RAC). The results are similar to those presented for SM. The magnitude of the differences between control and treated carcasses are smaller than would be expected. The composition of the cuts (Table 9) is improved a great deal (up to a 25% reduction in fat). The magnitude of the reduction is less than that of SM.

Table 9. Effect of diet and ractopamine on the composition of closely trimmed boneless wholesale cuts[a].

Cuts	*Protein %:*	*14.00*	*16.00*	*16.00*
	Lysine %:	*0.15*	*0.00*	*0.00*
	Ractopamine, ppm:	*20.00*	*20*	*0.00*
Picnic Shoulder				
Moisture, %		67.85[b]	68.17[b]	66.00[c]
Fat, %		13.66[b]	12.97[b]	61.75[c]
Protein, %		18.77[b]	18.98[b]	17.45[c]
Boston Butt				
Moisture, %		66.44[b]	65.17[b]	61.61[c]
Fat, %		17.95	17.02	22.23
Protein, %		17.73[b]	17.70[b]	15.97[c]
Ham				
Moisture, %		67.60[b]	68.28[b]	65.75[c]
Fat, %		12.79[b]	12.01[b]	16.00[c]
Protein, %		19.50[b]	19.50[b]	18.29[c]
Loin				
Moisture, %		60.03[b]	61.15[b]	57.62[c]
Fat, %		22.27[b]	20.54[b]	25.84[c]
Protein, %		17.65[b]	18.19[b]	16.61[c]
Belly				
Moisture, %		46.63[b]	48.82[b]	43.78[c]
Fat, %		40.10[c]	36.89[b]	44.02[d]
Protein, %		13.38[b]	13.97[b]	12.17[c]
Soft tissue				
Moisture, %		38.18[b]	40.95[b]	35.21[c]
Fat, %		50.93[b]	47.43[b]	55.03[c]
Protein, %		10.94[b]	11.43[b]	9.55[c]

[a] Adapted from Stites *et al.*, 1989.
[b,c,d] Means in the same row with common superscripts do not differ P>0.05).

Fresh meat characteristics (colour, marbling and firmness) were not affected or were improved with the use of BA (Table 10). Marbling score was increased in the two studies in swine. Limited data is available on the sensory properties of meat animals treated with BA. Stites *et al.* (1993) reported no difference in tenderness, juiciness and shear force of chops from pigs treated with RAC and Merkel (1988) found no difference in the shear force of pork treated with RAC. All other studies with other BA reported increases in shear force of muscle evaluated (Table 11). Merkel (1988) suggested that all BA do not affect tenderness in the same manner. Several studies have evaluated endogenous enzyme activity and found that some of the BA shift the activity of calcium dependent protease.

Table 10. Effect of beta adrenergic agonists on the colour, firmness, marbling and lipid content of muscle.

Swine			
Jones *et al.*, 1985[a]	CM	colour	N D
		firmness	N D
		marbling	N D
Moser *et al.*, 1986[a]	CM	colour	N D
		marbling	up to 0.7 ↑
Wallace et al., 1987a	$L_{644,969}$	colour	N D
		marbling	N D
Watkins *et al.*, 1990[a]	RAC	colour	up to 0.5 ↑
		firmness	up to 0.4 ↑
		marbling	up to 0.6 ↑
Stites *et al.*, 1991[a]	RAC	colour	N D
		firmness	N D
		marbling	N D
Warriss *et al.*, 1990a	SA	colour L*	N D
Warriss *et al.*, 1990b	SA	colour L*	N D
Cattle			
Ricks *et al.*, 1984	CL	marbling	N D
Miller *et al.*, 1988	CL	marbling	1.1 degree ↓
Allen *et al.*, 1987	CM	% lipid	N D
		colour	N D
Hanrahan *et al.*, 1987	CM	% lipid	N D
Chikhou *et al.*, 1993	CM	% lipid	up to 1.5% ↓
Anderson *et al.*, 1989	RAC	Quality grade	N D
Lamb			
Boucque *et al.*, 1987	CM	% lipid	N D
		colour	N D
Kim *et al.*, 1987	CM	colour	N D
Shackelford *et al.*, 1992	$L_{644,969}$	marbling	N D

[a] Using a 5-point scale.

Table 11. Effect of beta adrenergic agonists on the sensory properties of the *longissimus*.

Pork			
Jones *et al.*, 1985	CM	shear force	up to 0.5kg ↑
Warriss *et al.*, 1990a	SA	shear force	0.9kg ↑
Warriss *et al.*, 1990b	SA	shear force	0.8kg ↑
Merkel *et al.*, 1988	RAC	shear force	N D
Stites *et al.*, 1993	RAC	tenderness	N D
		juiciness	N D
		shear force	N D
Beef			
Miller *et al.*, 1988	CL	shear force	0.7kg ↑
Chikhou *et al.*, 1993	CM	shear force	up to 62N ↑
Lamb			
Koohmaraie *et al.*, 1991	$L_{644,969}$	shear force	up to 3.5kg ↑
Koohmaraie and Shackelford, 1991	$L_{644,969}$	shear force	up to 2.2kg ↑
Pringle *et al.*, 1993	$L_{644,969}$	shear force	3.5kg ↑
Merkel *et al.*, 1988	CM	shear force	up to 2.0kg ↑
Poultry			
Morgan *et al.*, 1989	CM	shear force	up to 1.3kg ↑
Gwartney *et al.*, 1991	CM	shear force	up to 1.2kg ↑

Processing characteristics (cured hams and bellies) are not affected by the use of RAC (Stites *et al.*, 1991; 1993). Results from these studies indicate that RAC had no effect on the processing yields of bacon or belly thickness and that processing yields of hams were increased. Sensory evaluation of the hams also indicated that there were no differences in the tenderness, juiciness or shear force of the *semimembranosus* muscle.

Conclusions

Repartitioning agents have positive effects on the composition of meat animals and have limited negative effects on carcass quality. Dressing percentage is negatively affected by SM although BA have a positive effect on this trait. The magnitude of changes in composition of carcasses and cuts are greater for SM-treated animals compared to animals treated with BA. Carcass quality was generally affected with the use of SM but the changes were small. BA created few tenderness of pork. Evaluation of the literature suggests that all BA do not affect tenderness the same in pork and that some of the BA have large effects on the tenderness of lamb.

References

ALLEN, P., QUIRKE, J.F., and TARRANT, P.V. 1987. Effects of cimaterol on the growth, food efficiency and carcass quality of Friesian cattle. In: J.P. HANRAHAN (Ed). *Beta-Agonists and Their Effects on Animals Growth and Carcass Quality*. Elsevier Applied Science, London and New York. p.83.

ANDERSON, D.B., VEENHUIZEN, E.L., WAGNER, J. F., WRAY, M.I., and MOWREY, D.H. 1989b. The effect of ractopamine hydrochloride on nitrogen retention, growth performance, and carcass composition of beef cattle. *J. Anim. Sci.* 67(Suppl. 1):222.

BAILE, C.A., DELLA-FERE, M.A., and MCLAUGHLIN, C.L. 1983. Performance and carcass quality of swine injected daily with bacterially-synthesized human growth hormone. *Growth*. 47:225-236.

BAKER, P.K., DALRYMPLE, R.H., INGLE, D.L., and RICKS, C.A. 1984. Use of a beta-adrenergic agonist to alter muscle and fat deposition in lambs. *J. Anim. Sci.* 59:1256-1261.

BARK, L.J., STAHLY, T.S., CROMWELL, G.L., and MIYAT, J. 1992. Influence of genetic capacity for lean tissue growth on rate and efficiency of tissue accretion in pig fed ractopamine. *J. Anim. Sci.* 70:3391-3400.

BEERMANN, D.H., FISHELL, V.K., RONEKER, K., BOYD, R.D., ARMBRUSTER, G., and SOUZA, L. 1990. Dose-response relationships between porcine somatotropin, muscle composition, muscle fibre characteristics and pork quality. *J. Anim. Sci.* 68:2690-2697.

BIDANEL, J.-P., BONNEAU, M., POINTILLART, A., GRUAND, J., MOUROT, J., and DEMADE, I. 1991. Effects of exogenous porcine somatotropin (pST) administration on growth performance, carcass traits and pork meat quality of Meishar, Pietrain and Crossbred gilts. *J. Anim. Sci.* 69:3511-3522.

BOLES, J.A., PARRISH, F.C.,Jr., SKAGGS, C.L., and CHRISTIAN, L.L. 1991a. Effect of porcine somatotropin, stress susceptibility and final end point of cooking on the sensory. physical and chemical properties of pork loin chops. *J. Anim. Sci.* 69:2865-2870.

BOLES, J.A., PARRISH, F.C.,Jr., SKAGGS, C.L., and CHRISTIAN, L.L. 1991b. Sensory and processing properties of cured semimembranosus muscle from stress-susceptible pigs treated with porcine somatotropin. *J. Anim. Sci.* 69:4049-4054.

BOUCQUE, Ch.V., FIEMS, L.O., SOMMER, M., COTTYN, B.G., and BUYSSE, F.X. 1987. Effects of the beta-agonist cimaterol on growth, feed efficiency and carcass quality of finishing Belgian white-blue beef bulls. In: J.P. HANRAHAN (ed). *Beta-Agonists and Their Effects on Animal Growth and Carcass Quality*. Elsevier Applied Science. London and New York. p.93.

BRYAN, K.A., HAMMOND, J.M., CANNINGS, S., MONDSCHEIN, J., CARBAUGH, D.E., CLARK, A.M., and HAGEN, D.R. 1989. Reproductive and growth responses of gilts to exogenous porcine pituitary growth hormone. *J. Anim. Sci.* 67:196-205.

CAMPBELL, R.G., STEELE, N.C., CAPERNA, T.J., McMURTRY, J.P., SOLOMON, M.B., and MITCHELL, A.D. 1989a. Interrelationships between sex and exogenous growth hormone administration on performance, body composition and protein and fat accretion of growing pigs. *J. Anim. Sci.* 67:177-186.

CAMPBELL, R.G., STEELE, N.C., CAPERNA, T.J., McMURTRY, J.P., SOLOMON, M.B., and MITCHELL, A.D. 1989b. Effects of exogenous porcine growth hormone administration between 30 and 60 kilograms on the subsequent and overall performance of pigs grown to 90 kilograms. *J. Anim. Sci.* 67:1265-1271.

CARROLL, L.H., KAUDERT, S.B., PARROTT, J.C., MOWREY, D.H., WHITE, D.R., ANDERSON, D.B., and MERRILL, J.K. 1990. Ractopamine HC1 dose titration in feedlot steers: Performance and carcass traits. *J. Anim. Sci.* 68(Suppl.):294.

CHIKHOU, J.F., MOLONEY, A.P., ALLEN, P., JOSEPH, R.L., TARRANT, P.V., QUIRKE, J.F., AUSTIN, F.H., and ROCHE, J.F. 1993. Long-term effects of cimaterol in Friesian steers: II. Carcass composition and meat quality. *J. Anim. Sci.* 71:914-922.

CHING, C.S., ETHERTON, T.D., and WIGGINS, J.P. 1985. Stimulation of swine growth of porcine growth hormone. *J. Anim. Sci.* 60:118-130.

CLARK, S.L., WANDER, R.C., and HU, C.Y. 1992. The effect of porcine somatotropin supplementation in pigs on the lipid profile of subcutaneous and intermuscular adipose tissue and *longissimus* muscle. *J. Anim. Sci.* 70:3435-3442.

COLE, D.J.A., WOOD, J.D., and WALLACE, M.M. 1987. Effects of the beta-agonist GAH/034 on growth, carcass quality and meat quality in pigs. In: J.P. HANRAHAN (ed). *Beta-Agonists and Their Effects on Animal Growth and Carcass Quality*. Elsevier Applied Science, London and New York. p.p. 137-142.

CONVERY, E.M. 1987. Effects of the beta-adrenergic agonist L644,969 on growth performance, carcass merit and meat quality. Proc. of Recip. Meat Conf. 40:47-55.

DALKE, B.S., ROEDER, R.A., KASSER, T.R., VEENHUIZEN, J.J., HUNT, C.W., HINMAN, D.D., and SCHELLING, G.T. 1992. Dose-response effects of recombinant bovine somatotropin implants on feedlot performance in steers. *J. Anim. Sci.* 70: 1230-1237.

DALRYMPLE, R.H. 1984. Repartitioning agents: Feed additives of the future to improve performance and carcass composition. University of Illinois 1984 Pork Industry Conference Proceedings. p.p. 93-104.

DALRYMPLE, R.H., BAKER, P.K., and RICKS, C.A. 1984a. Repartitioning agents to improve performance and body composition. Proc. Georgia Nutr. Conf. p.p. 111-118.

DALRYMPLE, R.H., BAKER, P.K., GINGHER, P.E., INGLE, D.L., PENSACK, J.M., and RICKS, C.A. 1984b. A repartitioning agent to improve performance and carcass composition of broilers. *J. Poult. Sci.* 63:2376.

DALRYMPLE, R.H., and INGLE, D.L. 1987. In: J.P. HANRAHAN (ed). *Beta-Agonists and Their Effect on Animal Growth and Carcass Quality.* Elsevier Applied Science, London and New York.

ETHERTON, T.D., WIGGINS, J.P., CHUNG, C.S., EVOCK, C.M., REBHUM, J.F., WALTON, P.E., and STEELER, N.C. 1987. Stimulation of pig growth performance by porcine growth hormone: determination of the dose-response relationship. *J. Anim. Sci.* 64:433-443.

ETHERTON, T.D., WIGGINS, J.P., CHUNG, C.S., EVOCK, C.M., REBHUM, J.F., and WALTON, P.E. 1986. Stimulation of pig growth by porcine growth hormone and growth hormone-releasing factor. *J. Anim. Sci.* 63:1389-1399.

GOODBAND, R.D., NELSSEN, J.L., HINES, R.H., KROPF, D.H., STONER, G.R., THALER, R.C., LEWIS, A.J., and SCHRICKER, B.R. 1993. Interrelationships between porcine somatotropin and dietary lysine on growth performance and carcass characteristics of finishing swine. *J. Anim. Sci.* 71:663-672.

GWARTNEY, B.L., CALKINS, C.R., and JONES, S.J. 1991. The effect of cimaterol and its withdrawal on carcass composition and meat tenderness of broiler chickens. *J. Amin. Sci.* 69:1551-1558.

HALLORAN, J.D., ROGERS, R.W., MIKEL, W.B., and ALTHEN, T.G. 1991. Processing characteristics of pork as influenced by porcine somatotropin (pST) administration to growing finishing swine. *J. Amin. Sci.* 56:859-862.

HANRAHAN, J.P., QUIRKE, J.F., BOWMANN, W., ALLEN, P., McKEWAN, J., FITZSIMONS, J., KOTZIAN, J., and ROCHE, J.F. 1986. Beta-agonists and their effects on growth and carcass quality. In: W. HARESIGN (ed). *Recent Advances in Animal Nutrition.* Butterworths, London. p.p. 125-138.

HANRAHAN, J. P. (ed). 1987. *Beta-Agonists and Their Effects on Animal Growth and Carcass Quality.* Elsevier Applied Science, London & New York.

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 (c1 263,780) on the growth and carcass composition of finishing swine. *J. Amin. Sci.* 61:905-913.

KIM, Y.S., LEE, Y.B., and DALRYMPLE, R.H. 1987. Effect of the repartitioning agent cimaterol on growth, carcass and skeletal muscle characteristics in lambs. *J. Anim. Sci.* 65:1392-1399.

KNIGHT, C.D., KASSER, T.R., SWENSON, G.H., HINTZ, R.L., AZAIN, M.J., BATES, R.O., CLINE, T.R., CRENSHAW, J.D., CROMWELL, G.L., HENDRICK, H.B., JONES, S.J., KROPF, D.H., LEWIS, A.J., MAHAN, D.C., McKEITH, F.K., McLAUGHLIN, C.L., NELSSEN, J.L., NOVAKOFSKI, J.E., ORCUTT, M.W., and PARRETT, N.A. 1991. The performance and carcass composition responses of finishing swine to a range of porcine somatotropin doses in a one-week delivery system. *J. Anim. Sci.* 69:4678-4689.

KOOHMARAIE, M., and SHACKELFORD, S.D. 1991. Effect of calcium chloride infusion on the tenderness of lambs fed a beta-adrenergic agonist. *J. Anim. Sci.* 69:2463-2471.

KOOHMARAIE, M., SHACKELFORD, S.D., MUGGLI-COCKETT, N.E., and STONE, R.T. 1991. Effect of the beta-adrenergic agonist L644,969 on muscle growth, endogenous proteinase activities and postmortem proteolysis in wether lambs. *J. Anim. Sci.* 69:4823-4835.

LEFAUCHEUR, L., MISSOHOU, A., ECOLAN, P., MONIN, G., and BONNEAU, M. 1992. Performance, plasma hormones, histochemical and biochemical muscle traits and meat quality of pigs administered exogenous somatotropin between 30 and 60 kilograms and 100 kilograms body weight. *J. Anim. Sci.* 70:3401-3411.

LONERGAN, S.M., SEBRANEK, J.G., PRUSA, K.J., and MILLER, L.F. 1992. Porcine somatotropin (pST) administration to growing pigs: effects on adipose tissue composition and processed product characteristics. *J. Food Sci.* 57:312-317.

MACHLIN, L.J. 1972. 1972. Effect of porcine growth hormone on growth and carcass composition of the pig. *J. Anim. Sci.* 35:794-800.

McKEITH, F.K., BECHTEL, P.J., and NOVAKOFSKI, J. 1989. Implications of somatotropin to the pork processing industry. In: Biotechnology for Control of Growth and Product Quality in Swine. Proceedings of an International Symposium Agricultural University. Wageningen, The Netherlands. p.p. 101-107.

McKEITH, F.K., and MERKEL, R.A. 1991. Technology of developing low-fat meat products. *J. Anim. Sci.* 69(Suppl.2):116-124.

McLAUGHLIN, C.L., BAILE, C.A., SHUN-ZHANG, Q., LIAN-CHUN, W., and JIN-PU, X. 1989. Responses of Beijing hogs to porcine somatotropin. *J. Anim. Sci.* 67:116-127.

MERKEL, R.A. 1988. Is meat quality affected by the use of repartitioning agents? Proc. Recip. Meat Conf. 41:101.

MILLER, M.F., GARCIA, D.K., COLEMAN, M.E., EKEREN, P.A., LUNT, D.K., WAGNER, K.A., PROCKNOR, M., WELSH, T.H., Jr., and SMITH, S.B. 1988. Adipose tissue, longissimus muscle and anterior pituitary growth and function in chenbuterol-fed heifers. *J. Anim. Sci.* 66:12-20.

MILLER, M.F., GEORGE, S.M., and REAGAN, J.O. 1991. Effect of exogenous porcine somatotropin on the functional textural characteristics of the porcine semimembranosus muscle. *J. Anim. Sci.* 69:1975-1982.

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

MOSELEY, W.M., PAULISSEN, J.B., GOODWIN, M.C., ALANIZ, G.R., and CLAFLIN, W.H. 1992. Recombinant bovine somatotropin improves growth performance in finishing beef steers. *J. Anim. Sci.* 70:412-425.

MOSER, R.L., DALRYMPLE, R.H., CORNELIUS, S.G., PETTIGREW, J.P., and ALLEN, C.E. 1986. Effect of cimaterol ($CL_{263,780}$) as a repartitioning agent in the diet for finishing pigs. *J. Anim. Sci.* 62:21-26.

NOVAKOFSKI, J. 1987. Repartitioned pork: sensory quality and consumer acceptance. 1987 University of Illinois Pork Industry Conference Proceedings. p.p. 84-92.

PRINGEL, T.D., CALKINS, C.R., KOOHMARAIE, M., and JONES, S.J. 1993. Effects over time of feeding a beta-adrenergic agonist to wether lambs on animal performance, muscle growth, endogenous muscle proteinase activities and meat tenderness. *J. Anim. Sci.* 71:636-644.

PRUSA, K.J., LOVE, J.A., and MILLER, L.F. 1989. Composition and sensory analysis of rib chops from pigs supplemented with porcine somatotropin (pST). *J. Anim. Sci.* 12:455-465.

RICKS, C.A., DALRYMPLE, R.H., BAKER, P.K., and INGLE, D.L. 1984b. Use of a beta-agonist to alter fat and muscle deposition in steers. *J. Anim. Sci.* 59:1247-1255.

SHACKELFORD, S.D., EDWARDS, J.W., SMARR, E.K., and SAVELL, J.W. 1992. Retail cut yields of Rambouillet wether lambs fed the beta-adrenergic agonist $L_{644,969}$. *J. Anim. Sci.* 70:161-168.

SOLOMON, M.B., CAMPBELL, R.G., STEELE, N.C. and CAPERNA, T.J. 1991. Effects of exogenous porcine somatotropin administration between 30 and 60 kilograms on longissimus muscle fibre morphology and meat tenderness of pigs grown to 90 kilograms. *J. Anim. Sci.* 69:641-645.

SOLOMON, M.B., CAMPBELL, R.G., STEELE, N.C., CAPERNA, T.J., and McMURTRY, J.P. 1988. Effect of feed intake and exogenous porcine somatotropin on longissimus muscle fibre characteristics of pigs weighing 55 kilograms live weight. *J. Anim. Sci.* 66:3279-3284

.STITES, C.R., McKEITH, F.K., BECHTEL, P.J., NOVAKOFSKI, J., OTT, R.S., EASTER, R.A., and MIYAT, J. 1989. Carcass cutting yields and proximate composition of finishing pigs fed different levels of protein, lysine and ractopamine. *J. Anim. Sci.* 67(suppl.1):190 (Abstr.).

STITES, C.R., McKEITH, F.K., SINGH, S.D., BECHTEL, P.J., MOWERY, D.H., and JONES, D.J. 1991. The effect of ractopamine hydrochloride on the carcass cutting yields of finishing swine. *J. Anim. Sci.* 69:3094-3101.

STITES, C.R., McKEITH, F.K., SINGH, S.D., BECHTEL, P.J., MOWERY, D.H., and JONES, D.J. 1993. Palatability and visual characteristics of hams and loin chops from swine treated with ractopamine hydrochloride. *J. Muscle Foods.* (At press).

WALLACE, D.H., HEDRICK, H.B., SEWARD, R.L., DAURIA, C.P., and CONVEY, E.M. 1987. Growth and feed utilization of swine fed a beta-adrenergic agonist (L644,969). In: J.P. HANRAHAN (ed). *Beta-Agonists and Their Effects on Animal Growth and Carcass Quality.* Elsevier Applied Science. London and New York. p.p.143-151.

WARRISS, P.D., KESTIN, S.C., ROLPH, T.P., and BROWN, S.N. 1990a. The effects of the beta-adrenergic agonist salbutamol on meat quality and pigs. *J. Anim. Sci.* 68:128-136.

WARRISS, P.D., BROWN, S.N., ROLPH, T.P., and KESTIN, S.C. 1990b. Interactions between the beta-adrenergic agonist salbutamol and genotype on meat quality in pigs. *J. Anim. Sci.* 68:3669-3676.

WATKINS, L.E., JONES, D.J., MOWERY, D.H., ANDERSON, D.B., and VEENHUIZEN, E.L. 1990. The effect of various levels of ractopamine hydrochloride on the performance and carcass characteristics of finishing swine. *J. Anim. Sci.* 68:3588-3595.

WELLENREITER, R.H., and TONKINSON, L.V. 1990. Effect of ractopamine hydrochloride on growth performance of turkeys. *Poult. Sci.* 69(Suppl.1):142 (Abstr.).