Balancing Beef Quality and Red Meat Yield with Ractopamine Hydrochloride

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Introduction

Optaflexx®, ractopamine HCL (RAC), is a feed additive commonly used in the final stages of the finishing period to increase live weight gain, improve feed efficiency, and increase carcass leanness of both steers and heifers. Optaflexx is approved in North American production systems for cattle during the last 28 to 42 d of the finishing period at a level of 70 to 430 mg/hd/d (United States and Mexico) or 10 to 30 ppm in the final feed (Canada). Typically, production systems in the US target RAC use at the recommended dose of 200 mg/hd/d for the last 28 d of the finishing period (data from AgSpan; Overland Park, KS). Feeding RAC at a level of 200 mg/hd/d to feedlot cattle has been shown to improve average daily gain (17.4%) and feed conversion (15.9%) during the supplementation period (Laudert et al., 2005a). Likewise, feeding RAC increases carcass protein gain per d and the efficiency of carcass gain per d (Schroeder et al., 2005a; Schroeder et al., 2005b) correlating to a desired improvement in beef production efficiency. Intuitively improving the efficiency of beef production has important economic consequences for both beef producers and consumers, however, new technologies or management practices should also be evaluated for their impacts on important beef demand drivers, such as quality and sensory characteristics. Optaflexx was the first product approved by the US FDA CVM that was evaluated for not only safety and efficacy, but also its overall impact on beef eating quality. In those studies, feeding RAC to either steers or heifers resulted in minimal impacts on either beef quality attributes or beef sensory characteristics (FDA, 2003). The objective of this paper is to review the most recent literature on the impact of Optaflexx on meat quality and red meat yield.

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Ractopamine and Beef Quality

Marbling Score and USDA Quality Grade

Marbling score has long been used as a primary descriptor of beef quality. Indeed, research has demonstrated that marbling score or quality grade can be used to predict overall eating satisfaction of beef (Platter et al., 2003). In a series of 5 studies evaluating both RAC dose (0 to 300 mg/hd/d) and feeding duration (28 and 42 d), Schroeder et al. (2005c; 2005d) reported marbling score was not influenced by feeding RAC to feedlot cattle. These results are similar to those of large pen studies conducted at commercial feedlot research facilities with either steers (Laudert et al., 2005b) or heifers (Laudert et al., 2007) that indicated feeding RAC at a level of 200 mg/hd/d did not impact marbling score or overall percentage of carcasses grading Choice and Prime (Table 1). Gruber et al. (2007), reported carcasses of steers of three distinct biological types (English, Continental and Brahman cross) fed RAC tended ($P = 0.07$) to have slightly reduced marbling scores compared to carcasses of control steers, however, this tendency was not of sufficient magnitude to influence distribution of USDA quality grade. Moreover, there was no RAC by biological type interaction for marbling score in this study that evaluated steers with a relatively low propensity to deposit marbling (Brahman cross) and steers that had a relatively high propensity (English) to deposit marbling. Vogel et al. (2005) reported that feeding RAC to calf-fed Holstein steers resulted in a reduction ($P < 0.05$) in marbling scores in carcasses of steers fed RAC at a level of 200 mg/hd/d, but not in steers fed 300/mg/hd/d. Other studies have reported no impact of RAC on carcass quality traits in carcasses of steers (Loe et al., 2005; Hutcheson et al., 2005; Greenquist et al., 2006; Van Koevering et al., 2006), heifers (Griffin et al., 2006; Sissom et al., 2007; Quinn et al., 2008), or Holstein steers (Lehmkuhler et al., 2007).

Today, video image analysis (VIA) systems offer another method of evaluating carcass marbling in addition to expertly assigned marbling scores. Platter (2006) conducted an analysis of VIA (Computer Vision System; RMS-USA Inc., Fort Collins, CO) evaluated carcass data from 12 RAC studies that compared steers fed RAC at a level of

Table 1. Marbling score and percentage of carcasses grading USDA Choice and higher for steers and heifers fed ractopamine HCL (RAC).

Trait	Dose RAC, mg/hd/d 0	200	Replications/ Dose	P_{dose}
Marbling score				
Steers[a]	Small^{04}	Small^{01}	32	0.50
Heifers[b]	Slight^{96}	Slight^{95}	14	0.80
USDA Choice and higher				
Steers[a]	47.6	45.6	32	0.36
Heifers[b]	40.4	38.9	14	0.79

[a]Elanco Animal Health study numbers T4V200321, T4V080342, T4V160328, T4V480326, T4V080325 and T4V200324. Data on file.
[b]Elanco Animal Health study numbers T4V200513 and T4V480415. Data on file.

200 mg/hd/d to steers fed a control diet. In this analysis, the total area of intramuscular fat within the *longissimus* muscle for carcasses of steers fed RAC was not different (P = 0.36) than carcasses of steers in the control group (3.47 cm^2 vs. 3.52 cm^2). This observation would imply that any potential reduction in marbling score in RAC-fed cattle may be due to a dilution of intramuscular fat as a result of increased total area of the *longissimus* muscle (approximately 3% in these studies) rather than from decreased accretion or increased lipolysis of intramuscular fat.

These studies suggest that feeding RAC to finishing cattle has little effect on marbling score and is not likely to result in significant shifts in USDA quality grade distribution.

Sensory Characteristics and Shear Force Measurements

An evaluation of feeding various levels of RAC to feedlot cattle on beef sensory properties and Warner-Bratzler shear force measurements (WBSF) was conducted prior to commercial availability of RAC to the US marketplace (FDA, 2003). Results of these evaluations from a representative sample of strip loin steaks from 4 heifer and 5 steer studies are presented in Table 2. Trained taste panel assessments of juiciness, beef flavor, and off flavor were not different for steaks from control cattle and steaks from RAC fed cattle. Steaks from cattle fed RAC at levels of 100 and 200 mg/hd/d were not different ($P \geq 0.38$) than steaks from control cattle for initial or sustained tenderness. Cattle fed RAC at a level of 300 mg/hd/d produced steaks that were slightly (approximately 6 points on a 150 point scale) lower ($P < 0.05$) for initial and sustained tenderness ratings than steaks from control cattle. Warner-Bratzler shear force measurements mirrored those results of trained panel evaluations of tenderness with no differences in WBSF values for steaks from cattle fed RAC at levels of 100 or 200 mg/hd/d, but higher ($P < 0.05$) values for cattle fed RAC at 300 mg/hd/d, when compared to steaks from control cattle.

The majority of more recent studies of the effects of RAC on beef sensory characteristics and WBSF values have been in cattle fed RAC at a level of 200 mg/hd/d. Tenderness has been the predominant attribute of interest in these comparisons and subsequently WBSF values have been reported in many studies evaluating RAC in beef cattle. Results of a meta-analysis of shear force data from 6 studies, comparing WBSF values of 14-d aged *longissimus* muscle steaks from cattle fed RAC at a level of 200 mg/hd/d vs. steaks from control cattle are presented in Table 3. Two individual studies used in this meta-analysis reported an increase ($P < 0.05$) in WBSF for steaks from cattle fed RAC compared to steaks from control cattle after 14 d of postmortem storage. Results of this meta-analysis, indicated feeding RAC to cattle tended (P = 0.09) to increase WBSF of *longissimus* steaks (3.72 vs. 3.88 kg). Although this is a relatively small shift in WBSF value, it is important to examine what the potential impact of this change would have on consumer acceptability of steaks. Using the model developed by Platter et al. (2003) relating changes in WBSF to overall consumer acceptance, this difference in WBSF would result in less than a 4% shift in overall consumer satisfaction.

Postmortem storage time (aging) improves beef tenderness, therefore, it is important to consider the impact of RAC on beef tenderness over multiple aging periods. Four of the above-mentioned studies used in the meta-analysis also examined the aging curves of *longissimus* muscle steaks from cattle fed RAC at a level of 200 mg/hd/d compared to the aging curve of steaks from control cattle. In one study (Elanco Animal Health, 2007), no differences existed between steaks from RAC-fed and control cattle after any of the postmortem storage periods. Platter (2007a) reported elevated WBSF values of steaks from steers fed RAC compared to steaks from control steers after 3 and 7 d of aging, but these differences were eliminated after 14 d of postmortem storage. Gruber et al. (2008) reported aging steaks 21 d postmortem tended (P = 0.16) to reduce the impact of feeding RAC to steers on WBSF of *longissimus* muscle steaks. In another study (Platter, 2007b) the aging by RAC treatment interaction was not significant (P = 0.57), resulting in a small increase in shear force in steaks from RAC-fed cattle compared to steaks from control cattle at each postmortem storage period. These results suggest the rate of aging of steaks from RAC fed cattle is either slightly more rapid or similar to that of steaks from cattle not fed RAC.

Gruber et al. (2008) reported the magnitude of the impact of RAC supplementation on WBSF was more pronounced among *longissimus* muscle steaks from Brahman crossbred than from steaks from Continental crossbred or British steers. Additionally, steers fed RAC in that study produced steaks that received lower taste panel ratings for tenderness and juiciness. In another study, WBSF of *longissimus* steaks was increased by increasing the percentage of Brahman breeding influence in steers from 25% to 50% (4.21 vs. 4.51 kg), but was not influenced ($P = 0.39$) by

Table 2. Effects of ractopamine HCL (RAC) on least squares means for sensory characteristics and Warner-Bratzler shear force (WBSF) of strip loin steaks[a].

Trait	Dose RAC, mg/hd/d				SEM
	0	100	200	300	
n	90	90	90	90	—
Juiciness[b]	104.6	104.5	106.0	103.3	1.6
Initial tenderness[c]	111.7[y]	110.7[y]	111.5[y]	106.0[z]	1.8
Sustained tenderness[c]	101.8[y]	100.5[y]	100.3[y]	95.2[z]	1.8
Flavor[d]	90.3	89.0	90.5	88.7	1.7
Off-flavor[d]	0.252	0.222	0.156	0.157	0.10
WBSF, kg	3.54[z]	3.49[z]	3.62[z]	3.95[y]	0.16

[a]Source: FDA. 2003. Freedom of information summary. Original new animal drug application. NADA 141-221. http://www.fda.gov/cvm/FOI/141-221.pdf Accessed Mar. 15, 2008.
[b]Juiciness: 0 = not juicy; 150 = very juicy.
[c]Tenderness: 0 = not tender; 150 = very tender.
[d]Flavor: 0 = none; 150 = intense.
[yz]Means in the same row that do not have a common superscript differ (***P*** < 0.05).

feeding RAC (0 vs. 200 mg/hd/d) to either of these two biological types (Elanco Animal Health, 2007).

In summary the impacts of feeding RAC on sensory characteristics of beef, especially beef tenderness, has been thoroughly investigated. Some studies indicate that RAC supplementation may slightly increase WBSF values, but the impact of this change would likely result in minimal impacts on consumer acceptability of beef.

Ractopamine and Red Meat Yield

Carcass Leanness

Phenethanolamines, the general class of compounds that describe RAC, are sometimes referred to as lean-enhancing feed ingredients because of their unique ability to partition nutrients toward protein vs. adipose tissue accretion. Moody et al. (2000) reviewed the various phenetha-

Table 3. Meta-analysis of Warner-Bratzler shear force (WBSF) values (kg) of strip loin steaks following 14 d of postmortem storage from cattle fed ractopamine HCL (RAC).

Study	Dose RAC, mg/hd/d [a]		SEM	Gender
	0	200		
FDA registration studies[b]	3.54	3.62	0.16	Steer and heifers
Steer value study[c]	2.67	2.80	0.06	Steers
Biological type study[d]	3.99[y]	4.34[z]	0.07	Steers
Ractopamine and zilpaterol study[e]	3.55	3.78	0.20	Steers
Heifer serial slaughter study[f]	4.33[y]	4.52[z]	0.12	Heifers
Brahman influence study[g]	4.32	4.16	0.10	Steers
Average	3.72	3.88	0.26	P = 0.09

[a]Least squares means WBSF values (kg) reported for each study. In the statistical model, dose was included as a fixed effect, and study was included as a random effect. The inverse of the squared standard error (w1) for each study was divided by the average w1 across the 6 studies, and included in the analysis as a weight variable.
[b]FDA. 2003. Freedom of information summary. Original new animal drug application. NADA 141-221. http://www.fda.gov/cvm/FOI/141-221.pdf Accessed Mar. 15, 2008.
[c]Laudert, S. B.. 2004. Evaluation of Optaflexx® on growth performance and carcass characteristics of feedlot steers-value study. Study Report T4V080342. Elanco Animal Health, Greenfield, IN.
[d]Gruber, S. L., J. D. Tatum, T. E. Engle, K. J. Prusa, S. B. Laudert, A. L. Schroeder, and W. J. Platter. 2008. Effects of ractopamine supplementation of postmortem aging on *longissimus* muscle palatability of beef steers differing in biological type. J. Anim. Sci. 86:205-210.
[e]Platter, W. J.. 2007a. Comparative effects of ractopamine and zilpaterol on growth performance, carcass traits and shear force of finishing steers. Study Report T4VME0605. Elanco Animal Health, Greenfield, IN.
[f]Platter, W. J.. 2007b. Evaluation of Optaflexx on growth performance and carcass characteristics of feedlot heifers-feedlot performance profile and serial slaughter. Study Report T4V080604. Elanco Animal Health, Greenfield, IN.
[g]Elanco Animal Health. 2007. Effect of Optaflexx on Warner-Bratzler shear force of *longissimus* muscle steaks from steers of two levels of Brahman breed influence. Customer data on file. Elanco Animal Health, Greenfield, IN.
[yz]Means in the same row that do not have a common superscript differ (*P* < 0.05).

Table 4. Effects of ractopamine HCL (RAC) on composition of carcass soft tissues of feedlot steers.[abc]

Item	Dose RAC (ppm)[d] 0	10	20	30	SEM
Pens, n	25	25	25	24	—
Carcasses, n	50	50	49	47	—
Side soft tissue, kg	140.3	139.4	140.3	141.2	4.13
Carcass bone, %	14.7	14.7	14.7	14.5	0.26
Protein, %	14.82^{z}	15.15^{z}	15.35^{y}	15.35^{y}	0.14
Moisture, %	52.5^{z}	53.1^{z}	53.7^{y}	53.4^{z}	0.58
EEL, %	31.2^{y}	30.3^{y}	29.5^{z}	29.7^{y}	0.74
Ash, %	0.8	0.8	0.8	0.8	0.02
Carcass protein gain per d, g	50.4^{z}	80.3^{z}	101.2^{y}	108.0^{y}	27.2
Efficiency of carcass protein gain per d	0.005^{z}	0.008^{z}	0.011^{y}	0.011^{y}	0.003

[a]Source: Schroeder, A., D. Hancock, D. Mowrey, S. Laudert, G. Vogel, and D. Polser. 2005a. Dose titration of Optaflexx® (ractopamine HCL) evaluating the effects on composition of carcass soft tissues in feedlot steers. J Anim. Sci. 83(Suppl. 1):111. (Abstr.)
[b]Least squares means.
[c]Steers were supplemented with RAC for either 28 or 42 d
[d]RAC supplementation at 0, 10, 20, and 30 ppm equals approximately 0, 100, 200, 300 mg/hd/d, respectively.
[yz]Means in the same row that do not have a common superscript differ ($P < 0.05$).

nolamines researched in livestock production, including their modes of action. Ractopamine is a category one ß-agonist and has a primary effect on increasing protein synthesis (Moody et al., 2000). Increasing the rate of protein synthesis has a net effect of increasing total percentage lean composition of carcasses of steers and heifers fed RAC.

Schroeder et al. (2005a) reported the effects of feeding RAC to steers at a level of 0, 10, 20, or 30 ppm in the finishing ration on composition of carcass soft tissue of steers (Table 4). In that study, carcass protein percentage was increased 3.6% in steers fed RAC at a level of 20 ppm (corresponding to approximately 200 mg/hd/d). Additionally compared to control steers, total carcass soft tissue ether extractable lipid was decreased by 2.2% in steers fed RAC at a level of 20 ppm. Feeding steers RAC at a level of 20 ppm increased carcass protein gain per d by 100.9%, more than doubling the amount of protein produced compared to control steers during the treatment period. Moreover, because daily dry matter intake did not differ between treatment groups, the efficiency of carcass protein gain per d was improved by a similar magnitude (120%) for steers supplemented with 20 ppm RAC in the diet. Comparable impacts on carcass soft tissue composition, carcass protein gain and efficiency were observed in heifers supplemented with RAC, however, responses were more similar to that of steers when heifers were fed at a level of 30 ppm RAC in the diet (Schroeder et al., 2005b).

Carcass Cutout Yields

A benefit of increased protein synthesis and carcass leanness in RAC-fed cattle is a concomitant improvement in carcass cutout yields. Schroeder et al. (2006) reported feeding RAC to steers at a level of 20 ppm in the diet (approximately 200 mg/hd/d) increased ($P \leq 0.05$) the ag-

Table 5. Yield of closely-trimmed (1/4 in.) subprimal cuts from carcasses of steers supplemented with ractopamine hydrochloride (RAC).[a]

Trait	Dose RAC, mg/hd/d 0	200	SEM	P_{dose}
Cold side weight (CSW), kg[b]	183.3	184.2	1.6	0.66
Trimmed cuts, % CSW[c]	39.1	40.0	0.3	0.02
Trimmed round cuts, % primal round[d]	51.9	52.7	0.5	0.14
Trimmed loin cuts, % primal loin[d]	48.2	49.7	0.5	0.03
Trimmed rib cuts, % primal rib[d]	39.3	39.6	0.4	0.61
Trimmed chuck cuts, % primal chuck[d]	25.6	26.1	0.2	0.06

[a]Source: Elanco Animal Health., 2005. Customer data on file.
[b]Weight of left carcass side immediately before fabrication without weight of kidney, pelvic and heart fat.
[c]Institutional meat product specification numbers or descriptions for cuts fabricated: 112A, 114D, 114E, 114F, 116A, 116B, 120A, 121C, 121D, 124, 130, 167A, 168, 170, 171C, 180, 184, 185A, 185B, 185D, 189A, 193, pectoral, rib lifter, cap and wedge. Aggregate weight of these cuts expressed as a percentage of cold side weight.
[d]Aggregate weight of trimmed cuts from respective primal expressed as a percentage of total primal weight.

gregate weight of 12 major subprimal cuts from their carcasses compared to carcasses of steers not supplemented with RAC. When the aggregate weight of these 12 cuts were expressed as a percentage of carcass weight, the mean yield of closely-trimmed subprimal cuts tended to be increased (P = 0.07) by 0.7 percent (36.4 vs. 37.1%) in steers fed RAC at a level of 200 mg/hd/d compared to control steers.

Carcasses of steers fed RAC (200 mg/hd/d) and control diets were selected from the study conducted by Greenquist et al. (2006) and evaluated for differences in yield of closely-trimmed subprimal cuts (Elanco Animal Health, 2005). In this study, pairs of carcasses (RAC and control) on each harvest date were selected for fabrication based on the criteria of having similar or equal 12th rib fat measurements and carcass weight differences comparable to treatment differences observed in this study. Left sides from carcasses (n=60) were shipped to the University of Illinois Meat Laboratory and fabricated into 25 closely-trimmed (1/4 in) subprimal cuts, lean trim, fat trim and bone. Effects of supplementing RAC to steers on yield of closely-trimmed subprimal cuts are presented in Table 5. Feeding RAC to steers increased ($P < 0.05$) carcass yield of closely-trimmed subprimal cuts (39.1 vs. 40.0%). Interestingly, the yield of closely trimmed cuts as a percentage of primal weight was numerically higher for the chuck, rib and round and significantly higher ($P < 0.05$) for the primal loin.

These data indicate feeding RAC to feedlot cattle can improve total carcass value in two ways; increasing total carcass weight and improving carcass cutability.

Conclusion and Implications

Improving the quality of meat products has been identified as a leading factor that would promote increased meat purchases by consumers (AMI, 2008). However, carcass weight is the primary driver of total value per head for feedlot cattle, followed by quality grade and finally yield grade in most carcass merit pricing systems (Tatum et al., 2005). The information summarized in this review suggest that feeding ractopamine to feedlot cattle offers a unique option to the beef industry to improve beef production efficiency and carcass cutability with minimal risk to impacting beef quality and sensory attributes.

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