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ACCELERATED VERSUS CONVENTIONAL BEEF PRODUCTION AND PROCESSING[1,2]

M. E. Dikeman, K. N. Nagele[3], S. M. Myers[4], R. R. Schalles, D. H. Kropf, C. L. Kastner and F. A. Russo[5]

Kansas State University, Manhattan 66506

ABSTRACT

Twenty-four 8-mo-old Angus × Hereford (A × H) reciprocal crossbred steers and 28 3/8 Simmental × 1/4 Chianina × 3/8 Angus or Hereford steers (S × C) were utilized to study two production systems and two carcass-processing systems. One-half of each type was allotted by weight (257.6 kg average) to either an accelerated (ACC) or conventional (CONV) production system. The ACC system consisted of feeding an 85% concentrate diet for 140 d to A × H cattle and for 180 d to S × C cattle. The CONV system included backgrounding on prairie hay and sorghum grain for 140 d (A × H) and 183 d (S × C) before finishing on an 82% concentrate diet (116 d for A × H and 122 d for S × C). The ACC system resulted in lower (P<.05) metabolizable energy to gain ratios (ME/G) and lower costs of gain. Cattle on the ACC system were slaughtered younger and at lighter weights (P<.05) and had lower (P<.05) yield grades and quality grades than CONV cattle. The S × C-ACC cattle had a lower (P<.05) ME/G and tended to have a lower cost of gain than A × H-ACC cattle. The S × C cattle had lower (P<.05) yield grades and higher (P<.05) percentages of carcass tissue water than A × H cattle. The S × C cattle had lower (P<.05) quality grades than A × H cattle. The ACC system resulted in higher (P<.05) longissimus (LD) and semimembranosus (SM) tenderness scores than the CONV system and equal flavor and juiciness scores. Economic analyses suggest that S × C-ACC cattle had the lowest break-even live price and lowest cost/kg retail product. The S × C-CONV cattle tended to have the highest break-even live price, whereas A × H-CONV cattle had the highest cost/kg retail product. The ACC processing involved electrical stimulation (ES) of each carcass right side at 1 h postmortem for 2 min with 400 V, 1 amp and a frequency of 60 Hz. At 2 h postmortem the inside round and boneless shortloin were hot-boned (HB) and chilled 6 d at 2 to 4 C. The control (C) side was chilled 48 h, boned, and muscles stored 4 d at 2 to 4 C. The ESHB resulted in slightly (P>.05) faster LD pH declines. The ESHB LD steaks had higher (P<.05) juiciness scores, but were not different in flavor or tenderness compared with C steaks. The ESHB treatment resulted in higher (P<.05) SM shear values and lower (P<.05) sensory-panel tenderness scores than those of C. The LD display-color scores did not differ (P>.05) between ESHB and C treatments. The combination of S × C cattle and ACC production was more attractive economically than CONV production of A × H cattle.

(Key Words: Performance, Carcasses, Nutrition, Palatability, Electrical Treatment, Boning.)

Introduction

Economic pressures to improve production efficiency have prompted the beef cattle industry and researchers to evaluate the performance of different biological types of cattle and methods used to produce cattle that yield a high proportion of high-quality meat. Feeding grain diets to cattle is generally considered to result in meat that is more tender, flavorful and juicy than that of forage-fed cattle. Most cattle feeders strive to feed cattle to sufficient fatness (25 to 35% carcass fat) so that a high percentage of them will be graded USDA Choice because of the price advantage of Choice carcasses. However, feeding to the Choice grade is inefficient because of the higher costs of gain associated with excess carcass-fat deposition. Fat synthesis is more energetically expensive than protein synthesis on a tissue-weight basis (Thorbek, 1977).

[1] Contribution No. 85-11-J, Dept. of Anim. Sci. and Ind., Kansas Agr. Exp. Sta., Manhattan 66506.

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[3] Present address: 1121 West Center Street, Dallas, TX 75090.

[4] Present address: Bartlett Cattle Co., Kansas City, MO 64112.

[5] Present address: Swift & Co., Kansas City, KS 66102.

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Feeding cattle for maximum rate of gain results in improved feed efficiency because of the dilution of maintenance requirements (Dikeman, 1973). In addition, yardage and interest costs per unit of gain decrease with increased rate of gain (Myers, 1979). Therefore, feeding for maximum rate of gain and terminating the feeding period when cattle have deposited a minimum amount of trimmable fat result in optimal feed efficiency.

Although grain feeding is known to result in high meat palatability, it may not be necessary to feed cattle to the Choice grade. Several research studies indicate that feeding a grain diet for a minimum of 100 d may result in desirable meat palatability (Smith et al., 1977a; Bowling et al., 1978; Dinius and Cross, 1978; Leander et al., 1978; Burson et al., 1980; Tatum et al., 1980). Furthermore, certain methods of processing beef carcasses may enhance meat quality and can be used to overcome any deficiencies in production practices (Dikeman, 1982).

Electrical stimulation has received considerable attention as a method for improving meat tenderness in addition to its potential for reducing muscle conditioning time before hot boning. Hot boning is an economically attractive procedure (Kastner, 1977; Nason, 1979). Gilbert and Davey (1976) and Gilbert et al. (1976) used electrical stimulation to accelerate the onset of rigor mortis to allow hot boning of beef muscles. They concluded that stimulation minimized problems associated with prerigor excision, overcame cold and thaw toughening and permitted additional tenderization from aging. Cross and Tennent (1980) and Seideman et al. (1979) investigated the physical and palatability traits of electrically stimulated and hot-boned beef carcasses and found them to be as palatable as conventionally processed beef.

Our objectives were to evaluate the effects of two types of cattle and two production systems on performance traits, efficiency of production, carcass traits and meat quality. In addition, we evaluated the effects of electrical stimulation and hot boning on meat quality.

Experimental Procedure

Cattle Production Systems. Twenty-four Angus × Hereford (A × H) crossbred steers and 23 large-type Simmental-sired crossbred steers (either Chianina × Angus or Chianina × Hereford females, S × C) were approximately 8 mo old and averaged 257.6 kg when purchased. One-half of each crossbred group was allotted by weight to one of two production systems. Accelerated (ACC) production consisted of a finishing phase only. Conventional (CONV) production consisted of backgrounding and finishing phases. Steers within type × production system were fed in pens of three or four head during backgrounding and finishing.

Compositions of diets for the two production systems are shown in table 1. The basic difference between the two regimens was that the backgrounding phase involved a diet of 66.8% prairie hay compared with the finishing diet, which contained no prairie hay. Steers were fed ad libitum, but feed was monitored so that only a minimum amount of feed remained in the bunks before the next feeding.

Slaughter endpoints of 430 and 505 kg for A × H and S × C cattle, respectively, were predetermined for the ACC system. These weights represent the point at which these two types of cattle would be expected to reach about 4.5% longissimus muscle lipid (Koch et al., 1976), which is equivalent to the minimum Choice quality grade. For cattle on the CONV system, slaughter endpoints of 522 and 591 kg were chosen to simulate weights at which A × H and S × C cattle, respectively, would be slaughtered by the industry. The A × H- and S × C-CONV cattle were started on the finishing diets at 342 and 380 kg, respectively, in order that they would begin the finishing phase at similar body compositions.

Individual live weights and average feed intakes were recorded and steers were weighed at 28-d intervals before the morning feeding.

Carcass-Processing Treatments. All steers were slaughtered at the Kansas State University meats laboratory. The right carcass side was electrically stimulated (ES) at 1 h postmortem by placing one stainless-steel electrode through the gastrocnemius muscle and another one anterior and parallel to the humerus. The electrical current delivered approximately 400 volts and 1 amp at 60 Hz for 2 min. The stimulated sides were stored for 1 h at approximately 2 C, then the inside round and boneless shortloin were removed. These hot-boned (HB) subprimal cuts were placed in vacuum bags and then stored in cardboard boxes at approximately 2 C until 6 d postmortem.

The left carcass side served as the nonstimulated control (C). These sides were chilled for 48 h at 2 C, then ribbed for yield and quality grading. Soft-tissue chemical composition of

TABLE 1. DIET COMPOSITIONS[a] FOR CATTLE TYPES AND PRODUCTION SYSTEMS

Ingredient	A × H-ACC S × C-ACC	A × H-CONV Back-grounding	A × H-CONV Finishing	S × C-CONV Back-grounding	S × C-CONV Finishing
Corn, dent yellow, grain, gr 2 US (IFN 4-02-931), %	80.2	3.1	82.5	3.1	81.3
Sorghum, milo, grain (IFN 4-04-444), %		26.9		26.9	
Sorghum, Sorgo, aerial part W heads, ensiled (IFN 3-04-468), %	5.1	3.2	5.1	3.2	11.8
Corn, aerial part, W ears, W husks, ensiled, mature (IFN 3-08-153), %	10.0		8.0		2.5
Prairie hay, mid bloom (IFN 1-07-956), %		62.8		62.8	
Supplement[b], %	4.7	4.1	4.4	4.1	4.4
ME/kg DM[c]	3.09	2.18	3.12	2.18	3.08
Crude protein (book value), %	11.5	11.0	11.4	11.0	11.4

[a]Percentage on dry matter basis.

[b]44% soybean meal, 20.3% rolled milo, 15% limestone, 10% urea, 1% KCl, .05% Z-10 trace minerals, 30,000 IU vitamin A, and 1.5% animal fat.

[c]Megacalories of metabolizable energy/kg dry matter.

the 9-10-11th rib section was used to predict carcass chemical composition (Hankins and Howe, 1946). The inside round and boneless shortloin were removed, placed in vacuum bags and stored (2 C) in cardboard boxes until 6 d postmortem.

Temperature and pH data from both the ESHB and C sides were collected simultaneously. Temperatures of both the longissimus (LD) and semimembranosus (SM) muscles and pH of the LD muscle were obtained at 1, 2, 4, 6, 8 and 24 h postmortem. Samples were removed from the LD at the fifth lumbar vertebra location with a 1.27-cm coring device. Then a 1- to 2-g sample was blended with 10 ml of 5 mM sodium iodoacetate in 150 mM KCl (Bendall, 1973) for pH determination.

Meat Sensory Evaluation. At 6 d postmortem, sensory evaluation and Warner-Bratzler shear (WBS) force steaks were cut 2.54 cm thick from the anterior end of the shortloin LD and proximal end of the SM muscle. An additional 2.54-cm steak was cut from the LD for fresh display-color evaluation. Sensory and WBS steaks were frozen and stored at −29 C until evaluated. Steaks were thawed for 16 h at 2 C before cooking. Both the sensory-panel and WBS steaks were modified-oven-roasted at 165 C to an internal temperature of 70 C monitored by thermocouples and a recording potentiometer. Cores 1.27 cm in diameter were removed from the sensory steaks with a drill-press-mounted coring device perpendicular to the steak's cut surface, and kept warm in small double boilers partially filled with warm water. The six-member sensory panel was trained according to AMSA (1978). Eight steaks were sampled and served in a randomized procedure at each session. Steaks for WBS were stored at approximately 21 C for 2 h after cooking, before coring and shearing.

The LD steaks for display-color evaluations were placed in styrofoam trays, overwrapped with PVC film and displayed for 5 d at 2 C under continuous General Electric Delux Warm White lighting at an intensity of 1,076 lux (100 foot candles) at the meat surface. Color was scored by four panelists at 0, 1, 2, 3 and 4 d of display to the nearest .5 point using a scale of 1 = very bright red to 5 = extremely dark red or brown (Kropf et al., 1975).

Treatments were analyzed for differences by analysis of variance and corresponding F-tests. The analysis was performed by using the General Linear Models procedure on the Statistical Analysis System (SAS, 1979).

Economic Assumptions. Our basic approach was to supplement data from this experiment with the appropriate assumptions to quantify the costs of producing beef. Three analyses involving different economic assumptions are presented.

For analysis A (table 6), it was assumed that ending value per unit of live weight was the same for each treatment combination, because palatability of ACC cattle was generally superior to CONV cattle even though quality grades were lower (table 3) for ACC cattle. For analysis B (table 7), purchase and feeding costs were increased 25% and interest cost was increased 50%, individually and collectively, over costs used in analysis A (table 6). For these two analyses, break-even live prices and costs/kg of predicted retail product were calculated. For analysis C, ending value was based on carcass value determined in two ways, and profit or loss was calculated.

For analysis A, purchase price for all steers was $1.54/kg, trucking charge was $2.00/head and feedlot processing charge was $4.50/head. Purchase weight was the shrunk on-feed weight and slaughter weight included a 2% "pencil shrink" from the off-feed weight. Mark-up on feed was $11.57/metric ton and yardage charge was $.07·head^{-1}·d^{-1}. Interest rate was 12%, and interest data assume a line of credit with a 2-wk billing period. Interest accumulated in weeks one and two represented interest on purchase cost, trucking and veterinary processing charges. For each additional 2-wk production period, the bill included the previous balance plus additional feed and yardage costs. Interest was not compounded.

Cash prices for feed ingredients were based on historical price relationships represented by the ratio of price of a utilized ingredient to price of corn. These ratios were averaged for the period of 1970 to 1977 (Myers, 1979). Prices were determined by multiplying the derived ratio of (historical feed-ingredient price)/(corn price) by the current corn price. This procedure resulted in the following prices: corn, $.115/kg as fed; grain sorghum, $.1037/kg as fed; supplement, $.2291/kg as fed; prairie hay, $.0633/kg as fed; corn silage, $.0372/kg as fed, and sorghum silage, $.0372/kg as fed.

For analysis C (table 8), ending carcass prices were based on 3-yr historical prices. Choice carcasses were priced at $220.50/100 kg, Good carcasses at $211.60/100 kg and Standard carcasses at $202.86/100 kg. A base yield grade of 3.5 was used and $19.85/100 kg adjustment was made for each full yield grade above or below 3.5 to reflect value differences of predicted retail-product percentages. Recent industry price differences were used for analysis D (table 8). The same quality-grade prices were used for yield grade 3 carcasses as in analysis C, except that carcasses over 386 kg and under 272 kg were discounted $4.41/kg, yield grade 4 and 5 carcasses were discounted $17.64/kg and yield grade 1 and 2 carcasses received a premium of $4.41/kg.

Results and Discussion

Performance of Cattle Types on Two Production Systems. Beginning weights were nearly identical for A × H and S × C cattle (table 2). Average daily gains (ADG), over the entire period, were higher ($P<.05$) for cattle on the ACC system than for cattle on the CONV system. This was expected because the CONV system involved feeding a low-energy-density diet during the backgrounding phase, which was not a part of the ACC system. However, ADG during the finishing phase were higher ($P<.05$) for the CONV system than for the ACC system. This was largely due to compensatory gain by cattle that were backgrounded and then fed a high-energy-density diet during the finishing phase.

The S × C cattle tended ($P>.05$) to gain faster than A × H cattle on each of the two production systems. This observation agrees with those of Koch et al. (1976), who found that Simmental-sired steers gained faster than Hereford-Angus reciprocal crossbred steers. Metabolizable energy (ME) consumption per day was also higher ($P<.05$) for S × C cattle than for A × H cattle, as would be expected.

Both cattle types on the ACC system had lower ($P<.05$) ME:gain ratios than cattle on the CONV system, due to a dilution of ME used for maintenance. The S × C-ACC cattle had lower ($P<.05$) ME:gain ratios than A × H-ACC cattle, whereas there was no difference between A × H and S × C cattle on the CONV system.

Carcass Traits of Cattle Types and Production Systems. Hot-carcass weights were different ($P<.05$) for all treatment combinations, primarily because of the experimental design (table 3). Dressing percentages did not differ ($P>.05$) between cattle types nor between production systems. However, there was a cattle type × production system interaction ($P<.05$) in that A × H cattle on the ACC system had higher ($P<.05$) dressing percentages than S × C cattle on the ACC system, whereas S × C cattle on the CONV system tended ($P<.10$) to have higher dressing percentages than A × H cattle on the CONV system.

The S × C cattle had less ($P<.05$) fat thickness, less ($P<.05$) KPH fat, larger ($P<.05$) LD

TABLE 2. CATTLE TYPE, PRODUCTION SYSTEM AND CATTLE TYPE × PRODUCTION SYSTEM MEANS FOR PERFORMANCE DATA

	Cattle type		Production system		Cattle type × production system			
					Accelerated		Conventional	
Item	A × H	S × C	Accel-erated	Conven-tional	A × H	S × C	A × H	S × C
Beginning height, cm	106.6^{b}	115.2^{a}	110.5	111.3	106.2^{b}	114.8^{a}	107.0^{b}	115.5^{a}
Backgrounding, d				162			140	183
Finishing, d	128	151	160	119	140	180	116	122
Total days	198	243	160	281	140	180	256	305
Beginning wt, kg	260.6	256.9	260.3	257.2	263.4	257.2	257.8	256.6
Post-backgrounding wt, kg	342.3^{b}	380.3^{a}		361.3			342.3^{b}	380.3^{a}
Slaughter wt, kg	480.3^{b}	548.4^{a}	468.2^{b}	560.5^{a}	429.6^{d}	506.8^{c}	531.0^{b}	590.0^{a}
Backgrounding ADG, kg	.60^{b}	.68^{a}		.64			.60^{b}	.68^{a}
Finishing ADG, kg	1.40	1.53	1.30^{b}	1.68^{a}	1.19^{c}	1.39^{b}	1.63^{a}	1.72^{a}
Overall ADG, kg	1.11	1.08	1.30^{a}	1.08^{b}	1.19^{b}	1.39^{a}	1.07^{c}	1.09^{bc}
ME consumption/day								
Backgrounding	17.43^{b}	19.42^{a}		18.56			17.43	19.42
Finishing	24.28^{b}	25.89^{a}	24.17	25.75	23.32	24.82	33.73	37.40
Overall	24.28^{b}	25.89^{a}	24.17	25.75	23.32	24.82	24.81	26.62
ME/kg gain								
Backgrounding				28.80			28.87	28.75
Finishing	19.75^{a}	20.01^{a}	18.86^{b}	20.01^{a}	19.64^{b}	17.90^{c}	20.74^{ab}	21.76^{a}
Overall	21.89^{a}	21.59^{a}	18.86^{b}	23.86^{a}	19.64^{b}	17.90^{c}	23.26^{a}	24.35^{a}

[a,b,c,d]Means in the same row within cattle type, production system or cattle type × production system that do not have a common superscript differ ($P<.05$).

TABLE 3. CARCASS TRAIT MEANS FOR CATTLE TYPES, PRODUCTION SYSTEMS AND CATTLE TYPE × PRODUCTION SYSTEM

Carcass trait	Cattle type		Production system		Cattle type × production system			
					Accelerated		Conventional	
	A × H	S × C	Accel-erated	Conven-tional	A × H	S × C	A × H	S × C
Hot carcass wt, kg	289.9[f]	328.2[e]	231.3[f]	336.9[e]	262.2[h]	300.4[g]	317.7[f]	356.1[e]
Dressing, %[a]	62.2	61.7	62.1	61.9	62.9[e]	61.3[f]	61.6[ef]	62.1[ef]
Fat thickness, cm	1.42[e]	.81[f]	1.01[f]	1.22[e]	1.30[f]	.72[g]	1.53[e]	.90[g]
Longissimus area, cm^2	66.78[f]	82.39[e]	72.18[f]	76.97[e]	65.87[g]	78.59[f]	67.62[g]	86.26[e]
KPH fat, %	3.5[e]	2.9[f]	3.0	3.3	3.4[e]	2.7[f]	3.6[e]	3.1[ef]
Yield grade	3.7[e]	2.5[f]	2.8[f]	3.3[e]	3.3[f]	2.3[g]	4.0[e]	2.7[g]
Marbling[b]	9.8[e]	8.5[f]	8.4[f]	9.9[e]	8.8[f]	8.0[f]	10.8[e]	9.0[f]
Quality grade[c]	9.3[e]	8.6[f]	8.4[f]	9.5[e]	8.8[ef]	8.0[f]	9.8[e]	9.1[ef]
Carcass soft tissue ether extract, %[d]	34.9[e]	26.7[f]	30.4	31.6	34.4[e]	26.3[f]	35.3[e]	27.1[f]
Carcass soft tissue water, %[d]	50.2[f]	56.2[e]	53.7	52.3	51.1[f]	56.4[e]	49.3[f]	55.9[e]

[a]Calculated on hot carcass weight basis.

[b]8 = slight (34 to 66%), 9 = slight (67 to 99%), 10 = small (0 to 33%), et cetera.

[c]8 = low Good, 9 = high Good, 10 = low Choice, et cetera.

[d]Predicted from 9-10-11th rib soft tissue chemical composition (Hankins and Howe, 1946).

[e,f,g,h]Means in the same row within cattle type, production system or cattle type × production system that do not have a common superscript differ ($P<.05$).

muscle areas, lower (P<.05) USDA yield grade numbers, lower (P<.05) percentages of carcass soft-tissue lipid, higher (P<.05) percentages of carcass soft-tissue water, lower (P<.05) marbling scores and lower (P<.05) USDA quality grades than A × H cattle. Koch et al. (1976) and Marion et al. (1980) reported similar differences in carcass traits between Simmental-sired steers and Hereford-Angus reciprocal crossbreds. In our study, A × H cattle were apparently at a somewhat different point on the growth curve than S × C cattle when slaughtered.

Cattle on the ACC system had less (P<.05) fat thickness, smaller (P<.05) LD muscle areas, lower (P<.05) USDA yield-grade numbers, lower (P<.05) marbling scores and lower (P<.05) USDA quality grades than cattle on the CONV system. However, percentages of predicted carcass soft-tissue lipid and water were not different (P>.05) between the two production systems, even though there was 92.3 kg difference in final weight between cattle on the two systems. This observation disagrees with those of Callow (1961), Reid et al. (1968), Jesse et al. (1976), Arthaud et al. (1977) and Trenkle et al. (1978), who stated that nutritional regimen had little influence on carcass composition so long as cattle were slaughtered at the same live weight. On the other hand, other researchers (Utley et al., 1975; Prior et al., 1977; Bidner et al., 1978; Young and Kauffman, 1978) have found that low-energy-density diets result in carcasses with lower percentages of fat when cattle are slaughtered at the same weight as cattle on high-energy-density diets. Although our cattle were not slaughtered at the same weights, it is very likely that cattle on the ACC system would have been fatter than those on the CONV system if the ACC cattle had been slaughtered at 92.3-kg heavier weights. This would be particularly true of A × H cattle. Muscle and bone growth of the carcass would have to increase at the same rate as fat deposition (twice as much muscle and bone weight as fat weight) with that additional 92.3 kg live weight in order for there not to be a difference in composition between ACC and CONV systems.

The A × H-ACC and S × C-ACC cattle had marbling scores of 8.8 and 8.0, respectively, which would correspond to LD lipid percentages of about 4.0 and 3.4% (Campion et al., 1975). Therefore, we did not quite achieve the intended endpoint of 4.5% LD lipid on the ACC system.

The A × H-CONV cattle had more (P<.05) fat thickness, higher (P<.05) USDA yield-grade numbers and higher (P<.05) marbling scores, but were not different (P>.05) in LD muscle areas from A × H-ACC cattle. On the other hand, S × C-CONV cattle had larger (P<.05) LD muscle areas, but were not different (P>.05) in fatness than S × C-ACC cattle. This further supports the observation that these S × C cattle were still in a "growth" stage, whereas A × H cattle were in more of a "fattening" stage when slaughtered on the CONV system. A live-weight endpoint of 625 kg (Koch et al., 1979) probably would have been more appropriate for the S × C-CONV cattle to achieve the same carcass quality as the A × H-CONV cattle, of which 83% graded Choice.

Meat-Palatability Traits for Cattle Types and Production Systems. The LD steaks were not different (P>.05) in palatability between cattle types (table 4). For SM steaks, there were no taste-panel differences (P>.05) for palatability; however, WBS values were higher for S × C cattle than for A × H cattle. This is somewhat surprising because taste-panel myofibrillar-tenderness scores were identical between cattle types, and connective-tissue amount tended (P<.10) to be less in S × C cattle (6.4 vs 6.2).

The ACC system resulted in lower (P<.05) WBS force values, higher (P<.05) taste-panel tenderness scores, less (P<.05) connective tissue, and equal flavor and juiciness scores for the LD muscle compared with the CONV system. For the SM muscle, the ACC system resulted in lower (P<.05) WBS force values, less connective tissue and higher flavor scores than for the CONV system. Therefore, the ACC system resulted in palatability somewhat superior to the CONV system, even though cattle were slaughtered at a considerably lighter weight and had lower USDA quality grades.

Palatability results make the ACC system look attractive. In addition, it required considerably less time (P<.05) from weaning to slaughter, required less total ME and less (P<.05) ME per unit of live-weight gain, and resulted in carcasses with less trimmable fat. Thus, the system was more efficient in utilizing feed to produce lean meat and still resulted in somewhat higher meat palatability. One disadvantage of the system was lower USDA quality grades (mostly Good grade carcasses) because the beef industry imposes a price differential between Choice and Good grade carcasses.

TABLE 4. CATTLE TYPE, PRODUCTION SYSTEM, CATTLE TYPE × PRODUCTION SYSTEM AND PROCESSING SYSTEM MEANS FOR LONGISSIMUS AND SEMIMEMBRANOSUS PALATABILITY

Palatability traits	Cattle type		Production system		Cattle type × production system				Processing treatment	
					Accelerated		Conventional			
	A × H	S × C	Accel-erated	Conven-tional	A × H	S × C	A × H	S × C	ESHB	Control
					Longissimus muscle					
WB shear, kg	2.88	2.92	2.69^{c}	3.11^{b}	2.74^{cd}	2.63^{d}	3.00^{bc}	3.22^{b}	2.81	2.99
Myofibrillar tenderness[a]	6.5	6.4	6.7^{b}	6.2^{c}	6.6^{bc}	6.8^{b}	6.3^{cd}	6.1^{d}	6.4	6.4
Connective tissue amount[a]	7.0	7.0	7.2^{b}	6.8^{c}	7.1^{b}	7.3^{b}	6.9^{c}	6.8^{c}	7.1	7.0
Flavor[a]	6.2	6.3	6.3	6.2	6.2^{c}	6.4^{b}	6.3^{bc}	6.2^{c}	6.3	6.2
Juiciness[a]	6.5	6.5	6.6	6.4	6.6	6.6	6.5	6.3	6.6^{b}	6.4^{c}
					Semimembranosus muscle					
WB shear, kg	3.7^{c}	4.0^{b}	3.63^{c}	4.08^{b}	3.42^{c}	3.86^{b}	3.99^{b}	4.17^{b}	4.13^{b}	3.58^{c}
Myofibrillar tenderness[a]	5.9	5.9	6.0	5.8	6.0	6.1	5.8	5.7	5.7^{c}	6.1^{b}
Connective tissue amount[a]	6.2	6.4	6.5^{b}	6.1^{c}	6.4^{b}	6.6^{b}	6.0^{c}	6.2^{c}	6.2^{c}	6.4^{b}
Flavor[a]	6.1	6.1	6.1^{b}	6.0^{c}	6.1^{bc}	6.2^{b}	6.1^{bc}	5.9^{c}	6.0	6.1
Juiciness[a]	5.4	5.2	5.3	5.3	5.4	5.3	5.4	5.1	5.3	5.3

[a]8 = extremely tender, no detectable connective tissue, extremely intense flavor or extremely juicy; 1 = extremely tough, abundant connective tissue, extremely bland or extremely dry.

[b,c,d]Means in the same row within cattle type, production system, cattle type × production system or processing system that do not have a common superscript differ ($P<.05$).

Another disadvantage might be that it relies more on grain feeding and does not use as much roughage as the CONV system, which may diminish the usefulness of the bovine for utilizing grass and other roughages. Reid and Klopfenstein (1983) stated that beef production in the future will be less intensive with more effective use of roughages.

The greater amount of detectable connective tissue and lower tenderness scores for cattle on the CONV system somewhat contradicts the current USDA quality-grade standards in that the standards for A-maturity carcasses are based on the premise that tenderness differences are negligible for cattle ranging from 9 to 30 mo of age. Yet, our results reveal tenderness differences for only 3 mo difference in age between ACC and CONV feeding. Thus, from a palatability standpoint, the S × C-CONV system is somewhat inferior to either A × H or S × C cattle on the ACC system.

Meat-Palatability Traits for ESHB and C Treatments. The ESHB and C LD were not different (P<.05) in WBS force or taste-panel scores for myofibrillar tenderness, connective-tissue amount or flavor (table 4). These tenderness results agree with those of Gilbert and Davey (1976), Gilbert et al. (1976) and Seideman et al. (1979), who concluded that ESHB LD is of comparable tenderness with that of C, cold-boned carcasses. The ES studies of Savell et al. (1977), Chrystall (1976) and Grusby et al. (1976) all showed significant differences in favor of ES-LD over C samples; however, they did not hot bone ES muscles.

The ESHB did result in increased (P<.05) LD juiciness. Savell et al. (1977) and Davey et al. (1976) reported no differences in LD juiciness due to ES, whereas Savell et al. (1978) reported that ES steaks were less juicy than C steaks. Axe et al. (1983) found that ESHB LD muscles were equal in tenderness, flavor and juiciness to C muscles.

The ESHB SM had higher (P<.05) WBS values, less myofibrillar tenderness and greater connective-tissue amount than C SM (table 4). Flavor and juiciness were not different between ESHB and C treatments. These tenderness results disagree with other researchers who used different ESHB techniques. By altering the ESHB treatment, ESHB could be made equal or superior to C (Kastner, 1983).

Temperature and pH Declines for ESHB and C LD and SM Muscles. Temperature declines for ESHB and C LD and SM muscles are shown in figures 1 and 2, respectively, while ESHB and C LD pH declines are shown in figure 3. It is generally accepted that cold-toughening can occur if muscles reach 10 C before pH 6.0 is reached (Chrystall, 1976). In our study, LD pH was below 6.0 for both ESHB and C treatments by 6 h postmortem, whereas LD temperature was above 14 C by 6 h for both ESBH and C treatments. It should be emphasized that we chilled ESHB muscles in cardboard boxes. Therefore, our ESHB LD muscle probably did not cold toughen, which resulted in tenderness equal to C LD.

The pH decline we achieved was not as rapid as those achieved by other researchers. Lowering the frequency from 60 Hz to a value between 15 and 25 Hz or, stimulating earlier postmortem, may have caused a more rapid pH decline (Bendall et al., 1976). Similarly, Chrystall and Hagyard (1975), Devine (1976) and Axe et al. (1983) have reported faster pH declines by pulsing ES treatments compared with continuous ES. Davey et al. (1976) observed more rapid pH declines in LD muscles by stimulating at 30 min postmortem.

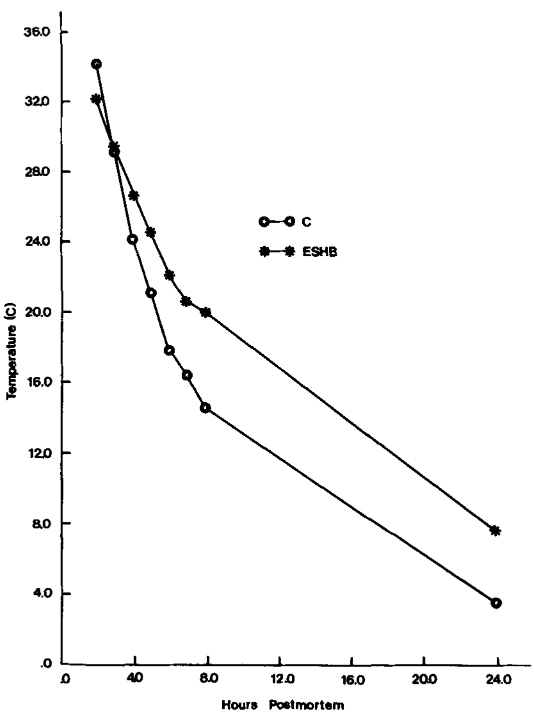

Figure 1. Control and electrically stimulated-hot boned temperature decline for the longissimus muscle.

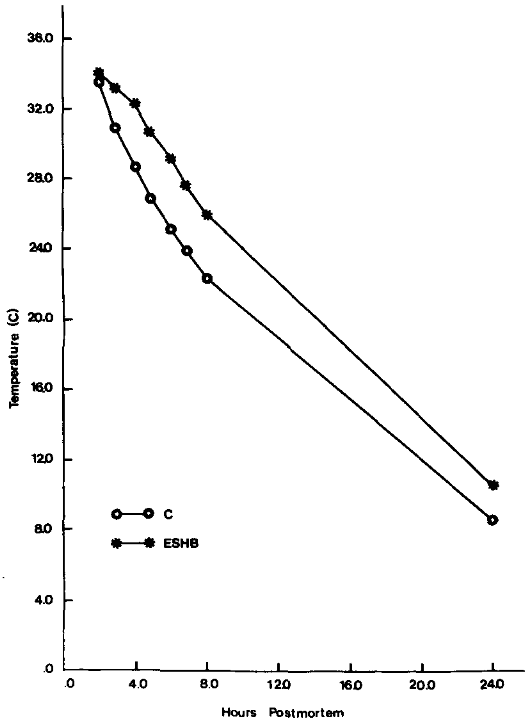

Figure 2. Control and electrically stimulated-hot boned temperature decline for the semimembranosus muscle.

Although we did not measure pH decline in the SM muscle, it is not likely that cold-toughening occurred for the ESHB treatment because the temperature was above 16 C at 12 h postmortem and, according to Locker and Hagyard (1963), cold-toughening should not occur under these conditions. Yet, our ESHB SM muscles were less tender (P<.05) than C. Therefore, heat shortening may have been a possible cause for the ESHB SM toughening and(or) shortening due to excision may have occurred (Herring et al., 1965).

Display Color of LD Steaks for Cattle Types and Production Systems for ESHB and C Carcass Treatments. After 1 d of display at 2 C, there were generally no color differences (P>.05) between cattle types or carcass-processing treatments (table 5). However, ESHB-ACC steaks had a brighter color than ESHB-CONV or C-CONV steaks. After 4 d of display, A × H cattle that were ESHB had brighter (P<.05) color scores than S × C cattle. The ESHB-ACC cattle had brighter (P<.05) color scores than either ESHB-CONV or C-CONV at 4 d. In addition, C-ACC cattle had brighter color scores than C-CONV at 4 d. Therefore, it appears that the combination of ESHB and ACC production results in brighter LD color scores. Our results for ESHB LD color tend to support the findings of Savell et al. (1978) and Smith et al. (1977b). Claus et al. (1981) also found ESHB and C LD steaks to be similar in color after 5 d.

Economic Analyses of Cattle Type × Production System Combinations. The S × C-ACC steers had the lowest break-even live price ($1.28/kg) and lowest cost/kg of predicted retail product ($2.97/kg) of all cattle type × production system combinations (table 6). Break-even live price was equal for A × H-ACC and A × H-CONV cattle at $1.39/kg, whereas cost/kg of predicted retail product tended to favor A × H-ACC cattle because of their advantage in retail-product percentage. The S × C-CONV cattle tended to have the highest break-even live price because of their lower overall ADG, resulting from the long time (183 d) on the backgrounding phase. However, because of their significant advantage in predicted retail-product percentage, their cost/kg retail product ($3.39/kg) was lower than for A × H-CONV cattle ($3.64/kg).

For the comparison in which purchase price was increased 25%, break-even live prices were less different among cattle type × production groups (table 7). The S × C-ACC cattle tended to have the lowest break-even live price,

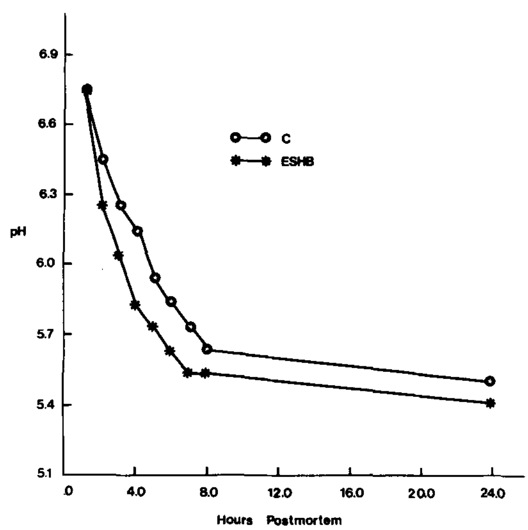

Figure 3. Control and electrically stimulated-hot boned pH decline for the longissimus muscle.

TABLE 5. CATTLE TYPE AND PRODUCTION SYSTEM MEANS FOR COLOR[a] OF ELECTRICALLY STIMULATED-HOT BONED AND CONTROL LONGISSIMUS STEAKS DISPLAYED FOUR DAYS IN POLYVINYL CHLORIDE FILM AT 2 C

Carcass treatment	Cattle type		Production system		Avg
	A X H	S X C	Accel-erated	Conven-tional	
			Day 1		
ESHB	1.55	1.54	1.44^{c}	1.65^{b}	1.54
Control	1.71	1.59	1.63^{bc}	1.68^{b}	1.65
			Day 4		
ESHB	1.75^{c}	2.14^{b}	1.80^{d}	2.09^{bc}	1.94
Control	1.95^{bc}	2.26^{b}	1.91^{cd}	2.30^{b}	2.10
Avg	1.74	1.88	1.70	1.93	

[a]1 = Extremely bright red, 2 = bright red, 3 = slightly dark red or brown, 4 = dark red or brown, 5 = extremely dark red or brown.

[b,c,d]Means within cattle type X carcass treatment or production system X carcass treatment within a day that do not have a common superscript differ (P<.05).

whereas A × H-ACC and S × C-CONV cattle tended to have the highest break-even live prices. Cost/kg of predicted retail product also tended to be lowest for S × C-ACC cattle ($3.45/kg) and highest for A × H-CONV cattle ($4.19/kg). Rapid growth and high carcass cutability were the main reasons for the lowest cost/kg of retail product for S × C-ACC cattle. Low carcass cutability was the major reason for the highest cost/kg of predicted retail product for the A × H-CONV cattle.

For the comparison in which feed, yardage, transportation and veterinary costs were increased 25%, S × C-ACC cattle had the lowest break-even live price ($1.33/kg), whereas S × C-CONV cattle had the highest break-even live price ($1.62/kg). In addition, cost/kg of predicted retail product was lowest for S × C-ACC cattle ($3.22/kg) and highest for A × H-CONV cattle ($4.03/kg). These rankings are the same as those in which purchase price only was increased 25%. Similar rankings occur when only

TABLE 6. ITEMIZED PRODUCTION COSTS, BREAK-EVEN LIVE PRICES AND COSTS PER KG RETAIL PRODUCT FOR CATTLE TYPE X PRODUCTION SYSTEM COMBINATIONS

Item	A X H cattle, accel-erated	S X C cattle, accel-erated	A X H cattle, conven-tional	S X C cattle, conven-tional
Purchase cost at $1.54/kg	$405.64	$396.09	$397.01	$395.16
Transportation and veterinary processing	$6.50	$6.50	$6.50	$6.50
Yardage at $.07/d	$9.80	$12.60	$17.92	$21.35
Feed				
Corn at $.115/kg	$111.41	$155.29	$140.35	$162.82
Sorghum grain at $.104/kg			$35.52	$54.37
Supplement at $.229/kg	$13.59	$18.37	$27.86	$36.91
Silage at $.037/kg	$15.19	$19.66	$18.68	$23.01
Prairie hay at $.063/kg			$49.30	$78.20
Total feed cost	$140.19	$193.32	$271.71	$355.31
Interest	$22.42	$29.92	$46.15	$59.16
Total costs	$584.55	$638.42	$721.37	$837.48
Break-even live price/kg	$1.39	$1.28	$1.39	$1.45
Cost/kg of retail product	$3.37	$2.97	$3.64	$3.39

TABLE 7. BREAK-EVEN LIVE PRICES AND COSTS PER KG RETAIL PRODUCT FOR CATTLE TYPE × PRODUCTION SYSTEM COMBINATIONS WHEN VARIOUS COSTS ARE INCREASED RELATIVE TO THOSE COSTS PRESENTED IN TABLE 6

	Accelerated[a]		Conventional[a]	
Item	A × H	S × C	A × H	S × C
Base values (from table 6)	$1.39 $3.37	$1.28 $2.97	$1.39 $3.64	$1.45 $3.39
Purchase cost increased 25%	$1.64 $3.99	$1.49 $3.45	$1.59 $4.19	$1.64 $3.82
Feed, yardage, transportation and veterinary costs increased 25%	$1.48 $3.62	$1.33 $3.22	$1.53 $4.03	$1.62 $3.79
Interest cost increased 50%	$1.42 $3.45	$1.31 $3.03	$1.43 $3.76	$1.50 $3.50
All costs increased 25% except interest cost increased 50%	$1.76 $4.31	$1.64 $3.80	$1.83 $4.81	$1.88 $4.38

[a]Values are per kg.

interest cost is increased, except that the magnitude of the difference is considerably lower.

When all costs were increased, S × C-ACC cattle had the lowest break-even live price ($1.64/kg) followed by A × H-ACC cattle ($1.76/kg), A × H-CONV cattle ($1.83/kg) and S × C-CONV cattle ($1.88/kg). Cost/kg of predicted retail product was again lowest for S × C-ACC cattle ($3.80/kg) and highest for A × H-CONV cattle ($4.81/kg), whereas A × H-ACC and S × C-CONV cattle were similar ($4.31 and $4.38/kg, respectively).

Profits and Losses of Cattle Type × Production System Combinations. For either method of determining ending-carcass value, only S × C-ACC cattle were profitable (table 8). They were most profitable when carcass value was based on predicted retail product differences rather than industry price differentials for yield grades. When carcass value was based on predicted retail product differences, A × H-ACC and S × C-CONV cattle lost about the same amount per head (−$14.55 and −$11.76, respectively) and A × H-CONV lost the most

TABLE 8. PROFITS AND LOSSES[a] OF CATTLE TYPE × PRODUCTION SYSTEM COMBINATIONS BASED ON TWO METHODS OF DETERMINING CARCASS VALUE

Item	A × H cattle, accel-erated	S × C cattle, accel-erated	A × H cattle, conven-tional	S × C cattle, conven-tional
Profit or [loss], analysis C[b]	[$14.55]	$68.03	[$56.69]	[$11.76]
Profit or [loss], analysis D[c]	[$29.12]	$9.99	[$58.89]	[$62.22]

[a]Values are per head.

[b]Predicted cutability differentials based on $19.85/100 kg adjustment for each full yield grade above or below 3.5. Choice, Good and Standard carcasses priced at $220.50, $211.60 and $202.86/kg, respectively.

[c]Industry price differentials based on $17.64/100 kg discount for yield grade 4 and 5 carcasses, $4.41/100 kg premium for yield grade 1 and 2 carcasses, and $4.41/100 kg discount for carcasses over 386 kg and under 272 kg. Choice, Good and Standard carcasses priced at $220.50, $211.60 and $202.86/kg, respectively.

(−$56.69) because of their low predicted yields of retail product. When carcass value was based on industry price differentials, A × H-CONV cattle lost considerable money (−$58.89) because of undesirable yield grades, whereas S × C-CONV cattle lost considerable money (−$62.22) because of a low percentage of Choice carcasses and high production cost. The A × H-ACC cattle lost money (−$29.12) primarily because of undesirably light carcass weights.

Based on the economic assumptions we used, and the performance and carcass differences that occurred in our study, it is clear that S × C cattle with genetic potential for rapid growth and a high percentage of retail product at traditional slaughter weights are most economical when fed for maximum growth after weaning. This minimizes feed utilized for maintenance and nonfeed costs. The A × H cattle did not have potential for rapid enough growth, and produced carcass weights unacceptably light to the industry when managed on the ACC system. The A × H cattle could be economical on a CONV system if slaughtered at a lighter weight, which would result in less carcass fat and more efficient feed utilization. The S × C cattle were not economical when not fed for maximum growth because maintenance feed and nonfeed costs became disproportionately high. Only when market value is based on actual cutability differences would the S × C-CONV system be efficient.

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