Sorting feeder cattle with a system that integrates ultrasound backfat and marbling estimates with a model that maximizes feedlot profitability in value-based marketing

J. A. Basarab[1], J. R. Brethour[2], D. R. ZoBell[3], and B. Graham[4]

[1]Alberta Agriculture, Food and Rural Development, Lacombe Research Centre, 6000 C & E Trail, Lacombe, Alberta, Canada T4L 1W1; [2]Kansas State University Agricultural Research Center - Hays, 1232 - 240 Avenue, Hays, Kansas 67601, USA; [3]Department of Animal, Dairy and Veterinary Science, Utah State University, 4815 Old Main Hill, Logan, UT, 84322-4815, USA; [4]Lakeside Feeders Inc., P.O. Box 800, Brooks, Alberta, Canada T1R 1B7. *Received 18 September 1998, accepted 12 April 1999.*

Basarab, J. A., Brethour, J. R., ZoBell, D. R. and Graham, B. 1999. **Sorting feeder cattle with a system that integrates ultrasound backfat and marbling estimates with a model that maximizes feedlot profitability in value-based marketing.** Can. J. Anim. Sci. **79**: 327–334. Studies were conducted to evaluate a feeder cattle sorting system for tracking future carcass merit. The Kansas State University (KSU) sorting system combines initial body weight, ultrasound backfat thickness and marbling score with economic data to project the number of days on feed that will maximize profitability. The KSU sorting system was applied, 3 to 4 mo before slaughter, on 4101 yearling steers at two large feedlots located in southern Alberta. In Feedlot 1, steers averaging 408.7 kg (SD = 45.2 kg) were randomly assigned to two treatment groups: sorted by weight (control; n = 856) and sorted by the KSU sorting system (n = 849). In Feedlot 2, steers averaging 494.4 kg (SD = 42.3 kg) were randomly assigned to two treatment groups: not sorted (control; n = 798) and sorted by the KSU sorting system (n = 1598). Whole pens were marketed when the majority of steers in the pen approached the carcass weight and grade characteristics required for optimal return. The KSU sorted steers gained 0.12 kg d^{-1} faster at Feedlot 1 (P = 0.043) and 0.05 kg d^{-1} faster at Feedlot 2 (P = 0.036) than control steers. Feed intake, feed efficiency, death loss, warm carcass weight, backfat thickness, l. dorsi area, marbling score and lean meat yield were similar between sorting systems regardless of feedlot. The KSU sorting system reduced dark cutting (B4) carcasses to zero (0.0% KSU vs. 1.3% Control; P = 0.005) and increased AAA quality grade carcasses by 40.8% (31.4% KSU vs. 22.3% Control; P = 0.001) in Feedlot 1. In Feedlot 2, the KSU sorting system reduced over-fat carcasses (Y3) by 47.4% (10.2% KSU vs. 19.4% Control; P = 0.001) and increased AA carcasses by 14.7% (52.3% KSU vs. 45.6% Control; P = 0.003). These changes resulted in the KSU sorted steers being more profitable than control steers by \$27.67 head^{-1} in Feedlot 1 and \$15.22 head^{-1} in Feedlot 2. The increased net return was primarily due to improved weight gains and a more desirable distribution of carcass yield and quality grades.

Key words: Ultrasound, carcass uniformity, steers

Basarab, J. A., Brethour, J. R., ZoBell, D. R. et Graham, B. 1999. **Triage des bovins d'engraissement au moyen d'un système intégrant les mesures du gras dorsal (par ultrasons) et de l'indice de persillé à un modèle maximisant la rentabilité de l'engraissement dans les conditions réelles de coût de production et de prix de marché**. Can. J. Anim. Sci. **79**: 327–334. Nous avons évalué un système de triage des bovins d'engrais quant à son aptitude à prédire la qualité des carcasses. Le système de tri mis au point à l'Université de l'État du Kansas (KSU) allie le poids corporel initial, le poids corporel de départ, l'épaisseur du gras dorsal mesurée par ultrasons et l'indice de persillé aux données économiques, pour prédire le nombre de jours d'engraissement qui maximisera la rentabilité. Le système KSU a été appliqué, 3 à 4 mois avant l'abattage, à 4101 bouvillons d'un an répartis sur deux grands parcs d'engraissement situés dans le sud de l'Alberta. Au parc 1, des bouvillons, d'un poids corporel moyen de 408,7 kg (ET=45,2 kg), étaient répartis au hasard entre deux traitements de triage, l'un au poids (témoin, n = 856), l'autre par le système de tri KSU (n=849). Au parc 2, les bouvillons de 494,4 kg (ET = 42,3 kg) étaient de même divisés en deux groupes, l'un sans triage (témoins, n = 798), l'autre trié selon le système KSU (n = 1598). Les bouvillons étaient vendus par parquet entier lorsque la majorité d'entre eux dans un parquet arrivaient au poids et aux qualités de carcasse nécessaire, pour une rentabilité maximale. Les bouvillons triés selon le système KSU prenaient 0,12 kg par jour plus de poids au parc d'engraissement 1 (P = 0,043) et 0,05 kg de plus (P = 0,036) au parc 2 que les bouvillons témoins. La prise alimentaire, l'indice de conversion, les pertes par mortalité, le poids de carcasse chaude, l'épaisseur du gras dorsal, la surface de la noix de côte, l'indice de persillé et le rendement de maigre étaient semblables pour tous les systèmes, quel que soit le parc d'engraissement. Au parc 1, le système KSU permettait de ramener à 0 le nombre de carcasses à coupe sombre (catégorie B4) par comparaison à 1,3 % avec le système témoin (P = 0,005) et d'augmenter de 40,8 % la proportion des carcasses de qualité AAA (soit 31,4 % KSU contre 22,3 % témoin; P = 0,001). Au parc d'engraissement 2, le système KSU produisait une diminution de l'ordre de 47,4 % des carcasses surengraissées (Y3) par rapport aux témoins, soit 10,2 % KSU contre 19,4 % témoin; P = 0,001) et un accroissement de 14,7 % du nombre de carcasses AA, soit

Abbreviations: **ADG**, average daily gain; **BrBr**, British × British breed group; **CBGA**, Canadian Beef Grading Agency; **CnBr**, Continental × British breed group; **CnCn**, Continental × Continental breed group; **DM**, dry matter; **DOF**, days on feed; **KSU**, Kansas State University; **KPH**, kidney, pelvic and heart fat

52,3 % KSU contre 45,6 % témoin; P = 0,003. Ces différences sont exprimées par un gain de rentabilité de 27,67 \$ aj^{-1} au parc 1 et de 15,22 \$ aj^{-1} au parc 2. Ce gain de rentabilité nette était principalement attribuable à l'amélioration des gains de poids et à une répartition plus souhaitable des rendements de carcasse et des niveaux de qualité des carcasses.

Mots clés: Ultrasons, homogénéité des carcasses, bouvillons

Various feeder cattle sorting strategies, conducted 3 to 6 mo prior to slaughter, have shown potential in improving the carcass uniformity and profit of finished cattle. In a study conducted at the Kansas State University (KSU), Brethour (1990, 1991a) used individual animal weight and backfat estimates to sort feeders into days on feed groups and increased net return by US\$20 head^{-1} slaughtered. Sainz and Oltjen (1994) used a computer model of growth (Oltjen et al. 1986) to integrate initial animal weight, frame size and backfat thickness and initial feeding information to sort feeders into uniform groups 4 to 6 mo prior to slaughter. In their trial, the variability in carcass backfat thickness of sorted cattle was reduced by 22.6% as compared with unsorted cattle. In a Canadian study, Basarab et al. (1997) also used a computer model (Oltjen et al. 1986) to theoretically sort animals into estimated days on feed groups 3 to 5 mo before slaughter. This sorting strategy reduced the variability in carcass backfat thickness by 15.5% compared with steers visually sorted at the end of the feeding period. Recently, Brethour (1994a,b) refined the KSU sorting system by incorporating a live animal measurement of marbling score. The KSU sorting system combines initial measures of body weight, ultrasound backfat thickness and marbling score with economic conditions such as the carcass price matrix and production costs to project the number of additional days on feed that maximizes profitability. This system appears to have economic potential and remains untested under Canadian feeding, grading and economic conditions. The objective of this study was to evaluate the KSU sorting system, applied 3 to 4 mo before slaughter, for its ability to improve the net return of finished cattle at slaughter under Canadian grading and economic conditions.

MATERIALS AND METHODS

Animals, Housing and Management

Yearling beef steers (n = 4101) were assembled by order buyers and delivered to two large commercial feedlots located in southern Alberta. The first group of 1705 yearlings, averaging 408.7 kg (SD = 45.2 kg), were delivered to Lakeside Feeders from 24 to 27 June 1996 (Feedlot 1). The second group of 2396 long yearlings, averaging 494.4 kg (SD = 42.3 kg), were delivered to Cor Van Raay Farms from 21 to 24 October 1997 (Feedlot 2). The cattle were from various genetic backgrounds and many different sources. Upon arrival, the cattle were subjected to induction procedures, which included the administration of an IBR-PI_3 vaccine and a growth-promoting implant at both feedlots. In addition, a combined clostridial vaccine and an injectable parasiticide was administered at Feedlot 1. Each animal was individually identified with an eartag, visually appraised for predominant breed cross and weighed. An ultrasound image, approximately 10 cm distal from the midline (over the longissimus muscle), was captured on each animal from the sagittal plane over the first and second lumbar vertebrae (Brethour 1991b, 1992). The captured image was passed to a computer equipped with a digitizing board. The digitized image was then processed using pattern recognition and neural network procedures, which provide an automated measurement of backfat thickness and intramuscular fat, or marbling. The entire induction procedure, which included ultrasound measurements and a four- to six-way sort was accomplished at a rate of 65–70 head h^{-1}.

Animals were randomly assigned to control or treatment pens within each feedlot. In Feedlot 1, the control or contemporary comparison group comprised of steers that were sorted by weight since this was the normal practice of the commercial feedlot. Within the weight sorted group, animals were sorted by individual body weight into light (≤362.8 kg), medium (362.9 to 408.1 kg) and heavy (≥408.2 kg) weight pens (142–250 head pen^{-1}). These pens corresponded to long, medium and short days on feed. In Feedlot 2, the control or contemporary comparison group comprised of steers that were not sorted by weight (260–270 head pen^{-1}). In both feedlots, steers were sorted into long, medium and short days on feed pens using the KSU sorting system (131–250 head pen^{-1} in Feedlot 1; 227–294 head pen^{-1} in Feedlot 2). This procedure was repeated for each sorting system for the purpose of two replicates in Feedlot 1 and three replicates in Feedlot 2. A replicate consisted of three pens (one pen of short, one pen of medium and one pen of long days on feed) for each sorting system in Feedlot 1. In Feedlot 2 a replicate consisted of three pens (one pen of short, one pen of medium and one pen of long days on feed) for the KSU sorting system and one pen for the unsorted control steers.

The KSU sorting system uses the ultrasound values, the weight of the animal, the local carcass price matrix and production costs to estimate the number of days an individual animal should be fed, after the evaluation date, to reach maximum profitability. Backfat thickness is used to project future yield, marbling accounts for future quality grade and live weight provides the basis for future carcass weight. The three dimensions of a typical carcass price matrix are therefore accurately represented. Projection equations for changes in live weight, marbling and backfat are derived from research involving serial ultrasound measures on hundreds of cattle (John Brethour, Pers. Comm. 1999, Kansas State University, Agricultural Research Center, Hays). A linear function for increases in carcass weight, an exponential function for changes in backfat thickness and a modified power function to predict a future marbling score are implemented within the computer program. The program uses a probability density function to estimate the likelihood of a

Table 1. Composition of the final finishing diet by feedlot

	Feedlot 1	Feedlot 2
Days on diet	72–102	63–110
Diet ingredients, % as fed		
Barley silage	19.58	16.90
Barley grain	75.18	79.90
Feedlot supplement[z]	1.79	3.20
Others[y]	3.46	—
Diet composition, DM basis		
Dry matter (%)	74.58	73.96
NEm (MJ kg^{-1})	8.46	7.86
NEg (MJ kg^{-1})	5.72	5.18
Crude protein (%)	12.31	12.32
Calcium (%)	0.52	0.66
Phosphorus (%)	0.34	0.37
Potassium (%)	0.72	0.67
Sulphur (%)	0.18	0.14
Magnesium (%)	0.17	0.15
Sodium (%)	0.10	0.14
Chlorine (%)	0.22	—
Salt (%)	0.11	—
Manganese (mg kg^{-1})	38.1	41.1
Zinc (mg kg^{-1})	97.6	75.7
Copper (mg kg^{-1})	15.0	14.8
Iron (mg kg^{-1})	140.2	105.4
Iodine (mg kg^{-1})	0.39	0.65
Cobalt (mg kg^{-1})	0.42	0.48
Selenium (mg kg^{-1})	0.12	0.27
Vitamin A (KIU kg^{-1})	4.95	4.46
Vitamin D3 (KIU kg^{-1})	0.50	0.00
Vitamin E (IU kg^{-1})	0.50	4.33
Crude fat (%)	2.34	—
Acid detergent fibre (%)	9.58	10.63
Antibiotic (mg kg^{-1})	11.04	11.42
Ionophore (mg kg^{-1})	15.37	25.18

[z]Feedlot 1 supplement analysis (DM basis) was: crude protein 21%; acid detergent fibre 5.7%; sodium 1.9%; calcium 14.7%; phosphorus 1.3%; potassium 0.2%; magnesium 1.31%; sulphur 0.25%; iron 2,161 mg kg^{-1}; iodine 17 mg kg^{-1}; copper 445 mg kg^{-1}; manganese 870 mg kg^{-1}; zinc 2,978 mg kg^{-1}; cobalt 4.6 mg kg^{-1}; selenium 5.4 mg kg^{-1}; vitamin A 216 091 IU kg^{-1}; vitamin D 21 612 IU kg^{-1}; vitamin E 393 IU kg^{-1}; monensin sodium 288 mg kg^{-1}; ethoxyquin 3.5 mg kg^{-1}. Feedlot 2 supplement analysis (DM basis) was: crude protein 8.9%; acid detergent fibre 7.6%; calcium 12.30%; phosphorus 0.38%; potassium 1.1%; magnesium 0.20%; sulphur 0.25%; sodium 2.13%, iron 163 mg kg^{-1}; iodine 13 mg kg^{-1}; copper 174 mg kg^{-1}; manganese 435 mg kg^{-1}; zinc 740 mg kg^{-1}; cobalt 1.7 mg kg^{-1}; selenium 3.5 mg kg^{-1}; vitamin A 89 663 IU kg^{-1}; vitamin E 87 IU kg^{-1}; monensin sodium 504 mg kg^{-1}; oxytetracycline 215 mg kg^{-1}.

[y]Others includes the following ingredients: water (46.5%); molasses (44.8%); grease (8.7%).

carcass falling into each cell of the price matrix. Each probability was then multiplied by the appropriate price premium or discount to compare carcass values for each day over a 200-day period following evaluation. A profitability curve was then generated by the program as a function of days on feed. A district peak representing the ideal number of additional days to feed an animal was usually evident. Because it was not feasible to sell cattle from a pen on a daily basis, the program clusters cattle into market groups representing optimal selling dates over 20-30 day intervals.

Cattle within each pen were managed as a unit after the initial sort. The steers in both feedlots were gradually adjusted from a high (70–90%) barley silage diet to a high barley diet over 15–21 days. The composition of the final finishing diets by feedlot are given in Table 1. Feed intakes were recorded daily. Daily dry matter intake was calculated for each pen by dividing total feed delivered to the pen by the proportion of dry matter in the diet and total head-days on feed. Slight adjustments were made to total feed intakes and head-days due to morbidity and mortality differences among pens. Average daily gain (ADG) for each pen was calculated by subtracting total shrunk weight marketed from total shrunk weight delivered to the pen divided by total head-days on feed. A feed:gain ratio was calculated for each pen by dividing daily dry matter intake by ADG.

Black Angus, Hereford, Shorthorn and Red Angus, and crosses among these breeds were classified into the British × British breed group (BrBr; Feedlot 1, n = 235; Feedlot 2, n = 870). Crosses between the Continental breeds (Blonde d'Aquitaine, Brown Swiss, Charolais, Gelbvieh, Limousin, Maine Anjou, Pinzgauer, Salers and Simmental) and the British × British breed group were classified as Continental × British (CnBr; Feedlot 1, n = 879; Feedlot 2, n = 1146). Crosses among the Continental breeds were classified as Continental × Continental (CnCn; Feedlot 1, n = 591; Feedlot 2, n = 380).

Steers from Feedlot 1 were processed at Lakeside Packers (Brooks, Alberta) while those from Feedlot 2 were processed at Cargill Foods (High River, Alberta) and Iowa Beef Processors (IBP, Pasco, Washington). A whole pen was marketed when the majority of steers in the pen approached the carcass weight and grade characteristics required for optimal return. This was determined by the feedlot manager using visual appraisal. In Feedlot 1, pens of steers for short, medium and long days on feed for both sorting systems were marketed in 1996 on September 25–26, October 15 and October 23, respectively. In Feedlot 2, KSU sorted steers in the short, medium and long days on feed pens were marketed on December 26, 1997 (IBP, Pasco, WA), February 4–7, 1998 (IBP, Pasco, WA) and February 10–12, 1998 (Cargill Foods, High River, Alberta), respectively. Steers in the control pens were marketed to the American IBP plant in Pasco on February 4–7, 1998. Technicians accompanied the cattle to the abattoir to record the visual eartag number in the sequence in which the animals were suspended on the overhead rail system. A technician also recorded the sequence number of any carcass that was removed from the overhead rail system. These data were used to link visual eartag numbers to carcass data. Management practices for all cattle followed the guidelines of the Canadian Council on Animal Care.

Graders certified under the Canadian Beef Grading Agency (CBGA) were used to collect individual animal carcass data at Lakeside Packers and Cargill Foods. A USDA grader was contracted to collect individual animal carcass data at IBP, Pasco. Warm carcass weight was taken shortly after slaughter and carcass backfat thickness, marbling score, lean meat yield, yield grade and quality grade were taken 24 h after slaughter at each abattoir. The USDA grader also collected percent kidney, pelvic and heart (KPH) fat 24 h after slaughter at the American IBP plant. Graders certified under CBGA recorded marbling score on an inverse

Table 2. Initial characteristics of control steers and steers sorted by the KSU sorting system

		Control[z]			Sorted[z]				
Feedlot	Trait	N	Mean	SD	N	Mean	SD	Prob.[y]	Prob.[x]
Feedlot 1	Live body weight (kg)	856	407.7	45.6	849	409.7	44.8	0.363	0.497
	Backfat thickness (mm)	856	2.51	1.15	849	2.51	1.10	0.987	0.341
	Marbling score[w]	856	3.75	0.42	849	3.74	0.41	0.705	0.869
	Breed group[v]								
	BrBr, %		12.4			15.1		0.106	
	CnBr, %		46.0			57.2		0.001	
	CnCn, %		41.6			27.7		0.001	
Feedlot 2	Live body weight (kg)	798	494.9	41.2	1598	494.2	42.9	0.695	0.233
	Backfat thickness (mm)	798	3.22	1.47	1598	3.34	1.58	0.067	0.194
	Marbling score[w]	798	4.03	0.51	1598	3.99	0.50	0.068	0.757
	Breed group[v]								
	BrBr, %		35.6			36.7		0.604	
	CnBr, %		48.1			47.7		0.841	
	CnCn, %		16.3			15.6		0.654	

[z]Control steers at Feedlot 1 were sorted by weight into light (≥ 408.2 kg; long days on feed), medium (362.9 to 408.2 kg; medium days on feed) and heavy (≤ 362.8 kg; short days on feed) weight pens at the beginning of the trial. Control steers at Feedlot 2 were not sorted. In each feedlot, the Kansas State University sorting system was used to sort steers into pens of short, medium and long days on feed based on initial weight, ultrasound backfat thickness and marbling score.
[y]Probability that treatment means are different.
[x]Probability that treatment variances are different.
[w]Marbling score is a measure of the intramuscular fat: trace marbling or less = 1.0 to 3.9 (Canada A quality grade; USDA Standard); slight marbling = 4.0 to 4.9 (Canada AA quality grade; USDA Select); small to moderate marbling = 5.0 to 7.9 (Canada AAA quality grade; USDA Choice); slightly abundant or more marbling = 8.0 to 11.0 (Canada Prime; USDA Prime).
[v]Breed group abbreviations are British × British (BrBr), Continental × British (CnBr) and Continental × Continental (CnCn) crosses.

descriptive scale, where 1.0 is extreme marbling and 10.0 is devoid of marbling. The USDA grader recorded marbling score on a descriptive scale, where 1.0 is devoid of marbling and 11.0 is very abundant marbling. The Canadian marbling scores were converted to USDA marbling scores where 1.0 to 3.9 equals trace marbling or less (Canada A quality grade; USDA Standard), 4.0 to 4.9 equals slight marbling (Canada AA quality grade; USDA Select), 5.0 to 7.9 equals small to moderate marbling (Canada AAA quality grade; USDA Choice) and 8.0 to 11.0 equals slightly abundant or more marbling (Canada Prime; USDA Prime). An imprint of the longissimus dorsi area was obtained using filter paper (Grade 601; 46 cm × 57 cm; Life Science Products, Inc., 10650 Irma Drive, Unit 26, P.O. Box 33090, Denver, Colorado 80233). This 100% cotton fibre paper was approved by both FDA and Agriculture and Agri-Food Canada as "generally regarded as safe" for food contact. The l. dorsi on each imprint was subsequently traced with a black felt pen. The area of the resulting polygon was then determined using an image analysis system (Kontron Bildanalyse Image Analysis System, release 1.3, Breslauer Strasse 2, 8057 Eching, West Germany). Marbling scores, quality grades and yield grades collected at IBP, Pasco were converted to their equivalent values under the Canadian Beef Grading Agency. Lean meat yields were calculated using the following equation: Lean meat yield, % = 57.96 + (0.202 × l. dorsi area, cm^2) – (0.027 × warm carcass weight, kg) – (0.703 × average backfat thickness, mm). The lean meat yield in Y1 carcasses is 59% or better, from 54% to 58% in Y2 carcasses and less than 54% in Y3 carcasses.

Economic Value

The net return for each pen of steers was calculated as follows:

$$\text{Net return} = \text{Income} - \text{Cost}_t;$$

$$\text{Cost}_t = \text{Cost}_d + \text{Cost}_i + \text{Cost}_f + \text{Cost}_y + \text{Cost}_{int};$$

Income was determined on actual selling price and was \$1.9087, \$1.8999 and \$1.9156 kg^{-1} slaughter weight (4% shrink) for short, medium and long days on feed in Feedlot 1. In Feedlot 2, the selling price was \$1.8669 kg^{-1} slaughter weight for all steers except those on short days on feed, which was \$1.9330 kg^{-1} slaughter weight. Cost_d equals feeder delivery cost and was calculated by multiplying average pen weight by buying price at the beginning of the trial plus \$8.93 $head^{-1}$ for buying and trucking. The buying price for 408.2 kg steers was \$2.0790 kg^{-1} in June of 1996 and \$1.7416 kg^{-1} in October of 1997 (Canfax, 215, 6715 – 8th Street, N.E., Calgary, Alberta T2E 7H7). Buying price decreased by \$.000972 kg^{-1} for average pen weights above 408.2 kg and increased by \$.000972 kg^{-1} for average pen weights below 408.2 kg. Cost_i equals induction costs or \$7.27 $head^{-1}$ in Feedlot 1 and \$2.00 $head^{-1}$ in Feedlot 2; Cost_f equals feed costs or \$0.079 and \$0.079 kg DM^{-1} delivered to each pen in Feedlot 1 and 2, respectively. Cost_y equals total yardage costs and is calculated by multiplying DOF by \$0.15 d^{-1}. Cost_{int} equals the sum of the feeder value and half the total feed costs multiplied by the proportion of the year on feed (DOF/365) and by 0.07 (7% interest). The cost of the KSU sorting system was \$3.50 $head^{-1}$. Additional profit or loss from differences in yield and quality grades were determined by using the grade discounts obtained from Canfax (215, 6715 – 8th Street, N.E., Calgary, Alberta T2E 7H7). A premium of \$0.2646 kg^{-1} carcass weight was given to AAA quality grade carcasses

Table 3. The effect of sorting system on the variation in initial weight, ultrasound backfat thickness and marbling score for each feedlot

	Trait	Days on feed	Control[z] N	Control[z] Mean	Control[z] SD	Sorted[z] N	Sorted[z] Mean	Sorted[z] SD	Prob.[y]
Feedlot 1	Live body weight (kg)	Short	408	445.7	31.1	246	456.9	35.6	0.0214
		Medium	307	386.3	12.9	256	414.8	19.0	0.0001
		Long	141	344.4	17.6	347	372.5	27.6	0.0001
		Overall[x]	856	407.7	22.3	849	409.7	27.3	0.0001
	Backfat thickness (mm)	Short	408	2.82	1.17	246	3.39	1.39	0.0001
		Medium	307	2.37	1.16	256	2.53	0.70	0.0021
		Long	141	1.93	0.76	347	1.88	0.52	0.0031
		Overall[x]	856	2.51	1.10	849	2.51	0.83	0.0025
	Marbling score[w]	Short	408	3.80	0.41	246	3.88	0.47	0.0145
		Medium	307	3.71	0.42	256	3.75	0.39	0.4453
		Long	141	3.70	0.45	347	3.63	0.34	0.1412
		Overall[x]	856	3.75	0.42	849	3.74	0.39	0.9896
Feedlot 2	Live body weight (kg)	Short				283	547.4	37.6	
		Medium				805	502.8	22.6	
		Long				510	450.9	24.8	
		Overall[x]	798	494.9	41.20	1598	494.2	26.0	0.0001
	Backfat thickness (mm)	Short				283	4.51	2.19	
		Medium				805	3.39	1.39	
		Long				510	2.61	0.89	
		Overall[x]	798	3.22	1.47	1598	3.34	1.37	0.8756
	Marbling score[w]	Short				283	4.14	0.60	
		Medium				805	3.98	0.48	
		Long				510	3.91	0.46	
		Overall[x]	798	4.03	0.51	1598	3.99	0.49	0.6471

[z]Control steers at Feedlot 1 were sorted by weight into short (≥ 408.2 kg), medium (362.9 to 408.2 kg) and long (≤ 362.8 kg) days on feed at the beginning of the trial. Control steers at Feedlot 2 were not sorted. In each feedlot, the Kansas State University sorting system was used to sort steers into pens of short, medium and long days on feed based on initial weight, ultrasound backfat thickness and marbling score.
[y]Probability that treatment variances are different.
[x]The overall standard deviations (SD) for the weight and KSU sorted cattle are the weighted average of the SD for short, medium and long days on feed within feedlot and trait.
[w]Marbling score is a measure of the intramuscular fat: trace marbling or less = 1.0 to 3.9 (Canada A quality grade; USDA Standard); slight marbling = 4.0 to 4.9 (Canada AA quality grade; USDA Select); small to moderate marbling = 5.0 to 7.9 (Canada AAA quality grade; USDA Choice); slightly abundant or more marbling = 8.0 to 11.0 (Canada Prime; USDA Prime).

and discounts of \$0.0661, 0.2205, 0.2205 and 0.7716 kg^{-1} carcass weight were given to Y2, Y3, B1 and B4 carcasses, respectively.

Statistical Analysis

All data were analysed using the General Linear Model Procedure (SAS Institute, Inc. 1992). Initial traits were subjected to an analysis of variance with sorting system as the only source of variation in the fixed effect model. Differences in variability between sort systems (control; KSU sorting system) for initial weight, backfat thickness and marbling score were tested for significance by subtracting the median for a trait from each animal's value (Lorenzen and Anderson 1993) and then subjecting the absolute deviations from the median to an analysis of variance. Sorting system was the only source of variation in the fixed effect model. The median for a trait was determined using the PROC UNIVARIATE procedure of the SAS Institute, Inc. (1992). Differences in breed group distribution between sorting systems were tested for significance using chi square analysis (SAS Institute, Inc. 1992).

A weighted average for each variable was determined for each replicate ($n = 2$ for Feedlot 1; $n = 3$ for Feedlot 2) within sorting system. Initially, the percentage of CnCn breeding in each replicate within sorting method and feedlot was used in an analysis of covariance to determine the effect of breed group distribution on sorting method. This covariate was not significant ($P > 0.1$) and was excluded from subsequent analysis. All data except yield and quality grade distributions were subjected to an analysis of variance with sorting system as the only source of variation. Yield and quality grade distribution data were subjected to chi square analysis (SAS Institute, Inc. 1992).

RESULTS AND DISCUSSION

Initially, steers allocated to the two sorting systems within each feedlot were similar ($P > 0.1$) in body weight, ultrasound backfat thickness and ultrasound marbling score (Table 2). Steers were also similar in terms of variability for each of these traits. However, the KSU sorting system assigned steers quite differently to the short, medium and long days on feed pens (Table 3). This difference is reflected by the standard deviation, which is a measure of the variation within a group. The higher the number is, the lower the uniformity of the group. Thus, in Feedlot 1 steers sorted by the KSU sorting system were 22.4% ($P = 0.0001$) less uniform in body weight, 24.5% ($P = 0.0025$) more uniform in backfat thickness and equally uniform in marbling score as compared to steers sorted by weight. In Feedlot 2, KSU sorted steers were more ($P = 0.0001$) uniform in body weight and equally uniform in backfat thickness and marbling score as compared with the unsorted control steers. These results

Table 4. Performance, feed efficiency and carcass characteristics of steers not sorted or sorted by the KSU sorting system

	Feedlot 1[z]				Feedlot 2[z]			
Trait	Control	Sorted	SEM	prob.[y]	Control	Sorted	SEM	prob.[y]
Number of steers	856	849			798	1598		
Performance traits								
Days on feed	102	108	2.2	0.212	105	100	2.9	0.291
Average daily gain (kg d^{-1})	1.87	1.99	0.02	0.043	1.40	1.45	0.01	0.036
Daily DM intake (kg d^{-1})	12.03	12.22	0.15	0.454	11.34	11.45	0.23	0.755
Feed:gain ratio (kg kg^{-1})	6.46	6.15	0.10	0.156	8.11	7.90	0.17	0.433
Death loss (%)	0.29	0.60	0.23	0.440	0.00	0.12	0.09	0.374
Carcass traits								
Warm carcass weight (kg)	353.0	368.1	2.6	0.049	376.6	378.6	1.9	0.488
Backfat thickness (mm)	6.3	7.0	0.2	0.121	9.5	10.8	0.8	0.295
L. dorsi area (cm^2)	86.8	86.7	0.2	0.758	85.3	88.1	1.3	0.202
Marbling score[x]	4.34	4.19	0.04	0.097	4.75	4.98	0.10	0.203
Lean yield (%)	61.6	60.6	0.2	0.047	58.3	57.9	0.7	0.752
Yield grade								
Y1 (%)	80.4	75.4		0.026	44.8	57.8		0.001
Y2 (%)	16.1	21.8		0.008	35.7	31.7		0.057
Y3 (%)	1.3	2.3		0.144	19.4	10.2		0.001
B1 (%)	0.9	0.5		0.381	0.0	0.0		1.000
B4 (%)	1.3	0.0		0.005	0.1	0.3		0.415
Quality grade								
A (%)	19.1	13.3		0.004	10.9	7.7		0.012
AA (%)	58.6	55.3		0.220	45.6	52.3		0.003
AAA (%)	22.3	31.4		0.001	43.5	40.0		0.112

[z]Control steers at Feedlot 1 were sorted by weight into short (≥ 408.2 kg), medium (362.9 to 408.2 kg) and long (≤ 362.8 kg) days on feed at the beginning of the trial. Control steers at Feedlot 2 were not sorted. In each feedlot, the Kansas State University sorting system was used to sort steers into pens of short, medium and long days on feed based on initial weight, ultrasound backfat thickness and marbling score.
[y]Probability that means are different.
[x]Marbling score is a measure of the intramuscular fat: trace marbling or less = 1.0 to 3.9 (Canada A quality grade; USDA Standard); slight marbling = 4.0 to 4.9 (Canada AA quality grade; USDA Select); small to moderate marbling = 5.0 to 7.9 (Canada AAA quality grade; USDA Choice); slightly abundant or more marbling = 8.0 to 11.0 (Canada Prime; USDA Prime).

suggest that sorting cattle by weight may have exacerbated the problem of clustering animals with different fattening rates, thus decreasing carcass uniformity relative to KSU sorted and unsorted steers.

The breed group distribution for control and KSU sorted steers by feedlot is presented in Table 2. In feedlot 1, the KSU sorted group consisted of a higher proportion of CnBr and a lower proportion of CnCn steers as compared with the control steers. This result occurred by chance as every second animal through the squeeze chute at processing was allocated to the control group. There were no differences in breed group distribution between control and KSU sorted steers in Feedlot 2. An analysis of covariance, where percent CnCn within feedlot and replicate was included as a covariate, revealed no significant effect of breed group distribution on sorting system. The breed group assigned to each animal was subjective and, for many animals, was difficult to determine.

Sorting systems were similar for days on feed in each feedlot (Table 4). This resulted because short, medium and long days on feed groups, regardless of sorting system, were marketed on the same date in Feedlot 1. In Feedlot 2 the control steers were marketed at the same time as the medium days on feed groups. The decision to market was left solely to the feedlot manager and was based on a visual appraisal of slaughter weight and finish.

The KSU sorted steers gained 0.12 kg d^{-1} or 6.4% more in Feedlot 1 and 0.05 kg d^{-1} or 3.6% more than the control steers in Feedlot 2 (Table 4). Feed intake and death losses in each feedlot were similar between the two treatment groups. There was a tendency for feed efficiency to be improved by 4.8% (P = 0.156) in KSU sorted steers in Feedlot 1 and 2.6% (P = 0.433) in Feedlot 2. These results are similar to those reported by Brethour (1991a). In his study, ADG and feed efficiency showed small increases of 2.7% and 2.0%, respectively, for steers sorted by the KSU sorting system. Sainz and Oltjen (1994), using a slightly different method for predicting days on feed to grade choice, found no difference in ADG, feed intake and feed efficiency in steers sorted by weight or sorted by their sorting system. The KSU sorting system is designed to improve ADG and feed efficiency. This is accomplished by estimating the number of days before an animal repartitions feed energy from lean growth to fat deposition. Performance is expected to decline at this time. Estimation of days to feed enables the marketing of early fattening animals sooner to avoid wasting feed merely to produce over-fat animals (Brethour 1991b).

Sorting system differences in carcass weight, backfat thickness, l. dorsi area and lean yield were either not significant or inconsistent between feedlots (Table 4). For example, in Feedlot 1 the average carcass weight for KSU sorted steers was 15.1 kg heavier (P = 0.049) than that for steers sorted by weight. In addition, carcasses from KSU sorted steers tended to have more marbling fat (P = 0.097) and lean meat yield (P = 0.047) than carcasses from weight sorted

Table 5. Economic performance of steers not sorted or sorted by predicted days on feed for two feedlots

	Feedlot 1[z]				Feedlot 2[z]			
Items	Not sorted	Sorted	SEM	prob.[y]	Not sorted	Sorted	SEM	Prob.[y]
Cost ($ hd^{-1})								
Delivery	722.17	719.50	12.31	0.892	996.07	994.09	7.99	0.870
Feed	214.73	229.20	5.62	0.210	201.44	193.93	5.19	0.364
Yardage	15.44	16.19	0.32	0.240	15.70	14.95	0.44	0.295
Interest	16.30	17.20	0.17	0.062	22.01	20.79	0.54	0.182
Induction	7.27	7.27			2.00	2.00		
Selling	0.50	0.50			0.00	0.00		
Total	976.41	989.86	7.70	0.342	1237.22	1225.76	6.54	0.284
Income ($ head^{-1})	1121.77	1156.14	8.13	0.096	1197.48	1200.17	3.59	0.625
Profit ($ head^{-1})	145.36	166.28	0.84	0.003	–39.74	–25.59	3.76	0.057
Difference ($ head^{-1})		**20.92**				**14.15**		
Discounts and premiums	(base price = $3.09 kg^{-1})				base price = $3.09 kg^{-1}			
Yield grade								
Y1, ($ 0.0000 kg^{-1})	0.0000	0.0000			0.0000	0.0000		
Y2, ($-0.0661 kg^{-1})	–0.0106	–0.0144			–0.0236	–0.0210		
Y3, ($-0.2205 kg^{-1})	–0.0029	–0.0051			–0.0428	–0.0225		
B1, ($-0.2205 kg^{-1})	–0.0020	–0.0011			0.0000	0.0000		
B4, ($-0.7716 kg^{-1})	–0.0100	0.0000			–0.0008	–0.0023		
A, ($0.0000 kg^{-1})	0.0000	0.0000			0.0000	0.0000		
AA, ($0.0000 kg^{-1})	0.0000	0.0000			0.0000	0.0000		
AAA, ($0.2646 kg^{-1})	0.0590	0.0831			0.1151	0.1058		
Price ($ kg^{-1})	3.1235	3.1525			3.1379	3.15		
Carcass weight (kg)	353.4	353.4			378.0	378.0		
Income ($ hd^{-1})	1103.84	1114.09			1186.13	1190.70		
Difference ($ hd^{-1})		**10.25**				**4.57**		
Ultrasound cost ($ hd^{-1})		3.50				3.50		
Total difference ($ hd^{-1})		**27.67**				**15.22**		

[z]Control steers at Feedlot 1 were sorted by weight into short (≥ 408.2 kg), medium (362.9 to 408.2 kg) and long (≤ 362.8 kg) days on feed at the beginning of the trial. Control steers at Feedlot 2 were not sorted. In each feedlot, the Kansas State University sorting system was used to sort steers into pens of short, medium and long days on feed based on initial weight, ultrasound backfat thickness and marbling score.
[y]Probability that means are different.

steers. Backfat thickness and l. dorsi area were similar between sorting systems. In Feedlot 2, warm carcass weight, backfat thickness, l. dorsi area, marbling score and lean yield were similar between sorting groups. The reason for this difference in response between feedlots may be due to the differences in fat end point and carcass weight desired by each feedlot manager. Study cattle at Feedlot 2 were primarily marketed under the USDA grading system where heavier carcass weights (greater than 426.4 kg) and more backfat thickness (USDA Y3; greater than 15 mm) are acceptable before discounts are applied. Cattle in Feedlot 1 were marketed under the Canadian Beef Grading Agency where over-weight carcass discounts are applied above 385.6 kg and over-fat discounts are applied at greater than 9 mm of backfat (Y2 yield grade).

The KSU sorted steers had a more desirable distribution of yield and quality grades as compared with control steers, though the distribution did differ between feedlots. For example, the KSU sorted steers in Feedlot 1 had a higher proportion of Y2 yield grade carcasses and zero B4 grade carcasses as compared with control steers. The KSU sorting system also gave a 40.8% increase in AAA quality grade carcasses, which was achieved with no significant increase in Y3 carcasses. In Feedlot 2, carcass yield and quality grade differences were reflected in a 47.4% decrease in Y3 and 14.7% increase in AA carcasses as compared with control steers. These differences reflect the strategy inherent in the KSU sorting system, which attempts to project carcasses into the high-value cells of the carcass price matrix without causing them to be over-weight or too fat. For example, since the premium for AAA carcasses exceeded the discount for Y2 carcasses, the model improved profitability by identifying those cattle that could be fed longer to attain AAA quality grade without becoming Y3 nor over-weight. The absence of B4 carcasses (dark cutting) in the KSU sorted group in Feedlot 1 was unexpected and may reflect a more favourable muscle energy status. A higher level of intramuscular fat has been reported to result in a lower incidence of dark cutting carcasses (Al Schaefer, Personal Communication 1997, Lacombe Research Station, Lacombe, Alberta). This explanation is consistent with the result observed in Feedlot 2 as levels of AAA carcasses in both treatment groups were high.

Total costs, which included animal delivery, feed, yardage and interest, and income were similar between the two sorting systems in both feedlots (Table 5). However, income minus costs revealed that the KSU sorting system increased profitability by $20.92 head^{-1} in Feedlot 1 and by $14.15 head^{-1} in Feedlot 2. When discounts and premiums were accounted for, the KSU sorting system, applied 3 to 4 mo prior to slaughter, was more profitable by $27.67 head^{-1} in Feedlot 1 and $15.22 head^{-1} in Feedlot 2 as compared with the controls. If a premium of $0.10 kg^{-1} had been offered for AA (USDA Select) carcasses then the KSU sorted steers would have been more profitable by \$26.51 head^{-1} in Feedlot 1 and \$17.76 head^{-1} in Feedlot 2 as compared with control steers. The increased net return was primarily due to improved ADG and a more desirable distribution of carcass yield and quality grades.

CONCLUSIONS

In North America, feeder cattle are frequently fed and marketed as heterogeneous groups. This practice results in a higher incidence of under-finished, over-finished and overweight carcasses. In the present study, the KSU sorting system clustered cattle, 3 to 4 mo before slaughter, into more uniform feeding and marketing groups. This had positive effects on growth rate, feed efficiency, carcass yield and quality grade and increased net return by \$15 to \$27 head^{-1} slaughtered. The use of sorting systems that combine ultrasound and computer technology have the potential to increase profitability by approximately \$47 to \$85 million annually in Canada and \$522 to \$940 million annually in the United States. However, the capital cost of implementation and the labour required to operate the system remain barriers to adoption of this technology. Advances in ultrasound, remote sensing and infrared technologies may eventually make feeder cattle sorting systems completely noninvasive and less labour intensive.

ACKNOWLEDGEMENTS

Funding for this project was received from Animal Industry Division, Alberta Agriculture, Food and Rural Development and the Matching Initiative Program through Agriculture and Agri-Food Canada. Special thanks is extended to Lakeside Feeders Ltd., Lakeside Packers, Cor Van Raay Farms and Iowa Beef Processors for the cooperation of their staff and the use of their cattle, weigh scales and facilities. Acknowledgments are also extended to Phyllis Day, Jim Hansen and Pat Ramsey of Alberta Agriculture, Food and Rural Development, Rod Wendorff of Windy Ridge Livestock and Howard Kirbyson of the Canadian Beef Grading Agency for assistance in data collection and processing.

Basarab, J. A., Milligan, D., McKinnon, J. J. and Thorlakson, B. E. 1997. Potential use of video imaging and real-time ultrasound on incoming feeder steers to improve carcass uniformity. Can. J. Anim. Sci. **77**: 385–392.

Brethour, J. R. 1990. Relationship of steer feedlot performance to ultrasound-measured backfat thickness. Kansas State Agricultural Experimental Reports of Progress 597. p. 31.

Brethour, J. R. 1991a. Sorting feedlot cattle for more profitable marketing. Kansas State Agricultural Experimental Reports of Progress 627. p. 12.

Brethour, J. R. 1991b. Relationship of ultrasound-measured backfat to feedlot performance of beef steers. Kansas State Agricultural Experimental Reports of Progress 627. p. 1.

Brethour, J. R. 1992. The repeatability and accuracy of ultrasound in measuring backfat in cattle. J. Anim. Sci. **70**: 1039–1044.

Brethour, J. R. 1994a. Technology to implement quality into beef production. Kansas State Agricultural Experimental Reports of Progress 706. p. 13.

Brethour, J. R. 1994b. Estimating marbling score in live cattle from ultrasound images using pattern recognition and neural network procedures. J. Anim. Sci. **72**: 1425–1432.

Lorenzen, T. J. and Anderson, V. L. 1993. Design of experiments: A no-name approach. Marcel Dekker, Inc., New York, NY.

Oltjen, J. W., Bywater, A. C., Baldwin, R. L. and Garrett, W. N. 1986. Development of a dynamic model of beef cattle growth and composition. J. Anim. Sci. **62**: 86–97.

Sainz, R. D. and Oltjen, J. W. 1994. Improving uniformity of feeder steers using ultrasound and computer modelling. Proc., West. Sec., Am. Soc. Anim. Sci. **45**: 179–181.

SAS Institute, Inc. 1992. SAS user's guide: Statistics. SAS Institute, Inc., Cary, NC.