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Tissue Distribution in Primal Cuts of Canadian Beef Composites and Opportunities for Harvesting Younger and Leaner Cattle

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Abstract: The objectives were to compare weights and proportions (%) of muscle (M), fat (F) and bone (B) in the carcass, primal cuts (brisket, loin and short loin, chuck, flank, plate, rib, round and shank) and fat depots in three BeefBooster® composites (n = 176) from 274-456 days at slaughter, and determine harvest times at which M is maximized and F is optimized. Composites were from lines M1, M2, M3, M4 and TX. The SM type contained M3 and other small breeds; AH contained M1 and M2 which had either Angus (A) or Hereford (H), and GLC contained both M4 made up of either Gelbveih (G) or Limousin (L) and TX made up of Charolais (C). Tissue weights and proportions were analyzed by covariance within slaughter time (274, 347, 372, 399, 427 and 456 d, respectively) with composite type (SM, AH and GLC) as fixed, year (1 & 2) as random and age within slaughter time as a covariate. In the carcass and primal cuts, the weight of M, weight and percent F increased while the percent M decreased with slaughter age. SM had less M ($p<0.05$) than AH and GLC in the carcass and primal cuts with the exception of the loin, plate and rib at 399 day, and the shank and rib at 427 day. The proportion of F in the carcass was similar ($p>0.05$) for SM and AH at 372, 399 and 427 day. The M:F ratio decreased with age and the decrease was more pronounced in SM and AH than GLC. The round had the least amount and proportion of F and the flank had the most. The weight and proportion of F in all primal cuts differed ($p<0.05$) between composites especially beyond 399ºC. The SM and AH can be harvested 60 and 30 days earlier respectively, so as to increase % M and decrease % F.

Key words: Fat, growth pattern, ideal carcass, muscle, slaughter time

INTRODUCTION

As cattle grow, develop and mature over time, their weight, proportion and the distribution of muscle (M), fat (F) and bone (B) change. At birth, calves have virtually no back fat (Berg and Butterfield, 1976), but as they grow, fat deposition occurs and muscle to fat ratios change. A number of serial slaughter trials were conducted (Berg and Butterfield, 1976; Koch and Dikeman, 1977; Jones *et al*., 1978; Jones *et al.,* 1980; Patterson *et al*., 1985) to study growth patterns and distribution of tissues in cattle. Tissue differences due to gender, breed, energy partitioning and biological types were identified (Jones, 1985; Patterson *et al*., 1985). Many of these studies dissected whole or half carcasses to get information on the distribution of tissues (Jones *et al*., 1980; Patterson *et al*., 1985; Bruns *et al*., 2004), but in recent times, few studies have been done on the distribution of M, F and B in relation to the primal cuts of the diverse biological types that contribute to Canadian beef.

The ideal carcass is defined as one containing maximum M, minimum B and optimum F that consumers want or are willing to accept. An understanding of the growth of tissues among biological types is necessary to determine optimum slaughter times within the confines of the definition of an ideal carcass. The present Canadian beef grading system emphasizes the level of finish and marbling. Premiums are paid for marbling and a Canada Prime was introduced in addition to the AAA grading so as to be better aligned with the US market. Although marbling in steaks has been attributed to tenderness, there is enough variation in tenderness that is not related to marbling (Jones and Tatum, 1994; O'Connor *et al*., 1997; Devitt *et al*., 2002). Australian consumers discriminate against marbled beef (Hearnshaw *et al*., 1994) and Canadian consumers avoid cuts that have excess back and seam fat. Consumer research has also shown that

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tenderness is the primary concern in Canadian and US beef (Jeremiah *et al*., 1993; Roeber *et al*., 2001; Devitt *et al*., 2002). In addition there is reluctance among some consumers to eat red meats such as beef due to the saturated fat and cholesterol content (May *et al*., 1992; Van Koevering *et al*., 1995). As such a marketing system for beef that emphasizes leanness (muscling) would be attractive to many domestic and international consumers.

The objectives were to compare the weight and proportions of total muscle, fat and bone in the carcass and in the primal cuts (brisket, loin and short loin, chuck, flank, plate, rib, round and shank) in three composite types of steers from 274-456 days of slaughter age, determine optimum slaughter times and ascertain how well cuts from these composites fit the definition of the ideal beef carcass.

MATERIALS AND METHODS

The research was conducted in 2002 and 2003 at Alberta, Canada and data were collected on180 spring-born steer calves over a 2 year period (90 in each year). At the start in the first year calves were 232±14 SD days old and weighed 296.6±37 SD kg and in the second year calves were 238±14 SD days old and weighed 285.4±39 SD kg. Four steers died during the study; two died ofperitonitis in the first year and two died of hemophiliosis in the second year. Five Beef Booster® lines (M1, M2, M3, M4 and TX) were used. The foundation breed for the M1 was Angus (A), M2 was Hereford (H), M3 contained various small breeds (SM), M4 was Gelbveih (G) or Limousin (L) and TX was Charolais (C) (Kress *et al*., 1996). Whereas the M1 and M2 composites represent the early maturing biological types, the M4 and TX represent the late maturing biological types (Basarab *et al*., 2003). Detailed information on the breed composition has been described in earlier studies (McNeil and Newman, 1994), and the management of steers described by Basarab *et al*., (2003).

In this study the M1 and M2 composites were referred to as (AH), the M3 and TX as (GLC) and M3 as (SM). After a 39-40 day pre trial adjustment period, steers were slaughtered (SL) on day 1 (SL age = 274 day), 71 (SL age = 347 day), 99 (SL age = 372 day), 127 (SL age = 399 day), 155 (SL age = 427 day) and 183 (SL age = 456 day), respectively. All steers were slaughtered at the Lacombe Research Station abattoir and carcasses split in half. The left side of each carcass was separated into the nine primal cuts, which were further dissected into muscle, fat and bone according to procedures described by Jones *et al*. (1984). The fat in each primal cut was further dissected into three depots: Subcutaneous (SC) or back fat, intermuscular (IM) or seam fat and body cavity (BC) fat.

All steers were started on a diet containing 88% barley silage, 10.4% barley grain and 1.6% feedlot supplement (as-fed basis) and over the next 34 days gradually adjusted to a diet containing 73.3% barley grain, 22% barley silage, 1.6% molasses and 3.1% feedlo supplement. The steers were fed twice a daily using the GrowSafe® feeding system. Experimental details and management of steers are provided by Basarab *et al*. (2003).

The dependent variables analyzed were total weight and proportion (%) of muscle, fat and bone in the carcass, muscle, fat and bone weight and proportions within each primal cut (brisket, loin, chuck, flank, plate, rib, round, shank and short loin) and the weight of SC, IM and BC fat within slaughter age (274, 347, 372, 399, 427 and 456 day, respectively). The mixed model (Proc Mixed) of SAS (2001) was used with type (SM, AH and GLC) as a fixed effect, year (1 and 2) as a random (block) effect and steer age as a covariate. The proportions were derived for each tissue by dividing the tissue weight by the sum of M+F+B. Age adjusted least square means were obtained within each slaughter time (age) for all dependent variables and orthogonal contrasts were used to compare fixed effect least square means. Significance was declared at $p<0.05$.

RESULTS

Carcass traits by serial slaughter age and type are shown in Table 1. As animals grew older slaughter

Table 1: Carcass traits (mean±SE) in composite types from 274-456 days of slaughter age

		Slaughter age (days) [number of observations]					
Trait	Type[a]	274 [n]	347 [n]	372 [n]	399 [n]	427 [n]	456 [n]
Slaughter age (d)	SM	274±6 [6]	346±6 [6]	378±6 [6]	408±6 [6]	435±7 [6]	460±6 [6]
	AH	272±4 [11]	352±4 [11]	368±4 [11]	400±3 [12]	426±3 [12]	456±3 [12]
	GLC	276±4 [11]	345±3 [12]	373±4 [12]	392±4 [12]	424±5 [12]	454±4 [12]
Slaughter wt (kg)	SM	289.33±19.72	369.22±14.37	411.88±15.93	424.67±21.77	457.03±29.22	452.36±15.29
	AH	356.58±18.14	440.98±10.77	500.30±11.79	529.10±14.53	530.46±24.25	588.75±10.70
	GLC	363.09±17.47	466.12±10.24	496.62±11.06	510.56±15.28	540.57±24.34	570.11±10.76
Carcass wt. (kg)	SM	79.16±6.07	103.82±4.57	117.37±4.70	123.75±6.66	137.19±6.82	130.99±5.00
(Left side)	AH	98.10±5.57	125.73±3.42	142.51±3.48	153.70±4.44	160.42±4.95	173.72±3.55
	GLC	101.91±5.36	134.24±3.26	145.98±3.26	149.70±4.67	162.17±4.99	170.82±3.57
Dressing %	SM	55.53±0.67	56.12±0.63	56.95±0.59	58.30±0.60	58.74±0.71	59.02±0.82
	AH	55.61±0.50	56.99±0.47	56.98±0.44	58.06±0.40	59.46±0.59	60.11±0.74
	GLC	56.89±0.50	57.60±0.45	58.80±0.41	58.65±0.42	59.02±0.59	61.08±0.75

[a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

Table 2: Weight and proportions of total muscle (M), fat (F), bone (B) (mean±SE) and ratios of M:F and M:B in the left side of the carcass in composites from 274-456 days of slaughter age

		Slaughter age (days)					
Trait	Type[W]	274	347	372	399	427	456
Total muscle (kg)	SM	49.15±3.60a	58.72±2.97a	65.81±3.09a	69.79±3.51a	74.52±3.32a	66.11±3.79a
	AH	61.01±3.21b	73.71±2.22b	80.05±2.28b	83.76±2.48b	87.66±2.35b	94.47±3.02b
	GLC	65.02±3.21b	80.96±2.11c	86.63±2.14b	86.82±2.48b	90.78±2.35b	96.27±3.02b
Total fat (kg)	SM	13.86±1.52	28.20±2.31	34.11±2.08	28.57±4.19a	42.44±2.99	47.41±2.49a
	AH	16.20±1.29	31.14±1.73	38.21±1.63	38.57±3.75b	48.66±2.08	54.90±1.74b
	GLC	16.20±1.25	31.16±1.65	35.77±1.55	29.87±3.88a	44.08±2.08	49.96±1.75a
Total bone (kg)	SM	12.93±1.07a	16.68±1.01a	17.35±0.99a	17.53±1.20a	20.04±1.14a	17.61±1.02a
	AH	17.57±0.92b	21.11±0.87b	22.63±0.74b	22.36±0.80b	23.50±0.79b	24.83±0.70b
	GLC	17.90±0.91b	22.10±0.87b	22.65±0.70b	22.89±0.84b	24.69±0.79b	23.98±0.70b
Muscle: fat ratio	SM	3.2	2.1	1.9	2.4	1.8	1.4
	AH	3.5	2.4	2.1	2.3	1.8	1.7
	GLC	3.9	2.6	2.5	2.9	2.1	2.0
Muscle: bone ratio	SM	3.6	3.6	3.6	3.9	3.7	3.7
	AH	3.4	3.5	3.4	3.7	3.7	3.8
	GLC	3.6	3.6	3.6	3.8	3.7	4.0
Muscle (% of M+F+B)	SM	62.81±1.11	57.20±1.19	55.80±0.99	59.71±1.67	54.34±1.15	49.84±1.10
	AH	62.92±0.97	58.80±0.89	56.96±0.73	58.59±1.49	54.91±0.79	53.86±0.77
	GLC	64.61±0.95	60.57±0.85	59.61±0.69	62.76±1.55	57.00±0.80	56.48±0.78
Fat (% of M+F+B)	SM	19.57±1.06	27.26±1.45	29.32±1.14	25.01±1.91	31.01±1.33	36.56±1.27
	AH	18.12±0.79	24.78±1.09	27.06±0.84	25.71±1.72	30.38±0.92	31.83±0.89
	GLC	17.00±0.77	23.40±1.03	24.77±0.79	20.72±1.78	27.53±0.93	29.36±0.89
Bone (% of M+F+B)	SM	17.59±0.92	15.77±0.55	15.77±0.65	15.06±0.61a	14.65±0.48	13.60±0.38
	AH	18.92±0.81	16.65±0.46	16.95±0.62	15.46±0.53ab	14.72±0.33	14.31±0.27
	GLC	18.37±0.79	16.27±0.46	16.55±0.60	16.27±0.55b	15.47±0.33	14.16±0.27

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; a, b: Least square means with different letters within age and trait are significant ($p<0.05$) and compare SM, AH and GLC composite types. Letters are only shown when means are different ($p<0.05$)

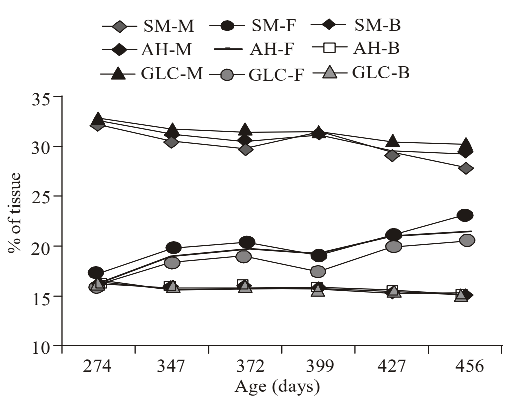

Fig. 1: Proportion of muscle (M), fat (F) and bone (B) in composites with slaughter age SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

weight, carcass weight and dressing percent increased. The weights and proportions of muscle, fat and bone expressed as a percent of total tissue (muscle + fat + bone) is shown in Table 2 and changes of proportions of muscle, fat and bone with respect to slaughter age for different composites are shown in Fig. 1. From 274 day to slaughter at 456 day, total side muscle increased by 16.54 kg (32.6%), 33.54 kg (53.5%) and 31.91 kg (48.0%) in the SM, AH and GLC groups respectively. During the same period, total side fat increased by 33.50 kg (242.1%), 38.7 kg (239.0%) and 33.76 (208.4%) in the SM, AH and GLC composites respectively. The M:F ratio decreased by over 50% in all three composite types. The greatest decrease in M:F ratio was in the SM, followed by AH and GLC. Percent muscle decreased by 12.3, 9.1 and 7.6% in the SM, AH and GLC respectively, while percent fat increased considerably in the three composites. Thus although the total side muscle increased, percent muscle decreased while both total and percent fat increased as steers got older. At 456 day (15.2 months) steers had proportionately more total fat and less muscle (M:F ratio range 1.4 to 2.0) than at 274 d of age (M:F ratio range 3.7 to 4.1). At all ages with the exception of 347 day total muscle weight in the SM was lower ($p<0.05$) than AH and GLC composites and no difference ($p>0.05$) observed between AH and GLC. At 456 day the AH had more ($p<0.05$) total fat than SM and GLC composites although % fat in SM was higher. The bone weight at all ages was similar ($p>0.05$) for AH and GLC but different ($p<0.05$) from SM composites. Percent muscle was higher ($p<0.05$) in the GLC compared to SM and AH at 372, 399 and 456 day of age. At 456 day the SM had proportionately more ($p<0.05$) fat (36.56%) in the tissues compared to the AH (31.83%) and GLC (29.36%) composites.

The weight of each primal cut at each age by composite type is shown in Table 3. As expected the weight of all primal cuts increased with SL age. In general, the chuck was the largest (28-30% of tissue) primal followed by the round (22-28% of tissue). However, at 274 day the difference between the weights of the chuck and round were lower than at other ages and at 456 day (Fig. 2). Therefore in younger cattle the ratio

Table 3: Comparison of total tissue weights (kg) on the left side of the carcass among composites in each primal cut by slaughter age

		Slaughter age (days)					
Cut	Type[W]	274	347	372	399	427	456
Brisket	SM	4.73±0.60a	6.38±1.22a	5.63±1.26a	6.71±0.54a	7.45±1.69	7.20±0.58a
Brisket	AH	5.65±0.56b	8.00±1.13b	7.51±1.30b	9.30±0.36b	8.91±1.62	10.26±0.41b
Brisket	GLC	5.92±0.54b	8.64±1.17b	7.67±1.26b	8.62±0.38b	8.71±1.63	10.15±0.41b
Loin	SM	5.87±1.00a	8.63±0.39a	9.96±0.43a	10.23±0.64a	11.04±0.61a	10.68±0.85a
Loin	AH	7.58±0.97b	10.28±0.29b	11.66±0.32b	12.39±0.43b	13.40±0.42b	14.48±0.82b
Loin	GLC	7.67±0.92b	11.15±0.28b	12.11±0.30b	11.91±0.45ab	13.38±0.43b	14.62±0.83b
Chuck	SM	22.86±2.02a	29.79±1.41a	33.71±1.40a	34.65±2.10a	39.71±1.83a	39.80±3.28a
Chuck	AH	27.59±1.91b	35.73±1.06b	40.42±1.03b	43.20±1.40b	45.77±1.26b	51.51±3.16b
Chuck	GLC	28.97±1.83b	38.42±1.00b	41.86±0.97b	43.10±1.48b	46.17±1.27b	50.71±3.19b
Flank	SM	2.86±0.26a	5.66±1.19	6.40±0.91	5.39±0.98a	7.34±1.40	9.23±0.47a
Flank	AH	3.55±0.19b	6.54±1.09	6.95±0.91	7.00±0.91b	8.09±1.32	11.24±0.33b
Flank	GLC	3.52±0.19b	6.23±1.14	6.88±0.88	5.98±0.94b	8.25±1.32	10.82±0.33b
Plate	SM	4.16±0.29a	6.01±0.95a	6.86±0.86a	8.09±1.22a	8.41±1.57	9.17±1.69a
Plate	AH	5.25±0.22b	7.32±0.88b	8.48±0.87b	10.46±1.18b	10.02±1.47	13.23±1.66b
Plate	GLC	5.15±0.22b	7.75±0.91b	8.66±0.84b	9.58±1.22ab	9.17±1.47	11.95±1.68b
Rib	SM	8.05±0.73a	10.38±0.51a	12.17±0.61a	13.11±0.61a	13.82±0.73a	13.66±1.35
Rib	AH	9.42±0.69b	12.19±0.38b	13.72±0.45b	15.19±0.40b	16.03±0.50	b16.88±1.32
Rib	GLC	9.75±0.66b	12.62±0.36b	13.85±0.43b	14.18±0.43ab	15.44±0.51ab	16.57±1.34
Round	SM	21.53±2.05a	25.03±1.25a	27.35±1.21a	28.68±1.76a	30.71±2.15a	29.44±1.54a
Round	AH	27.80±1.94b	31.94±0.94b	35.47±0.90b	36.63±1.17b	37.05±1.48b	40.08±1.08b
Round	GLC	29.29±1.86b	34.35±0.89b	36.31±0.84b	36.86±1.24b	37.71±1.49b	39.94±1.08b
Shank	SM	2.90±0.72a	4.13±0.55a	3.95±0.21a	4.61±0.29a	4.96±0.78a	4.12±0.81a
Shank	AH	4.04±0.70b	5.22±0.51b	5.35±0.16b	5.65±0.20b	5.20±0.75ab	5.93±0.79b
Shank	GLC	4.16±0.67b	5.71±0.53b	5.53±0.15b	5.80±0.21b	5.77±0.75b	5.63±0.79b
Short loin	SM	5.76±0.72a	8.61±0.56a	9.80±0.76a	8.75±0.44a	9.52±0.51a	11.65±0.59a
Short loin	AH	6.78±0.69b	9.36±0.50b	11.40±0.75b	10.02±0.29b	11.18±0.36b	13.92±0.55b
Short loin	GLC	7.18±0.66b	10.38±0.52c	11.39±0.73b	10.68±0.31b	10.83±0.36b	13.36±0.56b

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; a, b; Least square means with different letters within age and trait are significant (p<0.05) and compare SM, AH and GLC composite types. Letters are only shown when means are different (p<0.05)

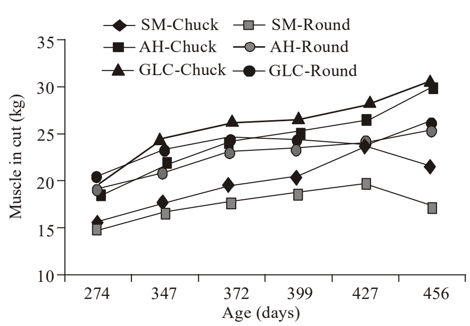

Fig. 2: Compoarison of muscle kg in the chuck and round of composites with alaughter age SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

of the chuck to round is lower while the ratio of chuck to round becomes higher with age. For example in the AH composite at 276 day the ratio of chuck to round was 1: 1 where as at 456 day the ratio was 1.3: 1. In the GLC composite, the round increased by 10.7 kg from 274 to 456 day while the chuck increased by 21.7 kg. Thus, as steers got older, the ratio of expensive cuts (round, loin, rib and short loin) to other cuts decreased from 1:1 in AH at 274 day to 1:1.1 at 456 day. In the SM, the ratio of expensive to other cuts at 274 day was 1:0.9 while it decreased to 1:1.1 at 456 day. At 456 day in all primal cuts SM had less (p<0.05) total tissue than AH and GLC while no differences (p>0.05) were observed between AH and GLC. This trend was often observed in the primal cuts at earlier harvest times as well.

The weight of muscle (kg) and proportion of muscle (%) in the primal cuts are shown in Table 4 and 5, while the weight of fat (kg) and proportion of fat (%) in the primal cuts are shown in Table 6 and 7. In all of the primal cuts the muscle weight of the AH and GLC at 456 day was higher (p<0.05) compared to SM. At 456 day no differences (p>0.05) were observed in muscle weight between AH and GLC. Whenever statistically significant (p<0.05) differences were observed between composites, in general the trend was for AH and GLC muscle weights to be higher than SM and no difference (p>0.05) between AH and GLC. For example, in the brisket and plate this trend was observed at 274, 347, 372, 399 and 456 day, in the loin at 274, 399, 427 and 456 day, in the flank at 274 and 456 day, in the rib at 274, 347, 427, and 456 day, in the round at 274, 372, 399, 427 and 456 day, the shank at 274, 372 and 456 day and in the short loin at 274, 372, 399, 427 and 456 day, respectively. The chuck was the heaviest primal cut after 347 day, followed by the round, loin, rib and short loin. At 456 day, in the chuck contained 32.1, 31.3 and 31.2% of the total muscle in SM, AH and GLC respectively while at 274 days the chuck contained 30.5, 29.3 and 29.6% of the total muscle in the SM, AH and GLC composites respectively. At 456 day the round contained 25.9, 26.8 and 26.7% of the total muscle in SM, AH and GLC respectively, whereas at 274 day the round

Table 4: Distribution of muscle (kg) on the left side of carcass in nine primal beef cuts in composite types by slaughter age

		Slaughter age (days)					
Cut (kg)	Type[W]	274	347	372	399	427	456
Brisket	SM	2.45±0.30a	2.37±0.31a	2.67±0.24a	2.91±0.24a	3.11±0.63a	3.12±0.30a
Brisket	AH	2.95±0.28b	3.34±0.23b	3.58±0.18b	3.88±0.16b	3.69±0.60ab	4.02±0.21b
Brisket	GLC	3.13±0.27b	3.58±0.22b	3.80±0.17b	3.93±0.17b	3.94±0.61b	4.39±0.21b
Loin	SM	3.83±0.63a	5.27±0.28a	5.76±0.30a	6.02±0.45a	6.37±0.37a	5.88±0.66a
Loin	AH	5.12±0.61b	6.47±0.21b	6.86±0.22b	7.40±0.30b	7.89±0.25b	8.42±0.64b
Loin	GLC	5.28±0.58b	7.29±0.20c	7.68±0.21c	7.51±0.31b	8.17±0.25b	8.78±0.64b
Chuck	SM	15.47±1.30a	17.76±0.88a	19.65±0.96a	20.45±1.22a	23.62±1.11a	21.60±2.31a
Chuck	AH	18.36±1.22b	22.02±0.66b	24.31±0.71b	25.24±0.81b	26.52±0.77b	30.11±2.22b
Chuck	GLC	19.66±1.17c	24.47±0.63c	26.29±0.67c	26.66±0.86b	28.23±0.77b	30.73±2.25b
Flank	SM	1.52±0.13a	2.50±0.51	2.64±0.48	2.99±0.51	2.80±0.55	3.42±0.19a
Flank	AH	2.06±0.10b	3.16±0.47	2.96±0.47	3.64±0.49	3.33±0.51	4.79±0.13b
Flank	GLC	2.16±0.10b	3.11±0.48	3.20±0.46	3.56±0.53	3.65±0.52	4.79±0.13b
Plate	SM	2.37±0.18a	2.58±0.36a	3.37±0.23a	3.93±0.28a	3.31±0.68	3.44±0.31a
Plate	AH	3.06±0.13b	3.50±0.33b	4.38±0.17b	4.63±0.19b	4.22±0.64	5.60±0.22b
Plate	GLC	3.03±0.13b	3.83±0.34b	4.72±0.16b	4.89±0.19b	4.21±0.64	5.35±0.22b
Rib	SM	4.75±0.42a	5.29±0.29a	6.10±0.57	6.84±0.59a	6.37±0.94a	6.22±0.66a
Rib	AH	5.51±0.39b	6.39±0.22b	6.86±0.42	7.50±0.56ab	7.56±0.91b	8.24±0.64b
Rib	GLC	5.80±0.38b	6.94±0.21b	6.99±0.39	7.91±0.58b	7.75±0.92b	8.71±0.64b
Round	SM	15.02±1.45a	16.47±0.94a	17.74±0.83a	18.73±1.16a	19.62±1.85a	17.43±2.70a
Round	AH	19.11±1.36b	20.98±0.70b	23.15±0.62b	23.45±0.77b	24.13±1.28b	25.76±2.65b
Round	GLC	20.50±1.31b	23.16±0.67c	24.51±0.58b	24.55±0.81b	23.94±1.28b	26.25±2.68b
Shank	SM	1.49±0.37a	1.87±0.30a	1.78±0.31a	2.62±0.20	1.67±0.44a	1.73±0.42a
Shank	AH	1.98±0.35b	2.32±0.28b	2.40±0.32b	2.40±0.13	2.11±0.42ab	2.69±0.41b
Shank	GLC	1.94±0.34b	2.62±0.29c	2.61±0.31b	2.62±0.14	2.47±0.42b	2.63±0.42b
Short loin	SM	3.60±0.40a	4.97±0.37a	5.01±0.54a	4.97±0.53a	5.20±0.27a	5.49±0.51a
Short loin	AH	4.31±0.38b	5.56±0.33b	6.09±0.54b	5.70±0.52b	5.93±0.19b	7.07±0.48b
Short loin	GLC	4.70±0.36b	6.32±0.34c	6.51±0.53b	6.11±0.54b	6.18±0.19b	7.15±0.49b

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; a,b; Least square means with different letters within age and cut are significant (p<0.05) and compare SM, AH and GLC composite types. Letters are only shown when means are different (p<0.05)

Table 5: Comparison of the proportion of muscle (%) on the left side of carcass in primal beef cuts of composites types by slaughter age

		Slaughter age (days)					
Cut	Type[W]	274	347	372	399	427	456
Brisket	SM	49.66±4.09	41.16±7.16	44.93±3.66	43.97±3.75a	41.61±1.46a	34.96±1.80a
Brisket	AH	50.67±3.94	45.16±6.69	46.08±3.76	42.24±3.69a	41.54±1.01a	39.14±1.25b
Brisket	GLC	52.38±3.77	44.41±6.97	47.74±3.64	46.22±3.82b	45.00±1.01b	43.31±1.26c
Loin	SM	63.56±2.39a	61.28±1.34a	57.92±1.38a	63.17±2.06a	57.58±1.06a	54.27±1.49a
Loin	AH	66.34±2.31ab	62.98±1.01a	58.81±1.02a	64.07±1.92a	58.95±0.73ab	57.91±1.04b
Loin	GLC	67.88±2.21b	65.31±0.96b	63.47±0.96b	67.53±1.98b	61.09±0.74b	59.62±1.05b
Chuck	SM	66.46±2.15	59.08±1.24	58.45±0.99a	64.32±1.93a	58.17±2.39ab	53.56±1.21a
Chuck	AH	65.55±2.06	61.77±0.92	60.14±0.73a	61.68±1.78b	56.64±2.27b	57.88±0.84b
Chuck	GLC	67.50±1.97	63.64±0.88	62.80±0.69b	64.20±1.84a	59.83±2.28a	60.36±0.85c
Flank	SM	48.55±4.87	46.76±1.92	45.51±5.57	45.59±2.94	41.84±1.88	37.66±4.61a
Flank	AH	53.24±4.63	49.71±1.44	46.71±5.79	49.50±2.74	43.94±1.30	42.79±4.54b
Flank	GLC	57.27±4.44	51.56±1.37	50.02±5.62	51.73±2.83	46.33±1.31	44.72±4.58b
Plate	SM	59.99±4.17	45.78±1.51a	45.92±1.60a	51.67±3.08ab	40.94±1.63a	36.85±1.39a
Plate	AH	61.16±3.89	49.76±1.13b	48.10±1.18ab	48.29±2.87a	43.07±1.13a	41.81±0.97b
Plate	GLC	61.73±3.82	51.42±1.08b	50.76±1.11b	54.26±2.97b	46.39±1.13b	44.37±0.97b
Rib	SM	58.05±1.25	50.03±3.81	50.15±3.12	52.33±2.37a	45.66±3.01a	43.05±1.48a
Rib	AH	57.44±0.93	51.65±3.53	50.14±2.31	50.00±2.22a	46.59±2.89a	46.79±1.03b
Rib	GLC	59.05±0.93	51.02±3.68	50.46±2.17	54.21±2.30b	49.64±2.90b	50.64±1.04c
Round	SM	69.14±1.50	65.94±0.90	64.86±0.76	65.57±2.24	65.65±7.70	61.31±1.72
Round	AH	68.32±1.44	65.64±0.68	65.26±0.56	64.33±2.20	67.07±7.42	64.49±1.66
Round	GLC	69.92±1.38	67.32±0.64	67.54±0.53	66.95±2.28	64.11±7.44	65.06±1.67
Shank	SM	45.26±8.59	44.52±1.02	44.61±2.60	46.91±2.48	37.69±5.51	42.25±0.74a
Shank	AH	44.99±8.33	43.51±0.76	44.62±2.67	42.54±1.66	42.01±5.29	42.88±0.52a
Shank	GLC	43.33±7.96	45.01±0.72	46.87±2.59	45.11±1.74	44.14±5.30	44.20±0.52b
Short loin	SM	62.11±1.40	58.56±1.51	53.50±3.25a	60.27±2.26a	53.99±3.81ab	48.33±1.58a
Short loin	AH	63.37±1.046	0.80±1.13	54.71±3.36a	60.60±2.08a	52.59±3.68a	52.43±1.11b
Short loin	GLC	65.72±1.046	2.33±1.08	58.91±3.26b	66.84±2.15b	56.44±3.68b	55.82±1.11c

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; a, b: Least square means with different letters within age and cut are significant (p<0.05) and compare SM, AH and GLC composite types. Letters are only shown when means are different (p<0.05)

Table 6: Distribution of fat (kg) in nine primal beef cuts on the left side of carcass in composite types by slaughter age

		Slaughter age (days)					
Cut	Type[W]	274	347	372	399	427	456
Brisket	SM	1.49±0.32	3.01±0.63	2.20±0.61	2.81±0.74a	3.42±1.06	3.84±0.36a
Brisket	AH	1.70±0.31	3.34±0.58	2.84±0.62	3.99±0.72b	4.17±1.02	5.03±0.24b
Brisket	GLC	1.73±0.29	3.68±0.60	2.73±0.61	3.32±0.74a	3.68±1.02	4.49±0.25ab
Loin	SM	1.16±0.10	2.13±0.21	2.88±0.18	2.41±0.36ab	3.24±0.23	3.43±0.23
Loin	AH	1.32±0.07	2.32±0.16	3.05±0.13	2.78±0.33a	3.67±0.16	3.95±0.16
Loin	GLC	1.22±0.07	2.27±0.15	2.72±0.13	2.25±0.35b	3.38±0.16	3.85±0.16
Chuck	SM	3.41±0.32	7.88±0.67	8.49±1.15	6.78±1.31a	10.74±0.76a	13.00±0.73
Chuck	AH	4.22±0.24	8.42±0.50	9.30±1.17	9.23±1.21b	13.04±0.53b	14.38±0.51
Chuck	GLC	4.12±0.24	8.39±0.48	8.69±1.13	7.32±1.25a	11.50±0.53a	13.15±0.51
Flank	SM	1.47±0.41	3.25±0.32	3.95±0.84	2.41±0.65a	4.63±1.13	5.68±1.12
Flank	AH	1.61±0.40	3.48±0.24	4.18±0.88	3.38±0.59b	4.84±1.08	6.32±1.10
Flank	GLC	1.48±0.38	3.22±0.23	3.86±0.86	2.46±0.62ab	4.68±1.08	5.90±1.11
Plate	SM	1.20±0.14	2.66±0.25	2.96±0.53	2.92±0.64a	4.36±1.04	4.72±0.91a
Plate	AH	1.37±0.11	2.88±0.18	3.33±0.54	4.27±0.60b	4.90±0.99	6.09±0.89b
Plate	GLC	1.36±0.11	2.98±0.18	3.13±0.53	3.10±0.62a	4.06±0.99	5.21±0.89a
Rib	SM	1.36±0.50	3.11±0.28	3.89±0.48	4.05±0.70	4.96±0.39	5.37±0.33
Rib	AH	1.56±0.49	3.42±0.21	4.30±0.35	5.03±0.67	5.60±0.26	6.06±0.24
Rib	GLC	1.54±0.47	3.31±0.20	4.27±0.33	3.62±0.69	4.82±0.27	5.41±0.24
Round	SM	2.82±0.36a	4.14±0.37	5.05±0.32	4.94±0.47a	5.76±0.49	6.59±0.43
Round	AH	3.30±0.34b	5.12±0.28	6.00±0.24	6.86±0.32b	6.71±0.34	7.87±0.30
Round	GLC	3.48±0.33b	4.92±0.26	5.59±0.22	5.76±0.33a	6.81±0.34	7.42±0.30
Shank	SM	0.32±0.14	0.61±0.11a	0.56±0.05a	0.67±0.14	1.01±0.13	0.68±0.24
Shank	AH	0.45±0.10	0.74±0.10ab	0.73±0.03b	0.96±0.09	0.83±0.09	0.88±0.23
Shank	GLC	0.57±0.10	0.80±0.10b	0.71±0.03b	0.78±0.09	0.79±0.09	0.79±0.23
Short loin	SM	1.20±0.36	2.33±0.37	3.01±0.34	2.32±0.37ab	3.19±0.81	4.53±0.43
Short loin	AH	1.25±0.35	2.32±0.34	3.29±0.34	2.62±0.34a	3.76±0.78	4.77±0.40
Short loin	GLC	1.25±0.33	2.53±0.35	2.91±0.33	1.91±0.35b	3.23±0.79	4.31±0.41

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; a, b: Least square means with different letters within age and cut are significant ($p<0.05$) and compare SM, AH and GLC composite types. Letters are only shown when means are different ($p<0.05$)

Table 7: Comparison of the proportion of fat (%) in primal beef cuts on the left side of carcass of composites types by slaughter age

		Slaughter age (days)					
Cut	Type[W]	274	347	372	399	427	456
Brisket	SM	33.38±2.13	44.93±6.95	42.28±5.17	42.20±4.24ab	44.03±2.05	53.23±2.25a
Brisket	AH	31.52±1.58	39.48±6.48	40.47±5.37	43.27±4.15a	44.78±1.42	49.12±1.58a
Brisket	GLC	29.40±1.58	41.05±6.75	38.41±5.22	38.72±4.29b	40.96±1.43	44.09±1.59b
Loin	SM	20.07±1.07a	24.55±1.73	28.78±1.38a	23.92±2.26a	29.50±1.13a	33.37±1.55a
Loin	AH	17.71±0.79ab	22.39±1.30	26.21±1.02a	22.08±2.10a	27.30±0.78ab	28.47±1.09b
Loin	GLC	15.96±0.79b	20.47±1.23	22.47±0.96b	18.69±2.17b	25.17±0.79b	27.15±1.09b
Chuck	SM	17.86±1.10	26.29±1.40a	25.92±2.37a	22.71±1.92a	27.05±1.28ab	34.28±1.31a
Chuck	AH	17.79±0.82	23.41±1.05ab	23.42±2.42ab	23.99±1.75a	28.47±0.89a	29.15±0.92b
Chuck	GLC	16.03±0.82	21.89±0.99b	21.11±2.34b	19.72±1.82b	24.88±0.89b	26.82±0.92b
Flank	SM	51.54±4.83a	52.38±1.96	53.73±5.74	48.30±3.03a	57.47±1.90	61.43±4.72a
Flank	AH	46.88±4.57ab	49.49±1.47	52.23±5.98	49.64±2.83a	55.33±1.32	56.45±4.66b
Flank	GLC	42.65±4.39b	47.75±1.40	48.93±5.81	45.40±2.93b	52.89±1.33	54.56±4.70b
Plate	SM	28.98±2.00	41.91±1.70a	43.44±1.74a	38.54±3.33a	48.54±1.96a	53.08±1.57a
Plate	AH	25.89±1.49	37.59±1.27b	40.04±1.29a	41.45±3.11a	46.26±1.35a	47.34±1.10b
Plate	GLC	26.15±1.49	36.85±1.21b	37.22±1.21b	36.14±3.22b	42.31±1.36b	44.70±1.10b
Rib	SM	19.81±1.59	29.91±1.68	31.79±3.24	29.69±2.74a	35.65±1.52a	39.99±1.60a
Rib	AH	19.06±1.18	27.84±1.25	31.26±2.40	31.35±2.55a	34.76±1.05a	36.42±1.12a
Rib	GLC	17.47±1.18	26.20±1.19	30.84±2.25	25.98±2.64b	31.13±1.06b	32.38±1.13b
Round	SM	13.01±0.53a	16.04±1.07	18.48±0.73a	16.59±2.34	18.19±3.83	23.14±0.82a
Round	AH	11.09±0.39b	16.00±0.78	16.92±0.54ab	17.97±2.27	17.35±3.69	19.71±0.58b
Round	GLC	11.76±0.39ab	14.42±0.74	15.35±0.51b	14.79±2.36	17.83±3.70	18.52±0.58b
Shank	SM	11.33±2.86	13.30±1.00	14.09±0.85	14.50±2.17	20.19±2.30a	17.68±1.03a
Shank	AH	11.41±2.12	13.03±0.75	13.72±0.63	16.82±1.45	15.50±2.17ab	15.24±0.72ab
Shank	GLC	13.36±2.12	12.85±0.71	12.84±0.59	13.05±1.53	14.82±1.59b	14.92±0.73b
Short loin	SM	20.88±1.63	27.94±1.70	31.43±1.32a	27.04±2.26a	33.72±4.71a	39.08±1.76a
Short loin	AH	18.15±1.21	24.85±1.28	29.54±0.98a	28.05±2.09a	33.64±4.55b	33.64±1.23b
Short loin	GLC	16.76±1.21	24.49±1.21	25.87±0.92b	23.97±2.17b	30.01±4.57b	31.15±1.24b

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; a, b: Least square means with different letters within age and cut are significant ($p<0.05$) and compare SM, AH and GLC composite types. Letters are only shown when means are different ($p<0.05$)

contained 29.6, 30.5 and 30.8% of the total muscle in SM, AH and GCL, respectively. At 456 day the muscles in the loins combined (loin + short loin) constituted 16.9, 16.1 and 16.2% of the total muscle in the SM, AH and GLC respectively, whereas at 274 day loins constituted 14.6, 15.0 and 15.0% of the total muscle in SM, AH and GLC respectively. At 456 day the rib cuts contained 9.2, 8.6 and 8.9% of the total muscle in SM, AH and GLC respectively and at 274 day it contained 9.3, 8.8 and 8.7% of the total muscle in SM, AH and GLC respectively. It appears that while in the chuck and loins the ratio of primal cut muscle to total muscle decreased as steers got older, in the round the ratio increased (average=3.8%) and in the rib cut it remained virtually unchanged in all composites.

The total weight and proportion of fat in the primal cuts increased with SL age (Table 6 and 7). During the 182 day period from 274 to 456 day, the increase in fat

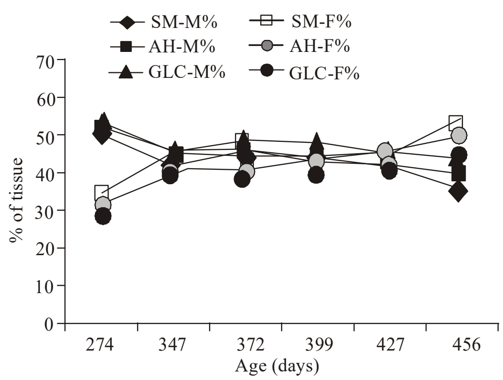

Fig. 3: Changes in the proportion of muscle (M) and fat (F) in the brisket of composites[a] by slaughter age [a]SM: composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

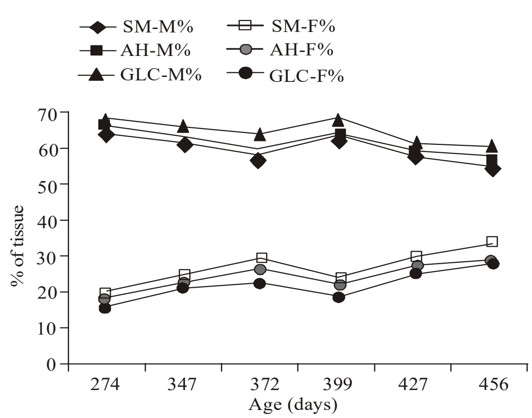

Fig. 4: Changes in the proportions of muscle (M) and fat (F) in the loin of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

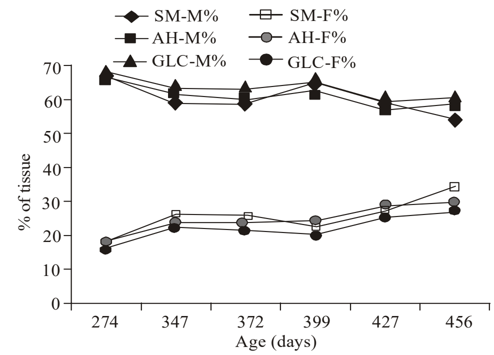

Fig. 5: Changes in the proportions of muscle (M) and fat (F) in the chuck of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

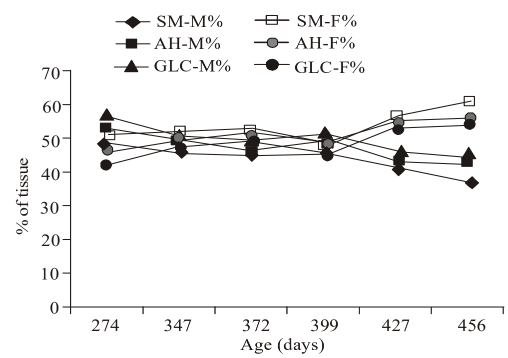

Fig. 6: Changes in the proportions of muscle (M) and fat (F) in the chuck of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

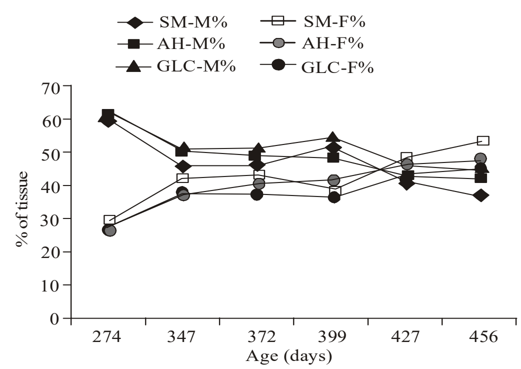

Fig. 7: Changes in the proportions of muscle (M) and fat (F) in the plate of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

weight arranged in ascending order in primal cuts was as follows: Shank increased by 1.4-2.2 times, round 2.1-2.4 times, brisket 2.6-2.9 times, loin 2.9-3.2 times, chuck

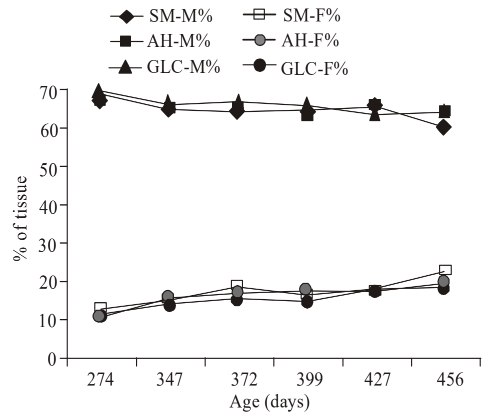

Fig. 8: Changes in the proportions of muscle (M) and fat (F) in the rib of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

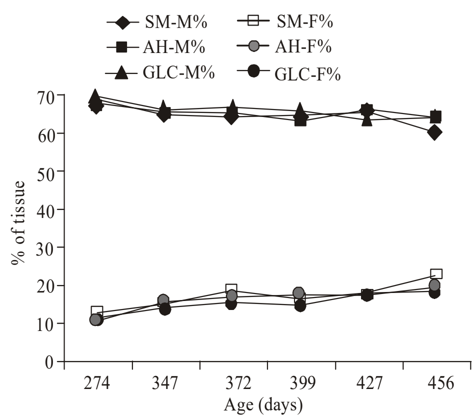

Fig. 9: Changes in the proportions of muscle (M) and fat (F) in the round of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

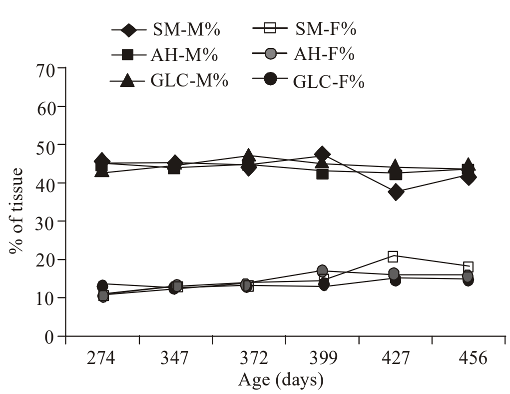

Fig. 10: Changes in the proportions of muscle (M) and fat (F) in the shank of composites[a] by slaughter age[a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

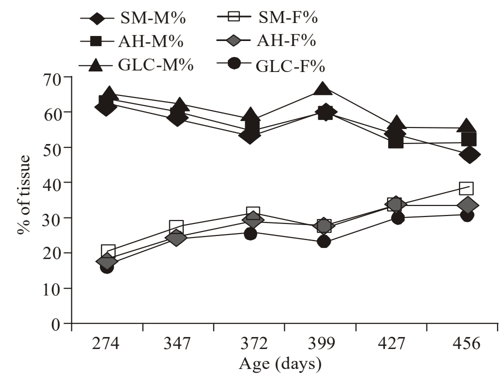

Fig. 11: Changes in the proportions of muscle (M) and fat (F) in the short loin of composites[a] by slaughter age [a]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base

3.2-3.8 times, short loin 3.5-3.8 times, flank 3.9 times, rib 3.5-4 times and plate 3.8-4.4 times in the composites. At 456 day, differences between composites were only observed in the brisket and plate, whereas in all other cuts the composites were equally ($p>0.05$) fat. At 427 day, the AH were fatter ($p<0.05$) than either SM or GLC in the chuck and no differences ($p>0.05$) were observed between composites in the other cuts (Table 6). The proportion of fat at 456 day was higher ($p<0.05$) in SM than AH and GLC in the loin, chuck, flank, plate, round and short loin whereas in the rib, brisket and shank the fat proportions were similar ($p>0.05$) for SM and AH (Table 7). At earlier harvest times, the proportion of fat in many primal cuts was similar ($p>0.05$) for SM and AH.

In all cuts, the proportion of muscle decreased andthe proportion of fat increased with age (Fig. 3 to 11). The standard errors are not shown in these figures but are included in Table 5 and 7. The flank contained less than 1% bone and approximately 50% fat and 50% muscle at 274 days of age. As the steers got older, the fat grew at the expense of muscle and at 456 day the flank contained proportionately more fat than muscle. The brisket contained around 50% muscle and 30% fat at 274 day and as steers got older, the former decreased in proportion and the latter increased such that at 456 day, the brisket had proportionately more fat than muscle. The proportion of muscle in the rib decreased by 8-15% in the composites as the steers got older (or heavier) while the proportion of fat increased by 15-20% in all composites. At 456 day the proportion of F was fast approaching that of M. The round was the leanest primal cut and the slopes of the lines showing either a decrease in the proportion of muscle (slopes or regression coefficients: SM-M = −1.12, AH-M = −0.45, GLC-M = -0.99) or an increase in the proportion of fat (slopes or regression coefficients: SM-F = 1.58, AH-F = 1.38, GLC-F = 1.24) were flatter than in all other primal cuts with the exception of the shank. The shank showed a slight decrease in the proportion of muscle (slopes or regression coefficients: SM-M = −0.95,

Table 8: Distribution of subcutaneous, intermuscular and body cavity fat (kg) on the left side of carcass in the expensive primal beef cuts (loin, rib, round and short loin) and the chuck in composite types by slaughter age

			Slaughter age (days)					
Cut	Type[W]	Fat depot[X]	274	347	372	399	427	456
Loin	SM	SC	0.45±0.16	0.95±0.22	1.13±0.10ab	1.21±0.33ab	1.23±0.12	2.02±0.27
Loin	AH	SC	0.43±0.15	0.93±0.21	1.22±0.07a	1.41±0.32a	1.51±0.08	2.25±0.26
Loin	GLC	SC	0.45±0.15	0.99±0.21	0.99±0.07b	1.08±0.33b	1.35±0.08	2.18±0.26
Loin	SM	IM	0.51±0.05	0.95±0.10	1.30±0.13	1.24±0.20	1.51±0.12	1.31±0.27
Loin	AH	IM	0.60±0.03	1.03±0.07	1.25±0.10	1.30±0.20	1.61±0.08	1.50±0.27
Loin	GLC	IM	0.54±0.03	0.99±0.07	1.19±0.09	1.20±0.21	1.54±0.08	1.52±0.27
Loin	SM	BC	0.22±0.02a	0.10±0.11	0.45±0.05	0.44±0.10	0.51±0.08	0.40±0.07a
Loin	AH	BC	0.32±0.02b	0.19±0.10	0.57±0.04	0.55±0.10	0.55±0.05	0.49±0.07b
Loin	GLC	BC	0.26±0.02a	0.12±0.10	0.53±0.03	0.40±0.09	0.49±0.05	0.45±0.07ab
Rib	SM	SC	0.66±0.19	1.39±0.30	1.47±0.15	1.81±0.16ab	1.70±0.18ab	2.12±0.48
Rib	AH	SC	0.70±0.18	1.56±0.28	1.64±0.11	2.06±0.11b	2.15±0.13b	2.34±0.47
Rib	GLC	SC	0.69±0.17	1.45±0.29	1.51±0.10	1.53±0.11a	1.76±0.13a	1.98±0.48
Rib	SM	IM	0.64±0.08	1.53±0.14	1.97±0.36	1.91±0.38a	2.57±0.20	2.71±0.22
Rib	AH	IM	0.73±0.06	1.67±0.11	2.22±0.27	2.43±0.36b	2.87±0.14	3.11±0.15
Rib	GLC	IM	0.75±0.06	1.67±0.10	2.29±0.25	1.85±0.37a	2.54±0.14	2.80±0.16
Rib	SM	BC	0.15±0.06a	0.42±0.06	0.46±0.06	0.43±0.12a	0.70±0.05a	0.46±0.12
Rib	AH	BC	0.22±0.06b	0.40±0.05	0.45±0.04	0.62±0.12b	0.59±0.04ab	0.53±0.11
Rib	GLC	BC	0.19±0.06ab	0.42±0.05	0.46±0.04	0.43±0.13a	0.53±0.04b	0.45±0.11
Round	SM	SC	1.42±0.37	2.14±0.23	2.67±0.21	2.76±0.33	2.97±0.30	3.59±0.32
Round	AH	SC	1.61±0.36	2.56±0.17	3.24±0.15	3.56±0.22	3.75±0.21	4.43±0.22
Round	GLC	SC	1.62±0.34	2.53±0.17	2.91±0.14	2.95±0.23	3.53±0.21	3.99±0.22
Round	SM	IM	1.18±0.16a	1.85±0.15a	2.19±0.17	2.00±0.16	2.52±0.68	2.61±0.41
Round	AH	IM	1.43±0.16b	2.34±0.11b	2.53±0.12	3.01±0.11a	2.73±0.66	2.99±0.39
Round	GLC	IM	1.59±0.15b	2.21±0.11b	2.47±0.11	2.57±0.11b	3.02±0.67	3.00±0.40
Round	SM	BC	0.12±0.04	0.15±0.03	0.19±0.03	0.16±0.08c	0.24±0.03	0.20±0.03
Round	AH	BC	0.15±0.03	0.22±0.02	0.24±0.02	0.21±0.08	0.20±0.02	0.24±0.02
Round	GLC	BC	0.17±0.03	0.17±0.02	0.22±0.03	0.17±0.08	0.23±0.02	0.22±0.02
Short loin	SM	SC	0.61±0.19	1.46±0.24	1.40±0.12	1.17±0.23	1.59±0.18	2.65±0.31
Short loin	AH	SC	0.60±0.18	1.49±0.21	1.51±0.09	1.38±0.21	1.97±0.12	2.69±0.30
Short loin	GLC	SC	0.64±0.17	1.63±0.22	1.34±0.08	1.40±0.22	1.68±0.12	2.47±0.30
Short loin	SM	IM	0.22±0.12	0.43±0.07	0.65±0.17	0.63±0.07ab	1.03±0.18	0.89±0.28
Short loin	AH	IM	0.24±0.12	0.44±0.05	0.77±0.18	0.76±0.04a	1.13±0.17	0.96±0.27
Short loin	GLC	IM	0.25±0.11	0.49±0.05	0.64±0.17	0.56±0.05b	0.98±0.17	0.88±0.28
Short loin	SM	BC	0.36±0.05	0.50±0.21	0.83±0.13	0.51±0.15	0.80±0.21	0.90±0.13a
Short loin	AH	BC	0.38±0.04	0.46±0.19	0.87±0.13	0.47±0.14	0.89±0.20	1.04±0.12b
Short loin	GLC	BC	0.34±0.04	0.47±0.20	0.81±0.12	0.34±0.14	0.79±0.20	0.90±0.12a
Chuck	SM	SC	0.74±0.36	1.94±0.26	2.13±0.25	2.19±0.32a	2.31±0.28	3.41±0.35
Chuck	AH	SC	0.85±0.35	2.13±0.19	2.44±0.19	3.00±0.21b	2.98±0.19	3.60±0.24
Chuck	GLC	SC	0.77±0.34	1.70±0.18	2.17±0.18	2.17±0.22a	2.43±0.19	2.97±0.24
Chuck	SM	IM	2.77±0.59a	5.65±0.50	5.97±0.91	4.42±0.93a	7.92±0.57	9.11±0.49
Chuck	AH	IM	3.46±0.57b	5.84±0.38	6.41±0.92	5.83±0.85b	9.52±0.39	10.28±0.34
Chuck	GLC	IM	3.44±0.55b	6.20±0.36	6.10±0.89	4.89±0.88ab	8.52±0.39	9.65±0.35
Chuck	SM	BC	0.17±0.02	0.30±0.19	0.39±0.06	0.27±0.40	0.50±0.10	0.49±0.07
Chuck	AH	BC	0.17±0.02	0.45±0.14	0.45±0.04	0.50±0.39	0.55±0.07	0.50±0.05
Chuck	GLC	BC	0.16±0.02	0.48±0.13	0.42±0.04	0.46±0.40	0.55±0.07	0.53±0.05

[W]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; [X]SC: Subcutaneous fat; IM: Intermuscular fat; BC: Body cavity fat; a, b: Least square means with different letters within age, cut and type are significant ($p<0.05$) and compare SM, AH and GLC composite types. Letters are only shown when means are different ($p<0.05$)

AH-M = −0.49, CLG-M = −0.0006) and a slight increase in the proportion of fat (slopes or regression coefficients: SM-F = 0.77, AH-F = 0.66, GLC-F = 0.40). The loin and short loin showed similar patterns of growth with respect to the proportions of muscle and fat.

In general, as animals got older all fat tissues increased in weight (Table 8). Differences between composites were less pronounced at 456 day possibly due to the greater variability of fat in the depots in each primal cut. The SC fat was the largest depot in the short loin while in the rib and chuck there was more IM fat than SC fat at each age. The fat in the SC and IM depots were similar in the loin and round from 274-399 day, but SC fat exceeded IM fat in both primal cuts beyond 399 day. BC fat was lower compared to SC and IM fat in all cuts. The ratio of IM: SC fat in the chuck was always higher compared to the other expensive cuts. For example, the IM: SC fat ratio for the composites combined at 456 day in the chuck was 2.9:1 whereas it was 0.67:1, 1.34:1, 0.72:1, 0.35:1 in the loin, rib, round and short loin respectively. From 274-456 day the greatest percent change in SC fat was in the loin and the greatest change in IM fat was in the rib (Table 9), although there was more IM fat in the chuck compared to all other fat depots and cuts at 456 day. The lowest change in SC and IM fat was in the round. In each of the expensive cuts, the percent increase in SC fat from 274 to 456 (182) days was higher in the AH than both SM and GLC (Table 9). The

Table 9: Changes in subcutaneous (SC) and intermuscular (IM) fat on the left side of carcass in the loin, rib, round, short loin and chuck in composites from 274 to 456 days (d), 399 to 456 d and 427 to 456 d

			274-456 d		399-456 d		427-456 d	
Cut	Fat depot[W]	Type[X]	Difference (kg)	% increase	Difference (kg)	% increase	Difference (kg)	% increase
Loin	SC	SM	1.57	348.9	0.81	66.9	0.79	64.2
Loin	SC	AH	1.82	423.2	0.84	59.6	0.74	49.0
Loin	SC	GLC	1.73	384.4	1.10	101.9	0.83	61.5
Rib	SC	SM	1.46	221.2	0.31	17.1	0.42	24.7
Rib	SC	AH	1.64	234.3	0.28	13.6	0.19	8.8
Rib	SC	GLC	1.29	187.0	0.45	29.4	0.22	12.5
Round	SC	SM	2.17	152.8	0.83	30.0	0.62	20.9
Round	SC	AH	2.82	175.2	0.87	24.4	0.68	18.1
Round	SC	GLC	2.37	146.3	1.04	35.3	0.46	13.0
Short loin	SC	SM	2.04	334.4	1.48	126.4	1.06	66.7
Short loin	SC	AH	2.09	348.3	1.31	94.9	0.72	36.6
Short loin	SC	GLC	1.83	285.9	1.07	76.4	0.79	47.0
Chuck	SC	SM	2.67	360.8	1.22	55.7	1.10	47.6
Chuck	SC	AH	2.75	323.5	0.60	20.0	0.62	20.8
Chuck	SC	GLC	2.20	285.7	0.80	36.9	0.54	22.2
Loin	IM	SM	0.80	156.9	0.07	5.6	-[Y]	-
Loin	IM	AH	0.90	150.0	0.20	15.4	-	-
Loin	IM	GLC	0.98	181.5	0.32	26.6	-	-
Rib	IM	SM	2.07	323.4	0.80	41.8	0.14	5.5
Rib	IM	AH	2.35	326.0	0.68	28.0	0.24	8.3
Rib	IM	GLC	2.05	273.3	0.95	51.4	0.26	10.2
Round	IM	SM	0.83	46.6	0.61	30.5	0.09	3.6
Round	IM	AH	1.56	109.1	-	-	0.26	9.5
Round	IM	GLC	1.41	88.7	0.43	16.7	-	-
Short loin	IM	SM	0.67	304.5	0.26	41.2	-	-
Short loin	IM	AH	0.72	300.0	0.20	26.3	-	-
Short loin	IM	GLC	0.63	252.0	0.32	57.1	-	-
Chuck	IM	SM	6.34	228.9	4.69	106.1	1.19	15.0
Chuck	IM	AH	6.82	197.1	4.45	76.3	0.76	7.9
Chuck	IM	GLC	6.21	180.5	4.76	97.3	1.13	13.3

[W] SC: Subcutaneous fat; IM: Intermuscular fat; [X]SM: Composites of small breeds; AH: Composites with angus or hereford base; GLC: Composites with gelbvieh, limousin or charolais base; [Y]: No increase

largest difference in SC fat between AH and GLC was in the short loin (62.4%) and the smallest difference in the round (28.9%). This may be attributed to the early maturating pattern of the British type beef cattle. The increase in IM fat in the loin, rib and short loin were similar for the SM and AH composites. In the SC fat of the short loin in AH, the rate of fat increase per day was calculated at 1.9%, in the IM fat of the rib cut in SM, the fat increase per day was 1.8%, whereas in the IM fat of the round in SM the increase per day was 0.26%. Greater increases in both the SC and IM fat were observed in the short loin compared to the fat in the other expensive primal cuts. The increase in IM fat in the rib was higher than SC as steers grew older while in the loin and round the increase in SC fat was higher than IM.

DISCUSSION

These results agree with earlier work on the growth and distribution of muscle, fat, bone and the proportions of fat in the IM, SC and BC depots in beef cattle (Berg and Butterfield, 1976; Patterson *et al*., 1985; Jones, 1985). However, slaughter weights appear to have increased over the years.

The dressing percent increased as steers got older and heavier (Table 1). Many studies have shown this relationship and it is accepted that higher dressing percentages are associated with fatter animals (Berg and Butterfield, 1976; Purchas *et al*., 2002; Bruns *et al*., 2004). Hanson *et al*. (1999) reported a range in lean percentage from 65.3 to 47.6% in steer carcasses ranging in weight from 251.3 to 424.6 kg, which agree with our results in Table 2. Percent fat (back and seam fat) increased and ranged from 14.3 to 35.7%, as steers got older (Hanson *et al*., 1999) which is similar to the fat growth patterns in our study.

As steers got older, the weight of muscle and fat increased in the whole carcass as well as in each primal cut while the proportion of muscle relative to the total of muscle + fat + bone decreased and the proportion of fat increased. This is characteristic of the manner in which muscle and fat grow with age in cattle (Berg and Butterfield, 1976; Jones *et al*., 1985). As such when muscle growth slows down the rate of fat growth increases. Furthermore, it is well established that gain and feed efficiency decreases with age in the feedlot (Schoonmaker *et al*., 2002; Bruns *et al*., 2004; Drager *et al*., 2004). It is also recognized that the gains and efficiencies of heavier animals (usually older) will fall faster than in lighter steers entering the feedlot (Schoonmaker *et al*., 2002; Pastoor, 2005). Also the total muscle to fat ratio decreased in all composites and in the SM, it decreased faster from 3.7:1 at 274 to 1.4:1 at 456 day (Table 2).

The proportion of total tissue (M+F+B) expressed as a % of total tissue of all nine cuts at 274, 399 and 456 day in the brisket of SM composites (Table 3) was 6.0, 5.6 and 5.3% respectively, loin was 7.5, 8.5 and 7.9%, respectively, chuck was 29.0, 28.9 and 29.5%, respectively, flank was 3.6, 4.5 and 6.8%, respectively, plate was 5.3, 6.7 and 6.8% respectively, rib was 10.2, 10.9 and 10.1% respectively, round was 27.4, 23.9 and 21.8% respectively, shank was 3.7, 3.8 and 3.0%, respectively and short loin was 7.3, 7.3 and 8.6%, respectively. In the SM composites at 456 day, the loin, rib, round, short loin and chuck made up 78% of the carcass while the brisket, flank, plate and shank made up 22% of the carcass. The total tissue in the round expressed as a percentage of the total carcass tissue decreased as steers got older as less fat was deposited in this primal cut whereas in the flank, plate and to some extent in the short loin the total tissue weight increased as steers aged and more fat tissue was deposited. In the other primal cuts the proportion of tissues did not change appreciably (Table 3). In all cuts of beef, between 372 and 456 day, although total tissue (Table 3) and muscle weight increased with age (Table 4), the proportion of muscle decreased by 8.59, 1.83 and 2.31% in SM, AH and GLC composites respectively (Table 5), which again shows the need for early harvest times for smaller biological types. However, the Canadian beef grading system encourages producers to slaughter all biological types at heavier weights as marbling usually occurs at heavier weights. At least in the early maturing types such as the SM and AH composites it would be more efficient to harvest them earlier rather than at 456 day if a system based primarily on leanness was developed.

In the SM from 399 to 456 day there was hardly any change in muscle weight in the expensive cuts of beef (loin, rib, short loin and round) (Table 4) but the weight of fat increased during this time (Table 6). In fact there was a decrease in muscle weight, as lighter steers may have by chance remained at the end of the study at 456 day or relatively heavier animals were by chance harvested at 427 day. It was only in the short loin of the SM composites that a 10.5 and 5.6% increase in muscle weight from 399-456 and 427-456 day was observed (Table 4). However, the increases in fat weight in SM from 399-456 day in the loin, rib, round and short loin were 42.2, 32.6, 33.4 and 95.3%, respectively and from 427-456 day in the loin, rib, round and short loin were 5.9, 8.3, 14.4 and 42.0%, respectively. In the GLC composites although fat growth takes precedence over muscle growth, from 399 or 427 to 456 day there is still an increase in muscle weight. From 399 day of age as little muscle and mostly fat is deposited in SM, these composite types can be harvested earlier than at 456 day.

As a part of the biological process, as animals get older or mature, the amount and proportion of fat in all primal cuts increased (Table 6 and 7) and muscle growth as determined by the rate decreased to a minimum. At this time energy is used for homeostasis and the synthesis of fat. In energetic terms, protein synthesis is more efficient than fat synthesis when turnover is not taken into consideration. Thus the relative efficiency of synthesis (energy stored/energy expended) is about 88 and 81% for protein and fat respectively. The efficiency of energy use is thus higher in young growing animals where a considerable part of the energy is stored as protein compared to fat in mature animals (Millward *et al*., 1976; McDonald *et al*., 1988). Thus the argument can be made that instead of using feed energy to produce fat, harvest the animal earlier when it is in a lean condition and save on energy expenditure to produce unwanted fat.

Beef cattle are usually fed to heavier weights to achieve a level of marbling but before retail sale some of this fat is trimmed. There is the cost of feeding to put on fat, estimated at $203.38/head and the cost of decreasing trimmable fat from 20.5-16.5% was estimated at $ 27.42 per head (Roeber *et al*., 2001; McKenna *et al*., 2002). Our study shows that whereas muscle weight increased by 9.8 and 8.3% from 427-456 day in AH and GLC composites respectively, fat weight increased by 13.0 and 13.3% during the same period in AH and GLC composites respectively (Table 2). Also in the SM, from 427-456 day, the proportion of muscle decreased from 54.34 to 49.84% (4.5%) while the proportion of fat increased substantially from 31.01 to 36.56% (5.55%). However, the increase in the proportion of fat in the AH and GLC was less than for SM and ranged from 1.43-1.46% (Table 2). The proportion of fat in the primal cuts in SM composites at 456 days was always higher than in AH and GLC (Table 7 and Fig. 3-11) while the proportion of muscle was lower in SM compared to AH and GLC with the exception of the shank (Table 5 and Fig. 3-11). Thus it is clear that the SM composites could be harvested earlier than at 456 day as feeding them a high energy diet does not improve the muscle to fat ratio. Thus harvesting SM composites can save 30 or 60 days of feed. Assuming that a 500 kg steer will consume 2% of its body weight on a dry matter basis for either 30 or 60 days, the saving on feed is either 300 or 600 kg respectively per head.

A primary reason for harvesting beef at heavier weights under the present grading system is to obtain some marbling and a better price. However, marbling is only important in steaks that are grilled which constitute 12-14% of the carcass (Hearnshaw *et al*., 1994). It is well established that marbling improves the flavor of steaks and some evidence that marbling is related to tenderness. Several studies have shown that a considerable proportion of beefsteaks do not satisfy consumers (Roeber *et al*., 2001; Devitt *et al*., 2002) and that 25% of beefsteaks are rated unacceptable. The inconsistency in beef tenderness has been identified by the US meat industry and the 2000 National Beef Quality Audit as a priority that needs to be addressed and improved (Koohmaraie *et al*., 2002; McKenna *et al*., 2002). Meat tenderness is a function of production, processing, value adding, and cooking method to prepare the meat for consumption by the consumer, and failure of one or more of these links in the beef supply chain increases the risk of a poor eating experience for the consumer (Thompson, 2002). The tenderness of meat, which is related to maturity, age and gender is determined primarily by the degree to which muscle fibres are contracted post slaughter, the amount and bonding complexity of connective tissue, solubility of collagen fibres (Swatland, 1984; Shorthose and Harris, 1990; Arthur, 1995; Hearnshaw *et al*., 1999; Purchas *et al*., 2002; Rhee *et al*., 2004) and the aging of meats post slaughter (Muir *et al*., 1998; Koohmaraie *et al*., 2002). As animal's mature or age, the amount and complexity of collagen increases, the solubility of collagen decreases and there is greater suppression of protein degradation in the muscle post slaughter thereby decreasing the tenderness of meat (Arthur, 1995; Koohmaraie *et al*., 2002; Rhee *et al*., 2004). Purchas *et al*. (2002) reported that beef tenderness was determined more by the age at slaughter than by early growth rates, although in their study it was not possible to separate age effects from effects of different nutritional levels and seasons of slaughter. Aging beef after slaughter improves tenderness (Swatland, 1984; Nishimura *et al*., 1998) and is considered more important than the connective tissue bonding complexity in muscle (Koohmaraie *et al*., 2002). However, a wide variation in tenderness related to aging exists between meat cuts and, between and within muscles (Shorthose and Harris, 1990; Thompson, 2002; Koohmaraie *et al*., 2002; Denoyelle and Lebihan, 2004). Also aging of beef post slaughter accounted for 29% of the variation in tenderness, which was more important than marbling, sex, breed, and ranch of origin or dark cutting (Hearnshaw *et al*., 1995; Wulf *et al*., 2002). There is evidence in the literature that meats from younger animals require less aging than meats from older animals thereby saving on freezer space and energy costs (Northcutt *et al*., 2001; Mandell *et al*., 2001). A seven-day aging is deemed optimum for veal while a 2-4 week aging has been recommended for beef with little improvement in tenderness after two weeks (Nishimura *et al*., 1998; Mandell *et al*., 2001; Thompson, 2002; Denoyelle and Lebihan, 2004). In meats from older animals the response to aging is less, as older animals have more and more complex connective tissue bonds and aging rates for meat cuts with low amounts of connective tissue are higher than for cuts with high amounts (Nishimura *et al*., 1998; Thompson, 2002). Furthermore, the mechanical strength of the intramuscular connective tissue changes slowly during post-mortem aging of beef and it remains almost unchanged for up to 10 days post-mortem and progressively decreases thereafter (Nishimura *et al*., 1998). Taking all these relationships into consideration, if the beef industry chooses to age meats for a predetermined length of time (eg: seven days), meats from younger animals would likely be more tender than beef from older animals. Hence scientific literature supports the general view that meats from younger animals are likely to be more tender and harvesting beef animals at younger ages (or lighter weights) will contribute to a more tender product.

The weight and proportion of fat in each primal cut increased with age (Table 6 and 7) and so did the weight of SC, IM and BC fat in the expensive muscle cuts and the chuck (Table 8). For example, of the total fat in the rib of SM composites at 456 day, 39.5% was SC fat and 50.5% IM fat whereas in the round, 54.5% was SC fat and 39.6% IM fat. Usually as some SC and IM fat is trimmed before retail, fat becomes a waste product. Marked increases in the rate of SC fat deposition were observed in the loin and short loin in all composites from 399-456 day. From 399-456 and 427-456 day the rate of SC fat deposition in the loins combined ranged from 59.6 to 126.4 and 36.6 to 66.7%, respectively in the composites (Table 9). However, the rate of IM fat deposition in the chuck (76.3 to 106.1%) and rib (28 to 51.4%) was high from 399-456 day in all composites. The muscles in the chuck are heavily worked and loosely held compared to the muscles in the round and this may be the reason for increased IM fat. Increases in IM fat in the chuck compared to other primal cuts have been previously reported in the literature (Swatland, 1984; Hanson *et al*., 1999; McKenna *et al*., 2003). It is established that British types such as the Hereford commence fattening early (around 8 months) whereas late maturing Continental types commence fattening later (around 10 months) (Berg and Butterfield, 1976). Also between 450-500 kg hot carcass weight, the rate of marbling supersedes that of back fat and whereas, the deposition of back fat is weight dependent, marbling is age dependent (Rouse *et al*., 2003). It is recognized that cattle tend to fatten rapidly after 12 months of age (Swatland, 1984) and deposit more SC and IM fat at this time. However, for every kg of marbling the animal also deposits 10 kg of SC, IM and BC fat (Rouse *et al*., 2003).

As society is becoming increasingly health conscious, current consumer trends have shifted towards the consumption of leaner beef products (May *et al*., 1992), although some consumers do not want to sacrifice eating quality such as flavor (Savell *et al*., 1987). Health and nutrition issues, specifically cholesterol, saturated fats and general health were the top reasons for consumers eating less beef (Van Koevering *et al*., 1995; Husted, 2005). Also selecting for lean meat is antagonistic to marbling (Bruns *et al*., 2004) and premiums are paid for marbling in both the Canadian and US grading systems. Fat typically has about twice the cholesterol content of muscle (Eichhorn *et al*., 1986). British x Continental yearling steers with initial weights of 329 kg were fed for 105, 119, 133 or 147 days in feedlot and fat and cholesterol (plasma and wet tissue) increased with age while protein (mainly muscle) in the rib eye remained constant (Van Koevering *et al*., 1995). Browning *et al*. (1990) measured nutrient content of muscle groups from eight typical (average yield grade 2.99) and eight lean (average yield grade 1.73) steer carcasses. Lean carcasses were higher in moisture and protein and lower in fat, cholesterol and calories compared to typical carcasses. The contents of saturated and monounsaturated fatty acids increased faster with increasing fatness (or weight) than did the content of polyunsaturated fats, resulting in a decrease in the relative proportion of polyunsaturated fats and consequently the polyunsaturated/saturated fatty acid ratio (De Smet *et al*., 2004). Hoelscher *et al*. (1988) reported that approximately 90% of the cholesterol found in adipose tissue was present in the storage fraction, leaving 10% in the membrane fraction. Thus increasing the fat in the storage form, as might be expected with increased marbling, would be expected to increase cholesterol concentration in the rib eye (Van Koevering *et al*., 1995). In addition, differences in saturated fats exist among beef muscles and retail cuts, and diet influences fatty acid profiles; grain fed cattle have more saturated fats than grass fed cattle (Moloney *et al*., 2001; Medeiros *et al*., 2005).

Canada has a diversity of beef breeds ranging from the British (B), Continental (C), B x C crosses and crosses with *Bos indicus*. In addition there are composite or synthetic beef lines that have been developed. Also, more that 80% of slaughter cattle are now crossbred and various breeding practices such as two-breed, three-breed and rotational crossing are used to maintain heterosis. Dairy breeds such as the Brown Swiss and Holstein have also been introduced to get more dairy genetics into beef herds. More recently, the Wagyu has been introduced to improve marbling. This provides a great diversity of gene pools. In addition, there are bulls, steers and heifers that are known to grow, mature and fatten differently (Berg and Butterfield, 1976; Jones *et al*., 1984). Among crossbreds, there is further differentiation into large, medium and small-framed cattle and early and late maturing biological types, which have different fattening patterns (Koch and Dikeman, 1977; Patterson *et al*., 1985; Jones, 1985). However, irrespective of the maturing patterns of these diverse genetic types and the production systems they are managed under, the carcass value of all slaughter cattle in Canada is dependent on their conformity to a single grading system. Thus the ideal carcass which is one that should contain maximum muscle, minimum bone and optimum fat that consumers want is replaced by one which compromises muscling for marbling (fat). According to Statistics Canada, Canada's beef cattle industry remains the largest single source of farm cash receipts. The Canadian beef cattle industry is large enough to accommodate more than one grading system or value chain, thereby giving producers an opportunity to diversify their product and consumers a choice of leaner beef.

CONCLUSION

In the carcass and all primal cuts of Canadian composites, the total weight of muscle, weight and proportion of fat increased while the proportion of muscle decreased as steers became older. The increase in the proportion and distribution of fat relative to muscle in all primal cuts differed between composites especially during the later harvesting times beyond 399 day. Whereas, the Gelbvieh, Limousin, Charolais composite can be harvested at later ages (15.2 months) the small breed based and the composites with Angus and Hereford breeding may be harvested 60 or 30 days earlier when they have between 25 and 31% fat respectively in the carcass.

IMPLICATIONS

Early harvesting of beef would maximize the proportion of muscle in the carcass and optimize fat to between 25-31% of total tissue, and would better fit the definition of the ideal carcass. A grading or marketing system, which emphasizes muscling, can be considered to run parallel to the present Canadian beef grading system. This gives producers greater flexibility in marketing diverse biological types grown under different production systems and better aligns biological with economic efficiency. Feed grain resources can be channeled into lean production rather than fat. A value chain built on carcass leanness will complement the health concerns regarding saturated fats and cholesterol and contribute to the production of younger, leaner and more tender beef. Consequently, domestic and global customers will have a variety of choices from very lean to marbled cuts of beef and be better aligned with their culinary preferences.

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