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Article *in* Journal of Animal Science · March 1991

DOI: 10.2527/1991.692631x · Source: PubMed

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JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Relationship between longissimus composition and the composition of other major muscles of the beef carcass

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J ANIM SCI 1991, 69:631-640.

RELATIONSHIP BETWEEN LONGISSIMUS COMPOSITION AND THE COMPOSITION OF OTHER MAJOR MUSCLES OF THE BEEF CARCASS[1]

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ABSTRACT

Left sides from 18 beef carcasses (9 steers and 9 heifers), selected to represent a wide range of marbling scores, were evaluated to determine the relationship between longissimus composition and the composition of other major muscles. The adductor (A), biceps femoris (BF), deep pectoral (DP) gluteal group (GL), infraspinatus (I), longissimus (L), psoas major (PM), rectus abdominis (RA), rectus femoris (RF), semimembranosus (SM), semitendinosus (ST), serratus ventralis (SV), spinalis (SP), supraspinatus (SU) and triceps brachii (TB) were removed, trimmed of external fat, weighed and ground for proximate analysis. Fat content of all muscles was related linearly ($P < .001$) to L fat content (R^2 values ranged from .67 to .84). The ST had the lowest mean fat content (4.4%) and SP had the highest mean percentage of fat (16.1%). The L ranged from 3.59% to 15.42% fat with a mean of 8.61%. Longissimus fat percentage can be used to predict the fat content of the other major muscles of the beef carcass.

Key Words: Muscles, Proteins, Fat, Water, Intramuscular Fat

J. Anim. Sci. 1991. 69:631–640

Introduction

Consumption of beef products in the U. S. has been static during the last several years (American Meat Institute, 1988). Consumer demand for meat and meat products appears to be changing. A consumer study by Yankelovich (1985) demonstrated that meat consumers fell into five basic categories. Of these, the active-lifestyle group and the health-oriented contingent, jointly accounting for 50% of the consumers surveyed, are consuming the least amount of meat. The active-lifestyle group spends little time cooking, does not view meat as a priority for mealtime satisfaction, and is concerned about the negative health implications of excessive dietary fat and cholesterol. The health-oriented segment is very concerned about meat from a nutritional standpoint and tends to avoid meat due to their desire to limit calorie, cholesterol and salt intake. Carcasses and cuts from carcasses low in fat should be identified for these consumers.

The composition of the muscles of the forequarters were described by Johnson et al. (1988). He described a wide range in the fat content of muscles (multifidus dorsi, 16.7% fat; triceps brachii, long head, 3.1%). Similar results were reported by McKeith et al. (1985) and Choi et al. (1987). Selection of muscles or muscle groups for consumption and(or) further processing based on composition is important for contemporary consumers.

Research has shown that subcutaneous and intermuscular fat can contribute a large amount of fat to a fresh beef cut (Parrett et al., 1989). Current trends in beef merchandising are toward trimming a greater percentage of these tissues prior to retail sale. With diminished subcutaneous and seam fat, the importance of marbling in determining the total composition of a beef cut increases markedly.

The objective of this study was to characterize the relationships between longissimus fat content and the composition of 14 other major muscles of the beef carcass.

[1]This project was funded by the Beef Industry Council of the National Live Stock and Meat Board.
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Received June 20, 1989.
Accepted August 15, 1990.

Materials and Methods

The left sides of 18 beef carcasses, ranging in weight from 138 to 155 kg, were selected by University of Illinois personnel to represent a wide range of marbling scores, ranging from traces to slightly abundant. Carcasses were divided equally into three groups of six based on marbling level. The low marbling group included traces and slight marbling levels; the intermediate marbling group included the small and modest marbling levels; and the high marbling group carcasses had slightly abundant marbling. Steers and heifers were equally represented within each marbling group. Yield grades ranged from 1.8 to 3.6. The carcasses were delivered from a commercial slaughter plant to the University of Illinois Meat Science Laboratory.

Fifteen whole muscles were dissected from each carcass side as described by Brackebusch et al. (1991). These muscles included the adductor (A), biceps femoris (BF), deep pectoral (DP), gluteal group (GL), infraspinatus (I), longissimus (L), psoas major (PM), rectus abdominis (RA), rectus femoris (RF), semimembranosus (SM), semitendinosus (ST), serratus ventralis (SV), spinalis (SP) supraspinatus (SU) and triceps brachii (TB). These muscles were completely trimmed of external fat and weighed. Each muscle then was chopped and thoroughly mixed with a Kramer-Grebe bowl cutter for 4 min. Five grab samples were obtained from the chopper bowl to make a 120-g composite sample from each muscle. This sample was placed in a Whirl-Pak sample bag, frozen and stored at –20°C until proximate analysis was completed.

Following sampling of each of these muscles, a total carcass soft tissue composite was made. Bones, cartilage, ligamentum nuchae and heavy connective tissue were separated and weighed. The remaining soft tissue and the chopped muscles were mixed and ground through a 1.27-cm plate. Representative samples were obtained and the samples were chopped and subsampled as described previously.

Samples were thawed and reground using a food processor. Duplicate 5-g samples were prepared; percentage of water and lipid were determined using an oven-drying procedure (105°C for 24 h) and repetitive washes of chloroform:methanol (Riss et al., 1983). Percentage of protein was determined on duplicate 1-g samples by the Kjeldahl procedure (AOAC, 1984). If duplicate determinations did not agree (>10% error), samples were reanalyzed until acceptable agreement was obtained.

Compositional information for the 15 muscles was pooled to give information on the overall muscle composite. This was accomplished by calculating weighted mean fat, water or protein contents. Percentage of fat composite = $\sum_{i=1}^{15}$ (percentage of fat muscle$_i$ × muscle weight$_i$) × $\sum_{i=1}^{15}$ muscle weight i, where i indexes the individual muscles.

Data were analyzed using SAS (1985). Linear and quadratic effects of marbling score and longissimus fat on percentage of fat in other muscles were evaluated. Prediction equations for intramuscular fat content also were generated for individual muscles based on stepwise regression analysis with sex; yield grade; carcass weight; ribeye area; kidney, pelvic and heart fat; fat thickness and marbling score as independent variables. Stepwise regression was completed using the forward procedure with a $P < .25$ significance level for entry into the model specified.

Results and Discussion

Characteristics of the beef carcasses evaluted were reported by Brackebusch et al. (1991). Significance levels for the main effects of sex and marbling group and the interactions of sex and marbling group are given in Table 1. Muscles from steers and heifers did not differ ($P > .05$) in percentage of fat or percentage of protein and differed ($P < .05$) for percentage of water in only 2 of the 15 muscles evaluated. The sex × marbling group interaction was not significant for the proximate composition of the muscles evaluated or the composite. Marbling groups differed ($P < .05$) in percentage of fat and water in all muscles and in percentage of protein in 9 of 15 muscles and the composite.

Longissimus marbling level was linearly related ($P < .001$) to the percentage of fat in each of the muscles studied, as well as to percentage of fat in the composite of the 15 muscles. A similar relationship was observed between marbling score and percentage of water ($P < .05$) for all muscles evaluated. Protein content was linearly related ($P < .05$)

to L marbling level in two-thirds of the muscles examined and the 15-muscle composite. These findings agreed with those of Garrett and Hinman (1971), who noted that fat content increased and water content decreased in steaks from five muscles as the marbling level increased.

Table 2 presents compositional information for each muscle and for the 15 muscle composite. Muscles lower in fat content than the mean of the composite muscle mass (8.3%) included the following: A (4.4%), ST (4.4%), SM (5.1%), GL (6.1%), RF (6.2%), TB (6.4%), SU (6.4%), DP (6.7%) and BF (7.2%). Muscles with higher fat contents than the composite muscle mass included the following: L (8.6%), PM (10.3%), I (10.4%), RA (14.4%), SV (14.6%) and the SP (16.1%). The RA, SU and the SP contained large amounts of closely associated intermuscular fat, making it difficult to distinguish between inter- and intramuscular fat.

These findings are in general agreement with McKeith et al. (1985), who reported that steaks from the major muscles of the round had a lower fat content than muscles from the chuck and those muscles associated with the maintenance of posture. Percentage of fat was higher in each muscle in this study than in the McKeith et al. (1985) study because of higher levels of intramuscular fat in the current population sample. These results also agreed with relative fat percentage information collected by Johnson et al. (1973) on the muscles of a single Friesian steer. The lipid percentage reported in our study were derived using a warm chloroform:methanol extraction; these would be expected to be higher than values obtained by ether extraction procedures (Marchello et al., 1968; Novakofski et al., 1988).

Proximate composition of each muscle and of the 15 muscle composite by marbling group are presented in Tables 3 and 4. Fat content of each muscle increased linearly ($P < .001$) with an increase in marbling score, and the moisture content of each muscle decreased linearly ($P < .05$) with an increase in marbling score. Protein content tended to decrease with increasing marbling levels but effects were not always significant. When ranked by fat content, muscles from the low marbling group had almost the same order as the muscles from the high marbling group. Similarly, the fattest muscles in the intermediate marbling group had the highest fat content in the high marbling group. These results are consistent with those of Garrett and Hinman (1971), who also found that an increase in quality grade (marbling score) was associated with higher fat content in the infraspinatus, serratus ventralis, longissimus, gluteus medius and semimembranosus plus adductor muscles.

TABLE 1. *F*-VALUES FROM ANALYSES OF VARIANCE FOR THE MAIN EFFECTS OF SEX, MARBLING AND SEX × MARBLING INTERACTION ON PERCENTAGE OF FAT, WATER AND PROTEIN OF 15 MAJOR BEEF CARCASS MUSCLES

	Fat, %			Water, %			Protein, %		
Muscle	Sex	Marbling	Sex × marbling	Sex	Marbling	Sex × marbling	Sex	Marbling	Sex × marbling
Adductor	.06	24.45**	.03	.93	14.99*	.00	.40	.70	.68
Biceps femoris	.22	24.57**	.00	.28	22.97**	.00	.01	5.05*	.02
Deep pectoral	.04	30.75**	.96	.34	46.30**	3.00	.12	2.91	.01
Gluteal group	.07	28.67**	.15	.26	32.90**	.01	2.46	2.47	.10
Infraspinatus	.41	26.51**	.28	2.06	29.42**	1.14	1.10	4.81*	.07
Longissimus	.46	103.21**	.07	2.99	139.02**	.00	1.60	21.43**	.13
Psoas major	1.87	36.24**	.01	4.65*	34.10**	.00	2.92	8.22*	.00
Rectus abdominis	1.83	49.37**	3.92	.71	52.06**	2.62	1.72	17.63**	1.44
Rectus femoris	1.92	32.44**	.25	3.89	32.57**	.15	.33	7.03*	.50
Semimembranosus	.30	41.97**	.20	.65	39.75**	.44	.15	6.42*	.04
Semitendinosus	.51	43.95**	.09	.25	34.41**	.14	.20	1.83	1.61
Serratus ventralis	.66	52.38**	.72	1.72	49.15**	1.02	.93	17.27**	.04
Spinalis	2.31	51.25**	.06	2.65	52.05**	.14	.02	20.59**	.14
Supraspinatus	1.75	25.79**	.34	.18	5.30*	.79	.05	2.44	.56
Triceps brachii	2.59	35.06**	.98	9.41*	41.69**	.00	.61	2.21	1.00
Composite of above	.50	85.78**	.19	2.15	80.74**	.48	.75	14.13*	.03

*$P < .05$.

**$P < .001$.

The strong linear relationship between intramuscular fat in the longissimus and intramuscular fat levels in other muscles allowed the development of equations to predict the fat content of the major beef carcass muscles. The relationship between percentage of longissimus fat and marbling score is presented in Figure 1. The equation y = 16.286 + 51.101x (residual standard deviation = 2.247) can be used to predict marbling score (y) from longissimus fat (x); the equation y = 1.310 + .017x (residual standard deviation = 1.234) can predict longissimus fat (y) if marbling score (x) is known. Both equations had R^2 values of .88.

Chemically determined percentage of longissimus fat was used to develop prediction equations for the fat content of individual muscles. Prediction equations for percentage of fat in the A, BF, DP and GL using longissimus fat are presented in Figure 2. The R^2 of these equations ranged from .68 to .78. Figures 3, 4 and 5 display the relationships between longissimus fat and the percentages of fat in the other muscles and the composite. Coefficients of determination (R^2 values) for all muscles evaluated ranged from .67 for the rectus abdominis to .90 for the 15-muscle composite. Clearly, there was a strong relationship between percentage of L fat and the fat content of the other major muscles.

Table 5 presents equations to predict percentage of fat in the 15 muscles and the composite using sex (heifers = 1; steers = 2), marbling score (Traces^0 = 100; Slight^0 = 200; Small^0 = 300, etc.), USDA yield grade, carcass weight (kg), ribeye area (cm^2), fat thickness (cm) and percentage of kidney, heart and pelvic fat. Coefficients of determination ranged from a low of .64 for the supraspinatus to .89

TABLE 2. PROXIMATE COMPOSITION OF 15 MAJOR BEEF MUSCLES REPRESENTING A WIDE RANGE OF MARBLING LEVELS

Muscle	Fat	Water	Protein
Adductor	4.44	72.28	22.85
	(.31)[a]	(.35)	(.21)
Biceps femoris	7.23	71.22	21.20
	(.61)	(.56)	(.23)
Deep pectoral	6.73	72.05	21.08
	(.63)	(.55)	(.20)
Gluteal group	6.06	71.85	21.66
	(.53)	(.48)	(.18)
Infraspinatus	10.43	70.50	18.90
	(.81)	(.69)	(.17)
Longissimus	8.61	69.95	21.34
	(.82)	(.70)	(.22)
Psoas major	10.26	69.25	20.37
	(.78)	(.71)	(.25)
Rectus abdominis	14.42	66.45	19.15
	(1.33)	(1.06)	(.36)
Rectus femoris	6.16	72.55	21.17
	(.56)	(.53)	(.17)
Semimembranosus	5.06	71.97	22.56
	(.40)	(.33)	(.21)
Semitendinosus	4.41	72.90	22.19
	(.36)	(.32)	(.21)
Serratus ventralis	14.57	67.08	18.33
	(1.22)	(1.08)	(.23)
Spinalis	16.06	65.49	18.46
	(1.39)	(1.19)	(.27)
Supraspinatus	6.39	72.86	20.26
	(.52)	(.51)	(.14)
Triceps brachii	6.36	72.56	21.02
	(.51)	(.49)	(.19)
Composite of above	8.33	70.62	20.84
	(.68)	(.59)	(.18)

[a]Standard error of the mean given in parentheses.

TABLE 3. PROXIMATE COMPOSITION OF 15 MAJOR BEEF CARCASS MUSCLES FROM CARCASSES CLASSIFIED LOW, INTERMEDIATE OR HIGH MARBLING LEVELS

	Low marbling[a]			Intermediate marbling[b]			High marbling[c]			Linear regression[d]		
Muscle	Fat	Moisture	Protein	Fat	Moisture	Protein	Fat	Moisture	Protein	Fat	Moisture	Protein
Adductor	3.24	73.66	23.05	4.45	72.04	22.81	5.64	71.12	22.70	**[f]	*	
	(.18)[e]	(.06)	(.48)	(.29)	(.36)	(.22)	(.52)	(.70)	(.36)			
Biceps femoris	4.79	73.49	21.83	7.43	70.87	21.10	9.46	69.30	20.68	**	**	*
	(.38)	(.26)	(.28)	(.84)	(.67)	(.31)	(.89)	(.91)	(.49)			
Deep pectoral	4.14	74.37	21.63	6.77	72.16	20.82	9.27	69.62	20.80	**	**	
	(.44)	(.25)	(.40)	(.78)	(.62)	(.28)	(.74)	(.63)	(.33)			
Gluteal group	3.89	73.83	21.95	5.99	71.90	21.65	8.28	69.81	21.37	**	**	
	(.48)	(.24)	(.44)	(.55)	(.49)	(.32)	(.66)	(.64)	(.11)			
Infraspinatus	7.09	73.38	19.35	10.57	70.23	18.87	13.63	67.89	18.47	**	**	*
	(.78)	(.75)	(.21)	(.98)	(.86)	(.34)	(.88)	(.69)	(.25)			
Longissimus	4.89	73.21	22.13	8.37	70.04	21.35	12.57	66.60	20.54	**	**	**
	(.39)	(.26)	(.27)	(.51)	(.54)	(.14)	(.69)	(.46)	(.37)			
Psoas major	7.10	72.24	20.79	10.11	69.04	20.83	13.58	66.47	19.47	**	**	*
	(.63)	(.53)	(.47)	(1.02)	(.86)	(.29)	(.78)	(.93)	(.32)			
Rectus abdominis	9.72	70.46	20.12	13.11	67.23	19.63	20.44	61.67	17.71	**	**	**
	(.88)	(.70)	(.45)	(1.09)	(.96)	(.49)	(2.00)	(1.49)	(.50)			

[a]Low marbling group = slight or lower.

[b]Intermediate marbling group = small, modest or moderate.

[c]High marbling group = slightly abundant or higher.

[d]Linear regression of muscle composition on marbling level, *$P < .05$, **$P < .001$.

[e]Standard error of the mean given in parentheses.

[f]Significant linear marbling effect on fat, moisture or protein.

TABLE 4. PROXIMATE COMPOSITION OF 15 MAJOR BEEF CARCASS MUSCLES FROM CARCASSES CLASSIFIED LOW, INTERMEDIATE OR HIGH MARBLING LEVELS

	Low marbling[a]			Intermediate marbling[b]			High marbling[c]			Linear regression[d]		
Muscle	Fat	Moisture	Protein	Fat	Moisture	Protein	Fat	Moisture	Protein	Fat	Moisture	Protein
Rectus femoris	4.07	74.64	21.51	5.99	72.52	21.37	8.41	70.49	20.64	**[f]	**	*
	(.37)[e]	(.27)	(.34)	(.71)	(.66)	(.26)	(.82)	(.79)	(.12)			
Semimembranosus	3.41	73.47	23.10	4.95	71.82	22.63	6.84	70.62	21.95	**	**	*
	(.31)	(.25)	(.46)	(.34)	(.20)	(.28)	(.46)	(.41)	(.16)			
Semitendinosus	2.93	74.06	22.49	4.35	73.17	22.13	5.94	71.45	21.95	**	**	
	(.38)	(.35)	(.50)	(.39)	(.30)	(.24)	(.33)	(.30)	(.31)			
Serratus ventralis	8.97	72.04	19.03	15.01	66.51	18.54	19.71	62.69	17.43	**	**	**
	(.88)	(.71)	(.45)	(1.16)	(1.10)	(.20)	(1.24)	(1.16)	(.21)			
Spinalis	9.97	70.77	19.48	16.20	65.26	18.48	22.03	60.44	17.43	**	**	**
	(.91)	(.75)	(.25)	(1.17)	(1.14)	(.32)	(1.70)	(1.37)	(.37)			
Supraspinatus	4.92	73.67	20.29	5.42	73.83	20.64	8.85	71.10	19.86	**	*	
	(.49)	(1.04)	(.23)	(.61)	(.53)	(.16)	(.60)	(.60)	(.23)			
Triceps brachii	4.27	74.60	21.44	6.45	72.32	20.83	8.36	70.74	20.80	**	**	
	(.38)	(.28)	(.36)	(.71)	(.75)	(.38)	(.61)	(.57)	(.23)			
Composite of above	5.31	73.31	21.42	8.20	70.59	20.89	11.49	67.95	20.21	**	**	*
	(.37)	(.22)	(.33)	(.59)	(.56)	(.22)	(.61)	(.59)	(.19)			

[a]Low marbling group = slight or lower.

[b]Intermediate marbling group = small, modest or moderate.

[c]High marbling group = slightly abundant or higher.

[d]Linear regression of muscle composition on marbling level, $*P < .05$, $**P < .001$.

[e]Standard error of the mean given in parentheses.

[f]Significant linear marbling effect on fat, moisture or protein.

TABLE 5. PREDICTION EQUATIONS FOR THE PERCENTAGE OF FAT IN INDIVIDUAL MUSCLES AND MUSCLE COMPOSITE[a]

Muscle	Intercept	Sex[b]	Marbling[c]	YG[d]	HCW[e]	REA[f]	Fat[g]	KPH[h]	R^2	Cp	Rsd[i]
Adductor	1.44		.0046				.49		.69	–.408	.767
Biceps femoris	–8.69		.0093			.12		1.15	.74	1.452	1.456
Deep pectoral	1.84		.012						.67	.048	1.567
Gluteal group	8.64		.0094			–.083			.70	2.878	1.322
Infraspinatus	–25.16		.0087		.097			1.54	.75	.296	1.877
Longissimus	1.31		.017						.88	–1.815	1.234
Psoas major	3.95		.015						.71	–1.897	1.833
Rectus abdominis	26.45	4.20	.030	6.83	–.31	.61	–4.87		.87	.866	1.633
Rectus femoris	.67		.0090					.78	.73	–.907	1.314
Semimembranosus	1.84		.0076						.73	–1.881	.898
Semitendinosus	–.11	.66	.0063					.40	.78	.703	.782
Serratus ventralis	1.01		.020					2.36	.87	.549	2.029
Spinalis	2.20		.025					1.60	.81	–1.415	2.754
Supraspinatus	2.42		.0094						.64	–2.740	1.382
Triceps brachii	.96		.0078					.97	.77	–.468	1.115
Composite of above	1.28		.013					.78	.89	–.576	1.022

[a]*Only significant factors* ($P < .25$) *included.*

[b]Heifers = 1; steers = 2.

[c]Tr^{o-}= 100; Sl^o = 200; Sm^o = 300; Mt^o = 400; Md^o = 500; Slab^o = 600; Mdab^o = 700.

[d]Yield grade.

[e]Hot carcass weight (kg).

[f]Ribeye area (cm^2).

[g]12th rib fat (cm).

[h]Percentage of kidney, pelvic and heart fat.

[i]Residual standard deviation.

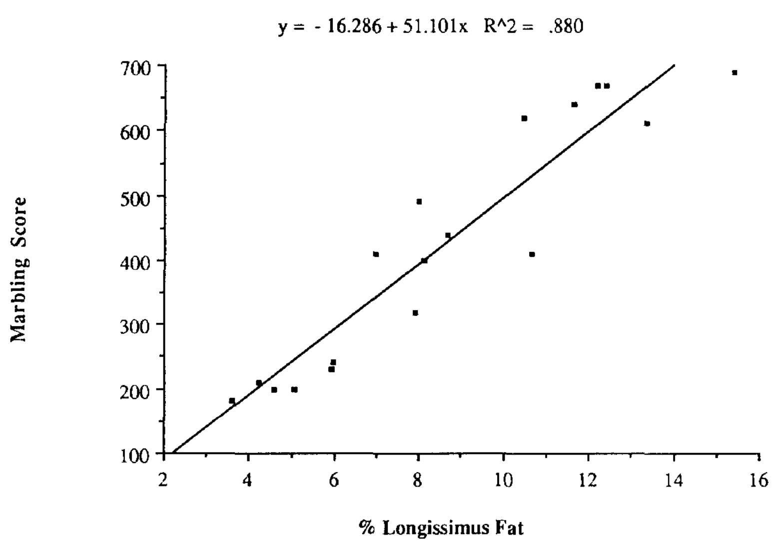

Figure 1. Relationship of marbling score to longissimus fat content.

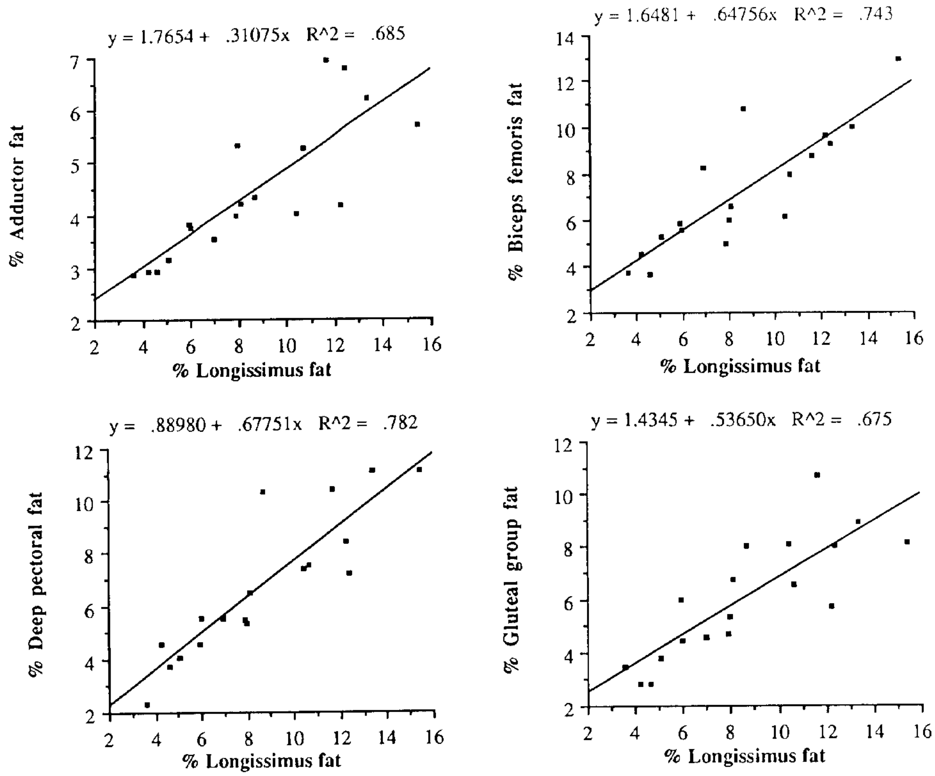

Figure 2. Relationship of longissimus fat content to the major muscles of the carcass.

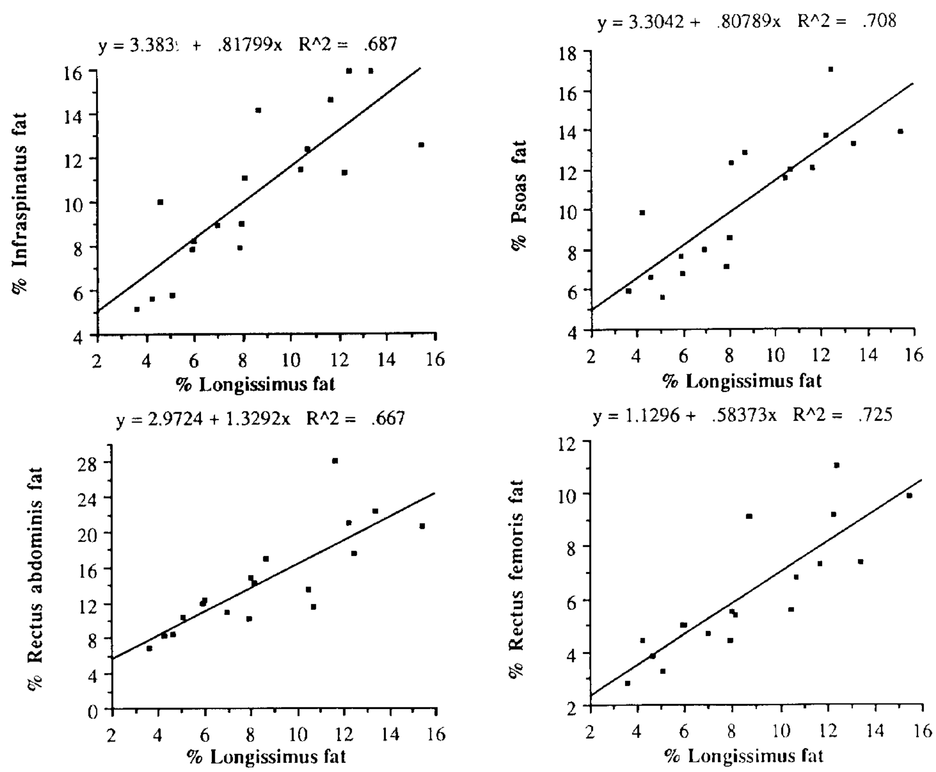

Figure 3. Relationship of longissimus fat content to the major muscles of the carcass.

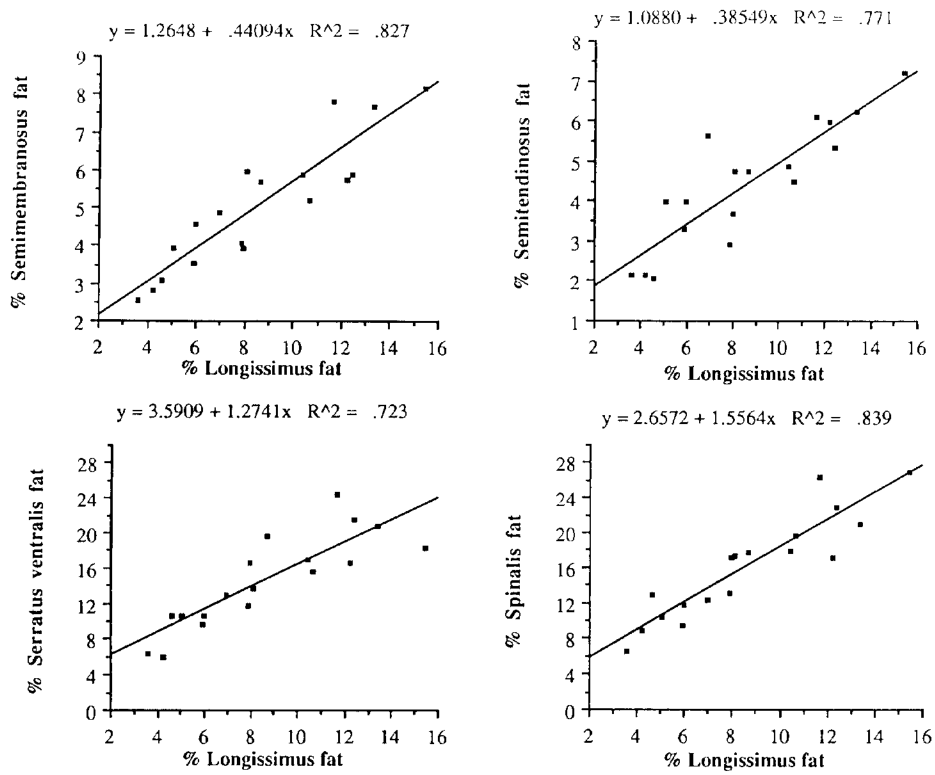

Figure 4. Relationship of longissimus fat content to the major muscles of the carcass.

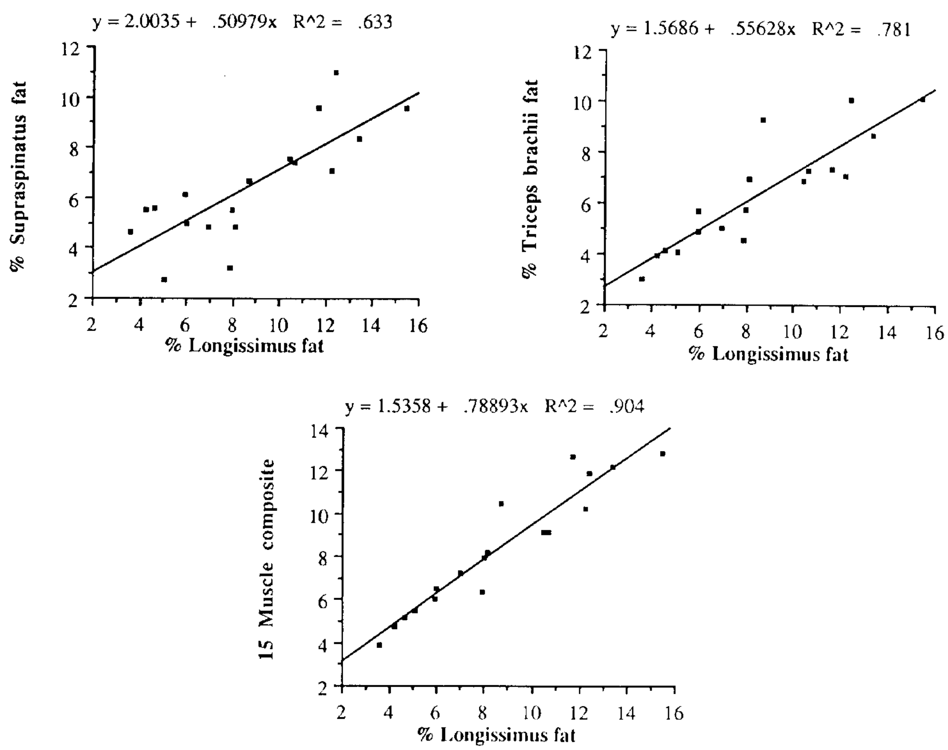

Figure 5. Relationship of longissimus fat content to the major muscles of the carcass.

for the 15-muscle composite. Marbling score was the most important factor in these equations; the other factors contributed very little toward improving the R^2 values.

Results of this study indicated that percentage of fat, moisture and protein in all major muscles of the beef carcass were related in a linear manner to subjective marbling scores and to objectively measured lipid content of the longissimus. Muscles from the round were the leanest muscles evaluated regardless of quality grade. Sex and(or) yield grade had limited effect on intramuscular fat in the beef carcass.

Implications

Identifying the composition of the major muscles of the carcass and the ability to predict muscle composition from longissimus fat content or marbling will allow the meat industry to select cuts and(or) carcasses for different uses. Some cuts may be merchandised with fat claims or for specific uses in further processing, which ultimately will increase the marketability of beef.

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