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ADIPOSE TISSUE GROWTH IN CATTLE REPRESENTING TWO FRAME SIZES: DISTRIBUTION AMONG DEPOTS[1]

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Summary

Adipose tissue growth was studied in 40 steers, progeny of Limousin, Maine Anjou and Simmental sires and crossbred cows. Cows were either two- or three-way crosses among Angus, Hereford, Holstein and Brown Swiss breeds. Steers were allotted into two growth groups of frame sizes (smaller and larger) according to their weights at 180 d of age and managed similarly. Steers within a size group were assigned at random into five slaughter groups. The left side of each carcass was separated into fat, lean, bone and connective tissue components. Omental and mesenteric adipose tissues also were weighed. Steers of both frame size followed a similar pattern of fat deposition, and no significant differences were observed in the rate of fattening with respect to muscle plus bone. Growth coefficients for the dissectible fat depots with respect to total fat in the body were homogeneous between frame sizes, Intramuscular fat, however, was not a later developing depot. Kidney and omental fat increased at the same rate as total fat in the body. Consequently, they should not be considered as earlier developing tissues among fat depots. Because of their rate of growth, and because they contribute up to 30% of the total fat, visceral fats (omental, mesenteric and kidney) should be considered in any attempt to reduce the amount of excess fat deposited in cattle and to increase efficiency of beef production. This study indicates that the fat thickness at the 12-13th rib is a better estimator of subcutaneous fat content than of fat content of other depots.
(Key Words: Body Composition, Growth, Adipose Tissue, Cattle.)

Introduction

Scientists and producers are attempting to reduce the total fat in beef cattle by genetic and nutritional procedures while maintaining desirable palatability of the lean portion of the carcass. The association of marbling scores with quality grades (Allen, 1969) and the additional problems associated with the removal of large quantities of intermuscular and subcutaneous fat for retail merchandising emphasize the importance of additional knowledge in the growth and distribution of adipose tissue (Allen, 1976).

Some studies indicate that breed differences exist in the partitioning of fat among depots (Ledger, 1959; Charles and Johnson, 1976; Kempster et al., 1976; Williams, 1978). The distribution and patterns for adipose tissue growth among depots and wholesale cuts in exotic crosses has not been studied thoroughly, and results from controlled experiments are scarce. The paper reports the distribution and pattern of growth for adipose tissue depots in carcasses from steers representing two different frame sizes and slaughtered from 11 to 19 mo of age.

Materials and Methods

Forty steers of similar birth date and progeny of Limousin, Maine Anjou and Simmental sires and crossbred cows were used in the study. The cows were either two- or three-way crosses

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among Angus, Hereford, Holstein and Brown Swiss breeds. The calves had access to a creep diet before weaning, and all the steers used in the study were weaned within the same week. The weaning weight of each steer was determined and adjusted to a standard 180-d value on the basis of weight gain per day from birth to weaning. Steers were allotted into two groups, small and large, on the basis of their adjusted 180-d weight. This classification was based on a breeding model that assigns a steer to the small class when its weight departs from the mean of all steers in a negative direction. Characteristics of the steers compared on the basis of frame sizes are shown in table 1.

Steers within a frame-size group were assigned at random into five slaughter groups. All steers were kept in the same pen and fed the same growing-finishing diet (72% ground shelled corn, IFN 4-02-931; 22% alfalfa-brome haylage, IFN 3-08-147 or oatlage, IFN 3-03-298; 6% of a pelleted 32% protein supplement) at the Iowa State University McNay Research Center, Chariton, Iowa. Eight steers, four of each frame size, were slaughtered at the Iowa State University Meat Laboratory every 2 mo from 11 to 19 mo of age.

Carcass Components. The left side of each carcass was kept in a cooler at 2 to 3 C until it was physically separated into fat, lean, bone and connective tissue. Omental fat (large and small omentum) and mesenteric fat (the fat around the small and large intestines) were separated after evisceration, chilled for 4 h at 2 to 3 C and weighed. The left side was separated into nine wholesale cuts: foreshank, chuck, brisket, plate, rib, loin, flank, round and hindshank according to Wellington (1953), with the following modifications: (1) The caudal point of the separation between the rib and the plate was located 10 cm from the lateral end of the M. longissimus. (2) The foreshank and brisket were removed from the chuck by cutting 2.5 cm above the lateral condyle of the humerus and parallel to the top line of the chuck. (3) The anterior point where the flank and the loin were separated was located 2.5 cm from the lateral end of the M. longissimus at the 13th rib. (4) Kidney fat was separated from the pelvic fat by cutting along the ventral edge of the pelvic bone from the anterior tip of the aitchbone to the caudal ventral corner of the last lumbar vetebra.

After weighing, each wholesale cut was physically separated into the following components: (1) Subcutaneous fat or external fat, without excavating in the grooves between muscles (fat underneath the M. cutaneous truncii was included with the intermuscular fat); (2) intermuscular fat [by definition, all the fat between muscles (seam fat) plus the fat inside the rib cage and brisket (thoracic fat)]; (3) lean, and (4) bone and connective tissue; these were combined in calculations for body composition. Kidney fat (without the kidney) and pelvic fat weights were recorded. After dissection, each component was weighed, and the total for any component in the left side was determined by summing weights for that component in all wholesale cuts. Kidney fat (without kidney)

TABLE 1. CHARACTERISTICS OF STEERS AS ALLOCATED BY FRAME SIZE

Characteristic[a]	Frame size: Smaller	Frame size: Larger
No. of steers	20	20
Date at birth, mo-d ± d	4– 21 ± 2.6	4– 18 ± 2.6
Adj. weaning weight[b], kg	205 ± 3	260 ± 5[d]
Actual weaning weight, kg	221 ± 6	279 ± 6
Weaning age, d	195 ± 3.7	196 ± 3.7
Average slaughter age, d	465 ± 2.2	468 ± 2.2
Average slaughter weight, kg	455 ± 6.5	530 ± 6.5[d]
Daily gain[c], kg (11 to 19 mo)	1.22 ± .08	1.18 ± .1

[a]Values for each characteristic (except no. of steers) are means ± SE for 20 animals of a specific fame size.

[b]Adjusted to 180 d by using weight gain/day from birth to weaning of steers.

[c]Daily gain was calculated for steers during period of 11 to 19 mo of age.

[d]Value for larger frame steers is different from that of smaller frame steers (P<.05).

and pelvic fat weights also were determined for the left side.

Because only the left side from each carcass was physically separated into its tissue component, the total amount of each fat depot in the carcass was estimated from its respective weight in the left side and the chilled right side weight. These data were used to analyze the contribution of each fat depot to the total dissectible fat in the body including omental and mesenteric fats. The percentages of muscle, fat and bone plus connective tissue of the chilled left side will be referred to as the carcass composition of the steers. The carcass fat thickness and M. longissimus area were determined at the 12th-13th rib of the left side.

Proximate Chemical Analysis. Samples of approximately .3 kg were removed from the following muscles and stored frozen until proximate chemical analyses were performed: (1) Anterior M. longissimus (chuck), (2) infraspinatus, middle portion (chuck), (3) M. longissimus at 12th rib (rib cut), (4) M. longissimus at third lumbar vetebra (loin cut), (5) semitendinosus, middle portion (round) and (6) biceps femoris at distal end (round). Determinations of moisture and lipid contents also were performed in samples from six fat depots (subcutaneous, intermuscular, kidney, brisket, omental and mesenteric) according to the procedures outlined by the AOAC (1975).

Each frozen sample was pulverized in a Waring blender previously chilled in liquid nitrogen. Pulverized samples were placed in double-walled polyethylene bags and stored at −15 C until subsequent proximate analysis. Equal weights of subsamples taken from the six muscle samples from each steer were mixed, and the chemical determinations were performed on a pooled sample. Proximate analysis for the six fat depots were completed on a depot basis per steer.

Statistical Analysis. Data were analyzed as a completely randomized design (Cochran and Cox, 1957), and the sum of squares were partitioned into effects of age, frame size and frame size and age interactions as described by Barr et al. (1979). Comparison of means were made with Student's t-test using the error mean square from the analysis of variance for each respective variable (Snedecor and Cochran, 1967).

The effect of size upon the rate of growth of the main tissues of the carcass and among the different fat depots was expressed with the exponential allometric equation in logarithmic form (Huxley, 1932): $Y = ax^b$; $\log Y = \log a + b \log x$, where Y is a part of the total (carcass tissue or fat depot in kg), x is the total (muscle + bone weight or total amount of fat in the carcass in kg) and b is the growth coefficient describing proportionate growth of a tissue with respect to the total.

The allometric model was chosen over the linear one because it explained more of the total variation of the dependent variable (1 to 2% more and with $r^2 > 90\%$) than the linear model (results not shown here).

Two multiple regression equations for muscle and bone weights as the dependent variables and fat and muscle plus bone weights as the independent variables were calculated for each frame size (Seebeck, 1968). Because no significant effect of fat weight on either muscle or bone weight was found, muscle plus bone weight, rather than the carcass weight, was used as the independent variate to study the rate of growth of the main tissues of the carcass (Everitt, 1966; Berg, 1968).

Where the regression coefficient were homogenous between frame size, amounts of specific fat depots ($Y_{adj.}$) for each frame size were adjusted to a common mean value with the equation: $\log Y_{adj.} = \log Y_i - b (\log x_i - \log \bar{x})$, where Y_i is the observed amount of a specific fat depot, b is a common regression coefficient for frame size, x_i is the observed total amount of dissectible fat in one type of steer and $\bar{x}$ is the average total amount of dissectible fat for both frame sizes of cattle. The antilogarithm values of the adjusted means were reported.

Results

The distribution and patterns for adipose growth among depots in cattle representing two frame sizes are reported in this study. Steers of both frame sizes grew at a similar rate from 11 to 19 mo of age (table 1). Regression coefficients of slaughter weight on age were not significantly different between the two frame sizes (1.22 and 1.18 kg/d for smaller and larger frame sizes, respectively).

Carcasses of smaller steers contained approximately 3% more fat than did those of the larger steers when all slaughter groups were pooled, but the difference in fat content was not statistically significant (table 2). Both types of steers were slaughtered at a similar age (465 vs 468 d), therefore smaller frame-size steers deposited fat at an earlier age. The carcasses from the smaller frame-size group had significantly less bone.

TABLE 2. CARCASS CHARACTERISTICS AND GROWTH COEFFICIENTS RELATING WEIGHT OF MUSCLE AND FAT TO WEIGHT OF MUSCLE + BONE (LEFT SIDE OF CARCASS) FOR TWO FRAME SIZES OF STEERS

	Item						
		% of carcass weight[a]			Growth coefficients[b]		
Frame size	Hot carcass weight, kg[a]	Lean	Fat	Bone	Muscle	Fat	Bone + C[c]
Smaller	284 ± 4.2	55.9 ± .8	29.0 ± 1.0	13.7 ± .3	1.02 ± .02	2.09 ± .30[d]	.90 ± .07
Larger	334 ± 4.2[e]	57.4 ± .8	26.1 ± 1.0	16.2 ± .3[e]	1.11 ± .03[d]	2.82 ± .50[d]	.61 ± .11[de]

[a]All values are means ± SE for 20 steers of specified frame size.

[b]All values are slopes of the regression of logarithm of specific tissue weight against logarithm of muscle + bone weight ± SE for 20 steers of specified size.

[c]Connective tissue.

[d]Values are different from one ($P<.01$).

[e]Values for larger frame steers are different from those for smaller frame steers ($P<.05$).

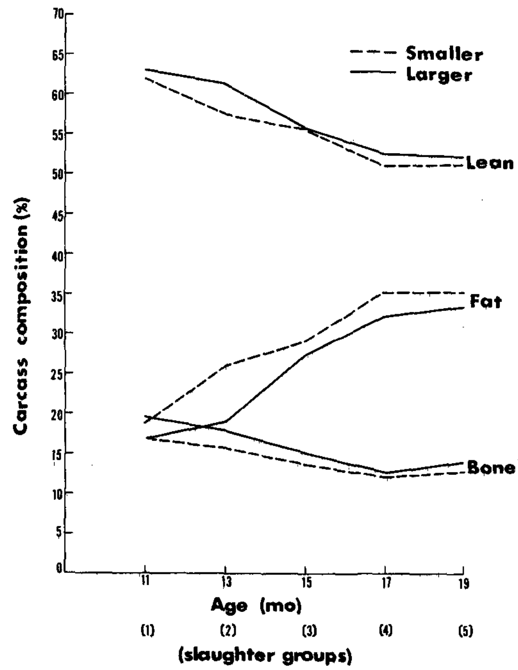

Figure 1. Changes in carcass composition with age in steers of two frame sizes.

Growth coefficients for skeletal muscle and for fat of carcasses of smaller and larger cattle were similar. These two comparisons demonstrate no significant differences in the rate of fattening between the smaller and larger cattle when compared from 11 to 19 mo of age (table 2). Variation in the age of onset of fattening, however, was suggested when the percentages of carcass tissues were plotted against age at slaughter (figure 1). Smaller type steers experienced an earlier but nonsignificant increase in rate of fat deposition from 11 to 13 mo of age (figure 1).

The unadjusted contribution of each dissectible fat depot to total fat in the body did not differ between the two frame sizes (table 3). Fat in the carcass contributed approximately 80% of the total while the remaining 20% came from fat around the stomach and intestines. Visceral fats (omental + mesenteric + kidney) plus pelvic fat accounted for 30% of the total dissectible adipose tissue in the body.

There were no differences in the rate of deposition of each fat depot with respect to total fat between frame sizes of cattle. Within the large frame-size group, however, subcutaneous fat made a greater contribution to adiposity

TABLE 3. CONTRIBUTION OF DISSECTIBLE FAT DEPOTS AND GROWTH COEFFICIENTS OF FAT DEPOT WIH RESPECT TO TOTAL FAT CONTENT OF STEERS OF TWO FRAME SIZES

Fat depot	Percentage contribution to total body fat[a]		Adjusted contribution (kg)[b]		Growth coefficient[a,c]	
	Frame size		Frame size		Frame size	
	Smaller	Larger	Smaller	Larger	Smaller	Larger
Subcutaneous	27.7 ± .7	26.0 ± .7	26.33	24.42[d]	1.07 ± .04	1.18 ± .05[e]
Intermuscular	42.9 ± .5	43.7 ± .5	40.78	41.57	.98 ± .02	.98 ± .02
Kidney	8.4 ± .3	9.4 ± .3	7.93	8.83[d]	1.13 ± .07	.93 ± .06
Pelvic	1.2 ± .1	1.3 ± .1	1.11	1.17	.52 ± .10[e]	.58 ± .11[e]
Omental	10.8 ± .4	11.3 ± .4	10.19	10.56	.93 ± .07	.92 ± .07
Mesenteric	8.8 ± .3	8.3 ± .3	8.23	7.82	.85 ± .09	.80 ± .07[e]

[a]Values are means ± SE for 20 steers of specified size.

[b]Values are mean for each depot, as kg, adjusted for total fat in body (95.19 kg; average for both frame sizes). Adjustment of fat contributions was performed as described in text.

[c]Values are slopes of the regression of logarithm of specific tissue weight against logarithm of total fat weight ± SE for 20 steers.

[d]Values for larger frame steers are different from those for smaller frame steers (P<.05).

[e]Values are different from one (P<.05).

in steers as weight increased than did the other depots (table 3). A steady increase in subcutaneous fat content during growth from 11 to 17 mo of age was observed with respect to total dissectible fat in the larger steers (figure 2). This figure also indicates that smaller steers had a greater percentage of subcutaneous fat that remained relatively constant during the growth periods. Therefore, the increased contribution of subcutaneous fat to total fat in the larger steers could reflect differences in time of onset of fattening between the two frame sizes of cattle. With the exception of pelvic fat, all fat depots increased at the same rate as total fat in the smaller type steers. In the larger steers, the growth rate of pelvic and mesenteric fat depots decreased as fattening proceeded (table 3). Smaller steers had greater amounts of subcutaneous fat, less kidney fat and more thickness of fat at the 12-13th ribs (.99 vs .68 cm) than did the larger steers when values were adjusted to the overall mean of total dissectible fat in the body (table 3).

Intramuscular Fat. Intramuscular lipid of the left side of the carcass increased at a rate similar to that of total lipid in both frame sizes (table 4). There were no significant differences between frame sizes in the growth coefficients of lipid content for the fat depots studied except for the growth coefficients of kidney and pelvic fats. The lipid portion of the subcutan-

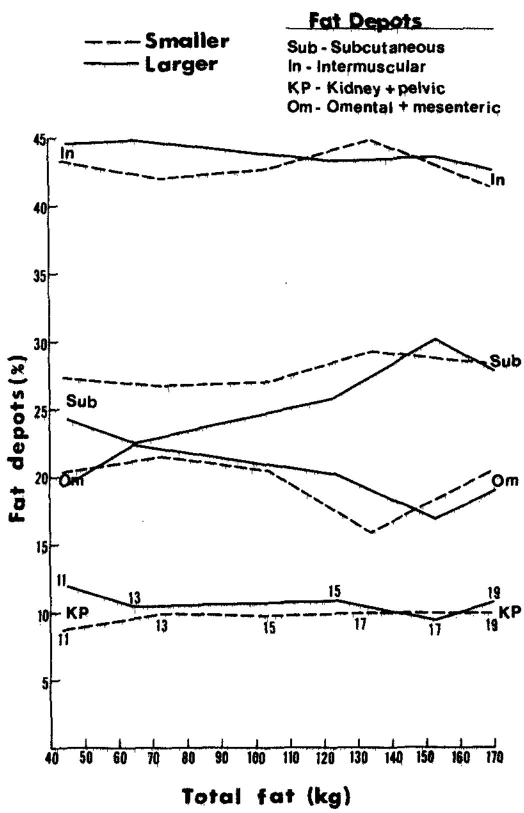

Figure 2. Contribution of dissectible fat depots to total fat in the body in steers of two frame sizes (numbers associated with KP data indicate months of age at slaughter).

TABLE 4. GROWTH COEFFICIENTS RELATING LIPID CONTENT OF FAT DEPOT TO TOTAL LIPID (LEFT SIDE) AND ADJUSTED MEANS OF LIPID CONTENT OF FOUR DEPOTS IN STEERS OF TWO FRAME SIZES

	Growth coefficients[a]		Adjusted lipid contents (kg)[b]	
	Frame size		Frame size	
Fat depot	Smaller	Larger	Smaller	Larger
Subcutaneous	1.07 ± .04	1.19 ± .04[c]	11.00	9.91[d]
Intermuscular	.96 ± .02[c]	.93 ± .01[c]	17.97	18.37
Intramuscular	.97 ± .09	1.10 ± .08	3.31	3.39
Kidney + Pelvic	1.02 ± .07	.81 ± .05[cd]	4.18[e]	4.65

[a]All values are slopes of the regression of logarithm of lipid content of specific depot on logarithm of total lipid content ± SE for 20 steers of specified size.

[b]All values are means, in kg, for each depot adjusted for total lipid content (left side; 36.66 kg, average of both frame sizes). Adjustment of fat contributions was performed as described in text.

[c]Values are different from one (P<.05).

[d]Values for larger frame steers are different from those for smaller frame steers (P<.05).

[e]Not analyzed statistically (regression coefficients within size were different, P<.05).

eous fat increased faster than did total lipid in the larger steers (table 4), which agrees with data for dissectible adipose tissue. This increase started at 13 mo of age (figure 3). The contribution of intermuscular lipid to total lipid decreased during growth, which suggests an earlier maturation of this fat depot in both types of steers. These results do not indicate that intramuscular lipid was the last type of lipid to be deposited, because growth coefficients were not significantly greater than one (table 4). Therefore, the percentage of intramuscular fat with respect to the total lipid in the left side remained approximately the same throughout the age range included in this study (figure 3).

The mean lipid content for each major fat depot was adjusted to the overall mean of lipid from the left side of the carcass (table 4). Adjusted accordingly, the subcutaneous fat depot from the smaller steers contained significantly more lipid than did the subcutaneous depots from the larger steers. No differences in lipid contents of the other three major fat depots were observed between the two sizes of cattle. Therefore, as also suggested in figure 2, some differences between smaller and larger cattle in the distribution of lipid among depots occur as the cattle fatten.

Simple correlation coefficients between fat thickness at the 12th rib and the amount of dissectible fat in the specific depots (table 5) were, in general, higher for the larger steers.

Discussion

At present, beef production is based mostly on crossbred animals where rapid growth and beneficial carcass characteristics of cattle of

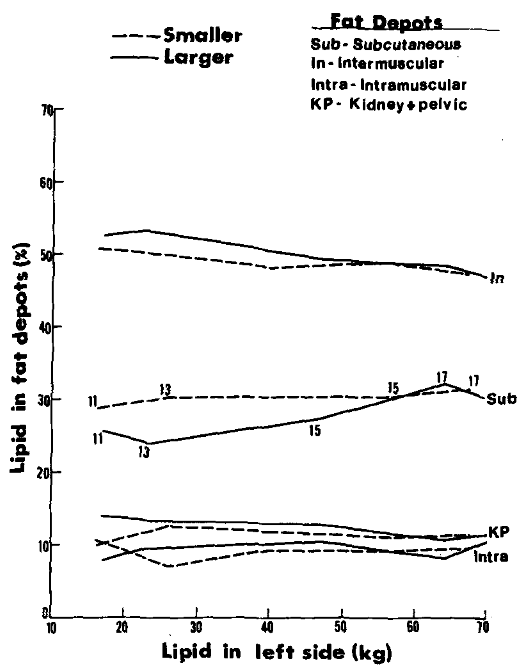

Figure 3. Contribution of fat depot lipids to total lipid in the left side of the carcass in steers of two frame sizes (numbers associated with Sub data indicate months of age at slaughter).

TABLE 5. SIMPLE CORRELATION COEFFICIENTS[a] BETWEEN THE AMOUNT OF FAT DEPOSITED IN THE DEPOTS IN THE BODY AND FAT THICKNESS AT THE 12TH RIB IN STEERS OF TWO FRAME SIZES

	Frame size		
Fat depots (kg)	Smaller	Larger	Pooled
Total fat	.76	.90	.82
Subcutaneous	.80	.95	.88
Intermuscular	.76	.88	.81
Kidney	.72	.72	.67
Pelvic	.30	.59	.46
Omental	.63	.77	.67
Mesenteric	.54	.72	.62
Marbling score	.63	.81	.74

[a]All coefficients are different from zero (P<.05).

the large frame-size breeds are exploited. In the research reported here, the expression "frame size" is used for animals with differences in live weight at a certain age (180 d) and raised under the same environmental conditions. Frame size, as a term, attempts to include the incompleteness of our knowledge of the interaction between genotypic, environmental and metabolic traits of cattle as they influence differences in growth rate and body composition.

The steers of the two frame sizes used in this study showed no differences in the rate of growth from 11 to 19 mo. This indicates that the differences observed in live weights between the types were set at an earlier age of the animals (before 180 d). It also may suggest that the criteria used to characterize the steers by type were not sensitive enough or that the growth period (11 to 19 mo) was not great enough to detect growth rate differences.

The factors associated with the differences in fat accretion among animals of varying genetic backgrounds could be explained by variation in the rate of fattening, age at the onset of fattening or both (Mukhoty and Berg, 1971). Furthermore, variations in fat distribution among depots have economic implications (Allen, 1969) and may affect predictability of carcass composition (Charles and Johnson, 1976). Results from this study suggested that steers of both frame sizes followed a similar pattern of fat deposition even when some differences in fat distribution were detected.

In this regard, Mukhoty and Berg (1971) and Charles and Johnson (1976) reported breed differences in the rate of fat deposition, but Berg et al. (1978) reported homogeneous allometric regression coefficients for fat deposition among sire breed groups classified as late fattening.

The increased contribution of subcutaneous fat to total adiposity in the larger steers is intriguing (table 3). It could either reflect true differences in fat distribution between frame sizes or could result from variation in the age of onset of fattening. Because the overall contribution of each fat depot to total adiposity was similar for both sizes of cattle (table 3), the increased growth rate of subcutaneous fat was probably more related to differences in the age at onset of fat deposition. This study could not test this hypothesis.

Intermuscular fat was not an early developing tissue, and, therefore, its contribution to total fat did not decrease as fattening progressed for the cattle used in this study (table 3). Other investigators who quantified growth of different fat depots in steers (Kemster et al., 1976) and in bulls (Berg et al., 1978), however, observed that the ratio of amounts of intermuscular fat to subcutaneous fat decreased as fattening progressed. The discrepancies may be explained by differences in cattle used, age of the animals and by the inclusion of omental and mesenteric fat depots in our study. In this regard, we found homogeneous growth coefficients for intermuscular fat between frame sizes of cattle (table 3), but they were significantly smaller than the absolute value of one within a type when total lipid in the left side was considered as the independent variable (table 4).

Kidney and omental fats increased at the same rate as total fat in the body. Therefore, they should not be considered as earlier developing tissues among fat depots. Because of their rate of growth, and because they contribute up to 30% of the total fat, visceral fats (omental, mesenteric and kidney) should be considered in any attempt to reduce the amount of excess fat deposited in cattle and to increase efficiency of beef production.

On the basis of cattle used in this study, there was no indication that intramuscular lipid was late developing. The differential growth coefficients between solvent-extractable intramuscular fat, which included structural as well as storage lipids, and total lipid in the left side of the carcass were homogeneous between frame sizes of cattle and not significantly different from one within sizes (table 4). Johnson et al. (1972) also reported that intramuscular fat did not rise with fattening and that it reached its maximum as a percentage of total fat very early postnatally. Because of the age range of the steers used in this study, we were unable to determine the weight or age at which the maximum contribution of intramuscular fat occurred, but there was no change in that contribution from 11 to 19 mo of age.

These findings for intramuscular lipid can be extrapolated to the marbling content because of the high and positive association between the two (Thornton et al., 1974). We found a simple correlation coefficient between the amount of lipid in the muscle of the half carcass and marbling score at the 12th rib of .85 ($P<.01$). Because intramuscular fat was not a late developing tissue, a simple measurement of this characteristic at an early age could be used to predict the potential for an animal to deposit marbling in later growth phases.

Fat thickness at the 12th to 13th ribs currently is used as an index of fat deposition because of its high positive association with the total fat in the carcass (Hedrick, 1968). In this study of exotic breeds, the pooled simple correlation coefficients indicated that fat thickness accounted for 67% of the variation in total separable fat in the body (table 5). It is clear from these coefficients that fat thickness is a better estimator of subcutaneous fat content than of other fat depots. This measurement accounted for 55% of the variation in marbling score of the M. longissimus at the 12th rib and for less than 45% of the variation in visceral fat content. Lower subcutaneous fat thickness, therefore, does not necessarily predict reduced marbling or lesser amounts of visceral fat.

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