BETWEEN-BREED DIFFERENCES OF CARCASS COMPOSITION IN CATTLE

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Summary

The validity of the hypothesis that between-breed differences of carcass composition in cattle can be reduced when compared at the same degree of maturity was assessed using carcass data of various breeds obtained from slaughter experiments in Denmark, Japan and Malaysia. All cattle were kept in intensive feeding conditions in this study. With respect to temperate data (Danish and Japanese data), although large between-breed differences were found in carcass composition in the comparison at the same slaughter weight, the differences were reduced when compared at the same degree of maturity. This result supported the above hypothesis. Kedah-Kelantan and their crosses in Malaysian data, however, had more muscle and bone contents but less fat content than temperate breeds, even if compared at the same degree of maturity. This could be attributed to the history that native Kedah-Kelantan breed has adapted itself in the direction of decreasing fat deposition which requires much energy and prevents heat evaporation, in order to survive under high temperature and high humidity conditions in Malaysia. In spite of the same tropical breed, carcass composition of Sahiwal Friesian was similar to that of other temperate breeds at the same degree of maturity.

(Key Words: Between-Breed Difference, Cattle, Carcass Composition)

Introduction

At present, a great variety of cattle breeds are utilized for beef production in their suitable environment all over the world. Nevertheless, the details of their beef characteristics and performance are seldom known except for some breeds kept in the temperate zone.

Many experiments have been conducted in Western countries in order to investigate the between-breed difference in carcass composition of cattle (Mukhoty and Berg 1971; Berg et al., 1978). However, most of such works were evaluated on the basis of similar age or weight group, and the results obtained thus include the confounding effects of the difference in genetic size and physiological age.

Taylor (1985) has proposed a hypothesis that between-breed variations for the growth traits can be reduced by comparing them at a constant degree of maturity. According to the hypothesis, carcass composition in cattle is similar at the same degree of maturity and thereby carcass composition of the breed whose data are not available may be extrapolated.

The purpose of this study is to assess the validity and application of Taylor's hypothesis using carcass data of various breeds collected in intensive confinement feeding conditions from Denmark, Japan and Malaysia.

Materials and Methods

Data for this study were obtained from various slaughter experiments which were conducted in Denmark (Liboriussen et al., 1982), Japan (Namikawa, unpublished) and Malaysia (Dahlan, 1986). The breeds using in the individual data sources are shown in table 1. All cattle were managed in intensive feeding conditions.

1. Danish data

The experiments were carried out in the periods from 1972 to 1980 and consisted of two series. Semen from total fifteen breeds were used to inseminate randomly Red Danish and Danish Black

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Received June 27, 1989
Accepted October 4, 1989

Pied cows. Their cross-bred bull calves were reared in an intensive confinement and were slaughtered at four different stages (300 kg, 12 months, 15 months and 18 months of age) in experiment I and at three different stages (320 kg, 440 kg and 560 kg) in experiments II. Detail descriptions of this data are given in Anderson et al. (1976) and Berg et al. (1978).

The published average values of breeds at each slaughter stage shown by Liboriussen et al. (1982) were adopted as Danish data in this study.

2. Japanese data

Carcass data for 35 Japanese Black steers and 22 Holstein steers were collected from the experiments conducted in Hiroshima University, Kobe University and Hyogo National Livestock Experimental Farm. These breeds were offered high concentrate diets under Japanese intensive feeding trials. All Japanese Black steers were slaughtered within the weight range from about 400 kg to 600 kg and Holstein steers were slaughtered serially.

3. Malaysian data

Carcass data for 11 native Kedah-Kelantan (KK) bulls, their crosses (5 Hereford x KK bulls and 11 Brahman x KK bulls) and 12 Sahiwal-Freiesian bulls were used. All bull calves were offered concentrate and by-product diets (palm kernel cake, pineapple waste, cocoa pod and so on) under the intensive confinement and they were slaughtered within the range of fattening period from 12 months to 15 months.

The dissection procedure varies with data sources; kidney knob and channel fat were excluded from carcass in Danish data, whereas they were included in carcass in Japanese and Malaysian data. Accordingly, we adjusted carcass composition in the Danish data by assuming that the ratio of kidney knob and channel fat to the total fat be 10% (Berg and Butterfield, 1976).

Carcass composition of the breeds obtained from the three sets of data sources were compared at the same constant slaughter weight and the same degree of maturity. In this study, the degree of maturity at time t (u_t) was defined as the ratio of slaughter weight at time t (W_t) to mature weight (W_A):

$$u_t = W_t / W_A \qquad (1)$$

As shown in equation (1), mature weight must be known in order to estimate degree of maturity. However, it is generally difficult to define the mature weight for a specific breed, because mature weight is affected by nutrient level and other environmental effects. Taylor and Murray (1987) reported that the between-breed relationship of birth weight (W_B) and mature cow weight (W_A) in cattle based on the published data is represented as:

$$W_B = 0.197\, W_A^{0.83} \qquad (2)$$

By transposing equation (2), mature cow weight could be estimated from:

TABLE 1. THE BREEDS USED IN THREE DATA SOURCES AND THEIR BIRTH WEIGHTS AND ESTIMATED MATURE WEIGHTS

Breed	Birth weight* (kg)	Estimated mature weight (kg)
1. Danish data (b)**		
Simmental x	41.7	952
Charolais x	45.0	1,043
DRK x	39.8	900
Romagnola x	43.6	1,163
Chianina x	42.9	1,139
Hereford x	36.2	920
Bl. d'Aqui x	41.3	941
Limousine x	38.7	870
Angus x	34.1	747
Tysk Gulkvaas x	41.5	947
Piemontese x	42.2	966
South Devon x	40.2	911
Sw. Brunkvaas x	42.9	985
Red belgisk x	48.6	1,145
Balhvidt belgisk x	44.8	1,038
2. Japanese data (s)		
Japanese Black	30.0	533
Holstein	40.0	750
3. Malaysian data (b)		
Kedah-Kelatan (kk)	15.4	287
Brahman x KK	20.2	397
Hereford x KK	20.1	395
Sahiwal-Friesian	23.0	465

*Literature: Danish data (Liboriussen et al., 1982), Japanese data (ordinary values), Malaysian data (Dahlan, pers. comm.)

**Sex b; bull, s; steer

$$W_A = (W_B / 0.197)^{1.205} \quad (3)$$

The mature weights for bull and steer were estimated by multiplying 1.5 and 1.25 by the mature cow weights, respectively. It is suggested that these estimated mature weights may represent the genetic body size of each breed; it can be regarded as body weights of animals which grew normally on a standard diet, in a thermo-neutral, disease-free environment. In an intensive confinement, animals may thus grow beyond these estimated mature weights. Table 1 shows the literature values of birth weight and the estimated mature weights for each breed exploited in this study.

The following two multiple regression models were used:

$$y_i = b_0 + b_1 W_t + b_2 W_t^2 \quad (4)$$
$$y_i = b_0 + b_1 u_t + b_2 u_t^2 \quad (5)$$

where y_i is carcass composition which was defined as the proportion of dissected muscle tissue weight (i=1), fat tissue weight (i=2) and bone tissue weight (i=3) to carcass weight,
W_t is the slaughter weight at time t,
u_t is the degree of maturity at time t. Regression coefficients were calculated from Japanese and Malaysian data which included all observations and from Danish data which only included average values of each breed.

All statistic analysis were carried out using the procedure for regression analysis (REG) in Statistic Analysis System (SAS, 1985).

Results

Figure 1 represents the relationship between carcass composition and the slaughter weight of each breed in Danish and Japanese data. In the breed comparison of carcass composition based on the slaughter weight, European cross-bred bulls in Danish data had generally more muscle and less fat contents, compared with Holstein and Japanese Black steers in Japanese data. Bone content of European cross-bred bulls was almost equal to that of Holstein steers, but Japanese Black had obviously less bone content than the other breeds.

Figure 2 represents the relationship between carcass composition and the degree of maturity.

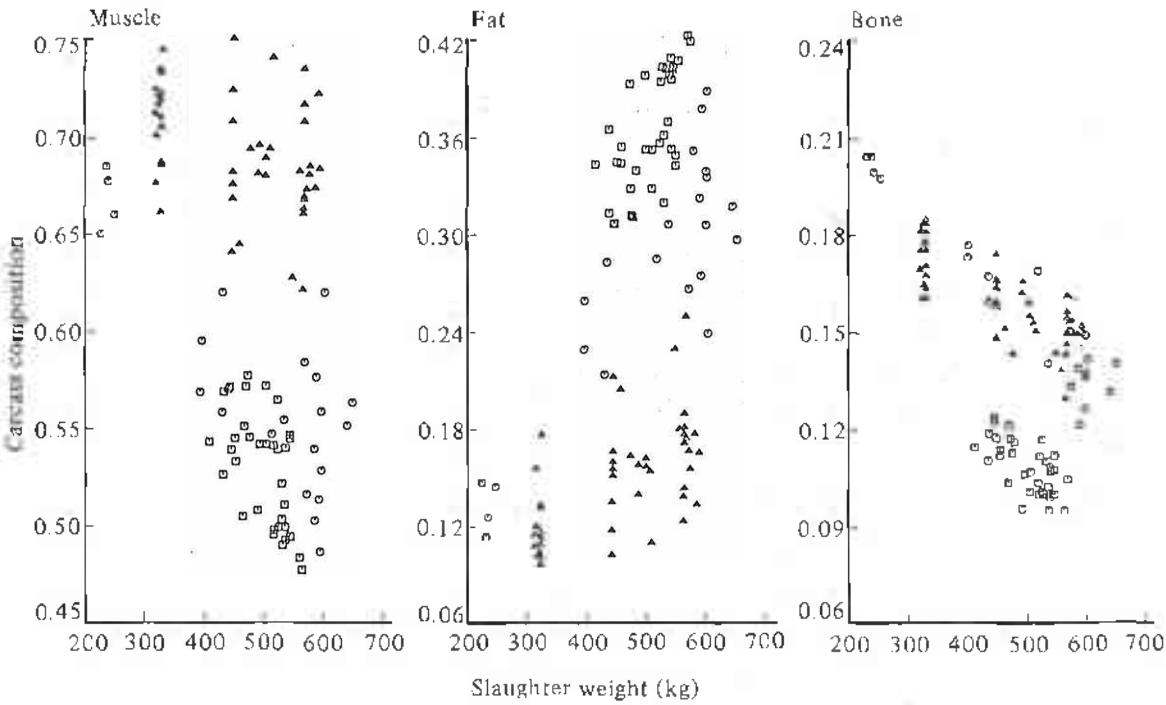

Figure 1. The relationship between carcass composition and slaughter weights of various breeds in Danish and Japanese data.
△ Danish breeds, ○ Holstein, □ Japanese Black

When comparison was made based on the degree of maturity, Holstein steers in Japanese data had slightly less muscle and more bone content than the other breeds. However, it is indicated that between-breed variations for all carcass tissue contents could be reduced when compared at the same degree of maturity.

Table 2 shows the quadratic regression coefficients of the slaughter weight or the degree of maturity on carcass composition. In all cases, R^2 values in the comparison based on the degree of maturity were higher, when compared at the same slaughter weight. In particular, the tendency was obvious in temperate data which both Danish and Japanese data were pooled: namely, in the comparison at the same slaughter weight, R^2 values of muscle, fat and bone contents were 0.20, 0.28 and 0.46, respectively, but the low R^2 values increased remarkably to 0.79, 0.88 and 0.86, respectively, when the degree of maturity was used as an independent variable.

The relationship between carcass composition and the degree of maturity in overall data is given in figure 3. When compared at the same degree of maturity, Kedah-Kelantan and their crosses (HK and BK) in Malaysian data had more muscle and bone contents but less fat content than temperate breeds. In spite of the same tropical breed, however, carcass composition of Sahiwal-Friesian breed was comparable to temperate breeds.

The results of regression analysis for overall data are also shown in table 2. Comparison at the same degree of maturity provided higher R^2 values of muscle and fat content but lower one of bone content than that at the same slaughter weight did. Nevertheless, when compared with analysis of

TABLE 2. PARTIAL REGRESSION COEFFICIENTS OF SLAUGHTER WEIGHT AND DEGREE OF MATURITY ON CARCASS COMPOSITION

Carcass tissue	Slaughter weight basis				Degree of maturity basis			
	b_0	b_1	b_2	R^2	b_0	b_1	b_2	R^2
(1) Danish data (48 observations)								
Muscle	8.259E-1	−5.133E-4	4.572E-7	0.162	7.026E-1	1.165E-1	2.743E-1	0.354
Fat	5.240E-2	7.255E-4	5.913E-7	0.377	9.720E-2	−3.638E-2	2.849E-1	0.645
Bone	2.265E-1	−2.122E-4	1.341E-7	0.602	2.002E-1	−8.015E-2	−1.064E-2	0.732
(2) Japanese data (57 observations)								
Muscle	9.451E-1	−1.492E-3	1.339E-6	0.591	7.615E-1	−3.648E-1	1.162E-1	0.655
Fat	−3.680E-1	2.706E-3	−2.542E-6	0.651	−1.340E-2	5.270E-1	1.245E-1	0.812
Bone	4.299E-1	−1.215E-3	1.203E-6	0.609	2.519E-1	1.622E-1	8.262E-3	0.878
(3) Malaysian data (39 observations)								
Muscle	8.994E-1	1.647E-3	2.308E-6	0.048	1.339E-1	1.066	−5.491E-1	0.368
Fat	−1.849E-1	2.131E-3	−3.045E-6	0.056	0.717E-1	−1.177	6.008E-1	0.388
Bone	1.733E-1	4.451E-5	−1.225E-7	0.014	4.837E-2	3.146E-1	-0.188E-1	0.070
(3) Temperate data (105 observations)*								
Muscle	9.364E-1	1.089E-3	8.212E-7	0.216	7.590E-1	−9.147E-2	−1.794E-1	0.791
Fat	3.222E-1	2.065E-3	−1.752E-6	0.290	3.666E-2	1.610E-1	2.151E-1	0.884
Bone	3.858E-1	−9.758E-4	9.308E-7	0.466	2.044E-1	−6.952E-2	−3.560E-2	0.866
(4) Overall data (144 observations)**								
Muscle	7.209E-1	−2.776E-4	6.571E-8	0.117	8.701E-1	−5.655E-1	2.591E-1	0.444
Fat	8.400E-2	1.025E-3	−6.605E-7	0.298	−8.553E-2	6.980E-1	−3.282E-1	0.352
Bone	3.051E-1	−5.879E-4	4.961E-7	0.468	2.160E-1	−1.312E-1	4.916E-2	0.241

*Danish data plus Japanese data
**Temperate data plus Malaysian data

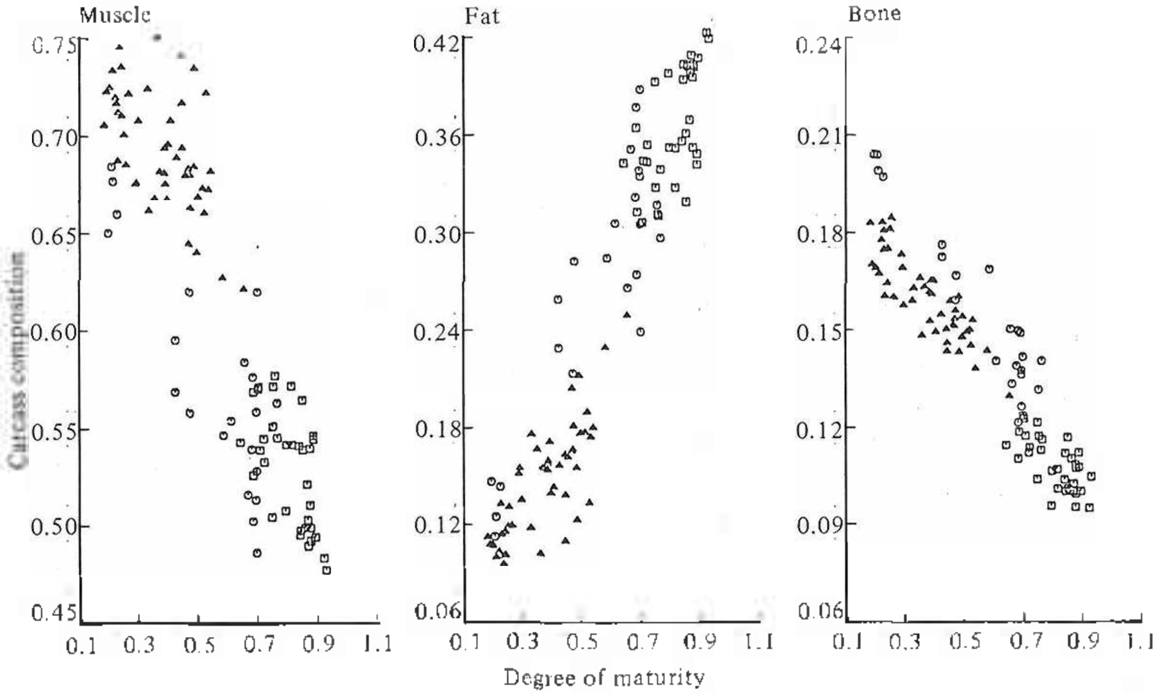

Figure 2. The relationship between carcass composition and degree of maturities of various breeds in Danish and Japanese data. Symbols of representing each breed are same as those in figure 1.

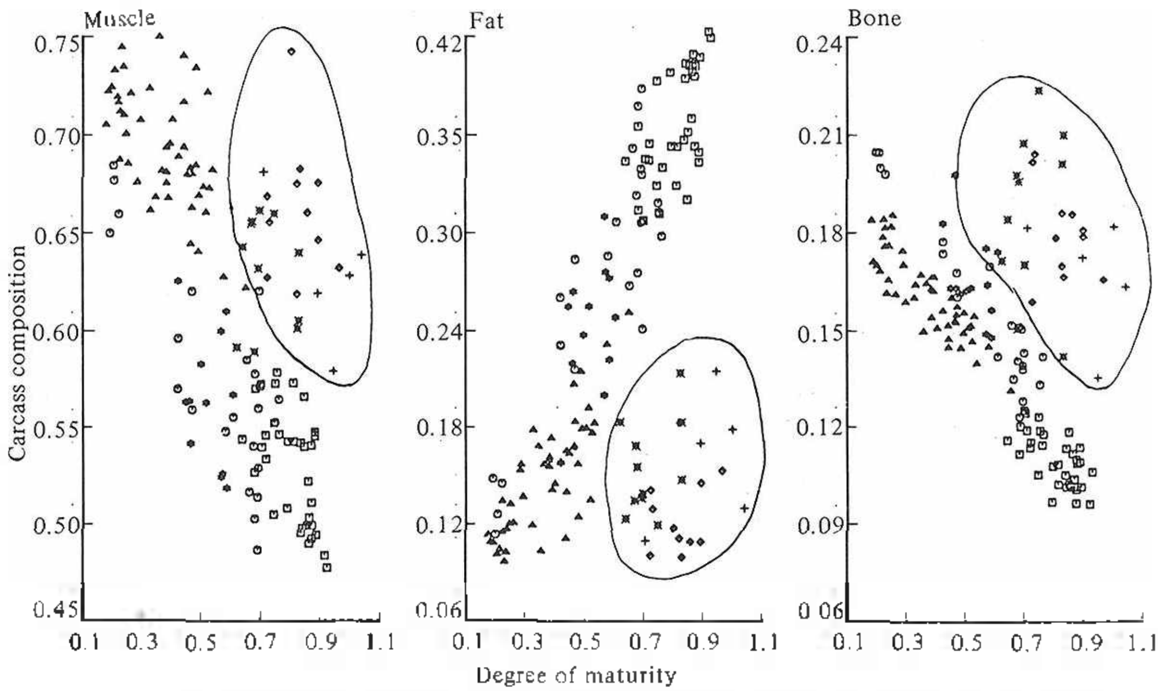

Figure 3. The relationship between carcass composition and degree of maturities of various breeds in all data. Encircled values represent Kedah-Kelantan and their crosses.
◇ Kedah-Kelantan, * BK, + HK, ☆ Sahiwal Friesian. Other symbols of representing each breed are the same as those in figure 1.

temperate data, all the R^2 values of carcass tissue contents in analysis of overall data were considerably lower, even if comparisons were made at the same degree of maturity.

Discussion

It has been generally known that the genetically larger breed and/or male animals had more muscle and bone content but less fat content than the smaller breed and/or female animals (Berg and Butterfield, 1976; Butterfield et al., 1983). However, this may be caused by the fact that larger size and/or male animals are less mature and physiologically younger than smaller and/or female animals, when such comparisons were made at the same weight and age basis. Therefore, comparison of carcass composition for different breeds at the same degree of maturity appears to be adequate, because the effects of genetic size and physiological age may be adjusted by adopting this criterion.

Unfortunately, there were limited studies that carcass composition was compared after adjusting the effects of genetic size and physiological age of animals. McClelland and Russel (1972) suggested that fat content for sheep breeds might be constant relative to the degree of maturity, and subsequently McClelland et al. (1976) reported that most of breed and sex differences disappeared when compared at the same degree of maturity. More recently, Butterfield et al. (1983) and Thompson et al. (1985) showed that differences between strains of Australian Merino sheep for carcass composition could be reduced by comparing at the constant degree of maturity.

With respect to cattle, Barber et al. (1981) compared empty body composition of Charolais and Angus steers at equal percentage of breed average mature cow weight. Their results showed that no between-breed difference in empty body composition was detected at the light and heavy slaughter groups (80 and 114% of breed average mature cow weight), but Angus had higher fat and lower protein than Charolais at the middle slaughter group (100% of breed average mature cow weight). Using the same data as Danish data in this study, Korver et al. (1987) reported an opposite result that between-breed differences in carcass composition still existed after adjusting for degree of maturity. This may be attributed by the fact that the effect of different genetic size can not be adjusted properly, because of their simple classification of mature weights; i.e. small (850 kg), medium (1000 kg) and large (1500 kg).

The results obtained from a comparison of Malaysian breeds with the other breeds showed that Kedah-Kelantan and their crosses had more muscle and bone contents but less fat content than temperatre breeds even if compared at the same degree of maturity (figure 3). This may be resulted from the fact that native Kedah-Kelantan breed has adapted itself in the direction of decreasing fat deposition which requires much energy and prevents heat evaporation, in order to survive under high temperature and high humidity condition in Malaysia.

Nevertheless, carcass composition of Sahiwal-Friesian was similar to that of temperate breeds when compared at the same degree of maturity. This may be caused by the fact that Sahiwal breed was originated in the West part of India and thus fat deposit of the animal appears to be permitted to some degree owing to adaptation under dry condition despite the same hot condition.

Above results suggest that if mature weight and degree of maturity are adequately defined, then carcass composition of unknown breed may be estimated irrespective to between-breed differences by using the inter-breed regression relationships (table 2), as far as temperate breeds are concerned. Nevertheless, it is also found that this hypothesis might not hold true when applied to some tropical breeds (figure 3).

Many general models for simulating growth of cattle were constructed under the assumption of equal body composition at the same degree of maturity (Notter et al., 1979; Oltjen et al., 1985). Also, Hirooka and Yamada (1985) developed a general model for simulating cattle growth and production, based on the assumption that the proportion of energy for fat and protein deposits to total retained energy was expressed by the function of the degree of maturity. However, the results from the present study indicated that more attention should be paid when such a model is applied to tropical breeds.

In addition, there are some limitations in this study. First, the differences in nutrient levels, dissection procedures and personal dissected skills were not taken into consideration, although the significance of these effects was recognized in each data set (Anderson et al., 1975; Dahlan et al., 1988). Secondly, breeds used were limited in those kept in Denmark, Japan and Malysia and therefore it appears impossible to draw general conclusions for between breed differences of carcass composition in cattle. Thirdly, sex of animals varied with data sources (i.e. steers in Japanese data and bulls in Danish and Malaysia data), so that it was tacitly assumed that sex differences could be also adjusted by comparing at the same degree of maturity. For these reasons, it is suggested that more accurate and precise data, which were collected by the same research group and had many more breeds from various areas, would be required to overcome above limitations and obtain a better understanding for between-breed differences of carcass composition in cattle.

Acknowledgement

We are indebated to Dr. K. Namikawa, who generously made his unpublished data (Japanese data) to us, and to Dr. T. Yoshimura, who prepared the data.

Literature Cited

Anderson, B. B., *T. Liboriussen, I. Thysen*, K. Kousgaard and L. Buchter. 1976. Crossbreeding experiment with beef and dual-purpose sire breeds on Danish dairy cows. Livestock prod. Sci. 3:227.

Barber, K. A., L. L. Wilson, J. H. Ziegler, P. J. Levan and J. L. Watkins. 1981. Charolais and Angus steers slaughtered at equal percentages of mature cow weights. II. Empty body composition, energetic efficiency and comparison of compositionally similar body weights. J. Anim. Sci. 53:898.

Berg, R. T., B. B. Anderson and T. Liboriussen. 1978. Growth of bovine tissue. 1. Genetic influences on growth pattern of muscle, fat and bone in young bulls. Anim. Prod. 26:245.

Berg, R. T. and R. M. Butterfield. 1976. New concepts of cattle growth. University of Sydney Press, Sydney.

Butterfield, R. M., D. A. Griffiths, J. M. Thompson, J. *Zamora and A. M. James. 1983. Changes in body* composition relative to weight and maturity in large and small strains of Austrian Merino rams. 1. Muscle, bone and fat. Anim. Prod. 36:29.

Dahlan, I. 1986. Performances of Kedah-Kelantan cattle and its crosses on ration containing sago pith, coffee pulp and palm kernel cake reared under smallholder's condition. In: Livestock Production and Disease in the Tropics. Proc. International Conf. on Livestock Production and Disease. Kuala Lumpur. pp. 91.

Dahlan, I., I. Sukri and O. Abu Hassan. 1988. Carcass characteristics of four types of cattle fed on agricultural by-products diets. In: Proc. VI World Conference on Animal Production. Helsinki, July 1988. pp. 697.

Hirooka, H. and Y. Yamada. 1985. A systems analysis of beef cattle growth and production. I. Model. (in Japanese) Jpn. J. Zootech. Sci. 56:557.

Korver, S., W. M. Tess, T. Johnson and B. B. Anderson. 1987. Size-scaled lean and fat growth patterns of serially slaughtered beef animals. J. Anim. Sci. 64: 1292.

Liboriussen, T., F. Lauritzen, B. B. Anderson, L. Buchter, S. E. Sorensen, S. Klastrup and K. Kousengaard. 1982. Crossbreeding and production experiments with European meat breeds. I and II. No. 527. Beretning fra Statens Husdyrbrugs forsog. Copenhagen.

McClelland, T. H. and A. J. F. Russel. 1972. The distribution of body fat in Scottish Blackface and Finnish Landrace lambs. Anim. Prod. 15:301.

McClelland, T. H., B. Bonaiti and St C. S. Taylor. 1976. Breed differences in body composition of equally mature sheep. Anim. Prod. 23:281.

Mukhoty, H. and R. T. Berg. 1971. Influence of breed and sex on the allometric growth patterns of major bovine tissues. Anim. Prod. 13:219.

Notter, D. R., *J. O. Sanders, G. E. Dickerson, G. M.* Smith and T. C. Cartwright. 1979. Simulated efficiency of beef production for a Mid-west cow-calf feedlot management system. II. Mature body size. J. Anim. Sci. 49:83.

Oltjen, J. W., A. C. Bywater and R. C. Baldwin. 1985. Development of a dynamic model of beef cattle growth and composition. J. Anim. Sci. 62:86.

SAS Institute. 1985. SAS User's Guide: Statistic, Version *5 Edition. SAS Institute Inc., North California.*

Taylor, st. C. S. 1985. Use of genetic size scaling in evaluation of animal growth. J. Anim. Sci. 61:suppl. 2, 118.

Taylor, st. C. S. and J. Murray. 1987. Inter-breed relationships of birth weight and maternal and paternal weight in cattle. Anim. Prod. 44:55.

Thompson, J. M., R. M. Butterfield and D. Perry. 1985. Food intake, growth and body composition in *Australian merino sheep selected for high and low* weaning weight. 2. chemical and dissected body composition. Anim. Prod. 40:71.