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# PRACTICAL IMPLICATIONS OF ANATOMICAL RESEARCH IN BEEF CATTLE

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## SUMMARY

Anatomical research in beef cattle in Australia has been directed towards three main objectives:

- (1) Determining the comparative muscle weight distribution of Brahman and British cattle.
- (2) Studying relative growth of the musculature.
- (3) Developing methods of estimating body composition.

Maximum changes of relative weights of individual muscles occur in the first eight months of post-natal life. Age, breed and a period of semi-starvation from which the animals have recovered have been shown to have no important effects on the proportion of "expensive" to "cheap" muscles. Levels of fatness above 20% of dissectible fat cause a depression of the proportion of expensive muscles.

The results presented indicate that no progress has been made in the improvement of muscle weight distribution by selection for beef characteristics.

Knowledge of fat distribution and of muscle/bone ratio are inadequate and these fields are suggested for future work.

FEW ANATOMISTS have contributed to research on the body composition of domestic animals as it is related to utilization for meat. Appleton co-operated with Hammond in a study of the leg of mutton (Hammond, 1932) and Butterfield (1962, 1963a, b, c) has worked on the musculature of the ox.

The lack of interest by anatomists is clearly reflected in the dearth of accurate anatomical texts based on dissections of large numbers of meat animals. It is the responsibility of veterinary anatomists to produce these texts.

Most earlier work on the body composition of meat animals was based on the study of butcher's "cuts" or so-called "anatomical cuts" (Hammond, 1932; Palsson, 1939, 1940; McMeekan, 1940, 1941; Wilson, 1958). The major works on cattle are those of Moulton *et al.* (1922) and Luitingh (1962).

Under present market conditions the relative value of muscles and fat have become widely separated and every effort must be made to divorce muscle data from the confusing shroud of fat. Further, the division into "cuts"

destroys the physiological relationship between the weights of individual muscles demonstrated in Hereford cows, (Orme, *et al.*, 1960), in a heterogeneous collection of steers (Butterfield, 1962) and in Angus cattle (Walker, 1963). Walker (1961) commented on the difficulty of separating large carcasses into cuts with accuracy.

A more logical anatomical approach to dissection studies of meat animals was initiated when a technique of individual muscle dissection was adopted some sixteen years ago at Ruakura Animal Research Station (Walker, 1961, 1963; Fourie, 1962).

Anatomical studies of beef cattle in Australia have so far been directed towards three main objectives:

- (1) The determination of the effect on carcass composition brought about by the introduction of Brahman cattle into the Australian cattle industry (Butterfield, 1963a, c; Butterfield and Francis, 1963).
- (2) The study of the relative growth of the musculature with its many implications in the fields of genetics and nutrition (Butterfield, 1963a, c).
- (3) The development of satisfactory methods of estimating carcass composition for experimental purposes (Butterfield 1962, 1963b, 1965; Clark *et al.*, 1964) and for use within the trade (Charles, 1964; Charles *et al.*, 1965).

In anatomical dissection the carcass is divided into its functional systems and into units within these systems. The following discussion will follow a similar systematic pattern.

### MUSCLE WEIGHT DISTRIBUTION

Most beef breeders believe that their breed has most meat "in the right places". If there is any basis for their convictions, then major differences in conformation of beef breeds must be due to variation in the weight distribution of muscle, fat, or both.

The term "muscle weight distribution" means the weights of all of the carcass muscles considered relative to each other and is demonstrated by considering the weight of each muscle, or group of muscles, as a percentage of total carcass muscle weight. This relationship is influenced by many factors and knowledge of their effects can be of great value in understanding the differences revealed by dissection of individual animals or groups of animals.

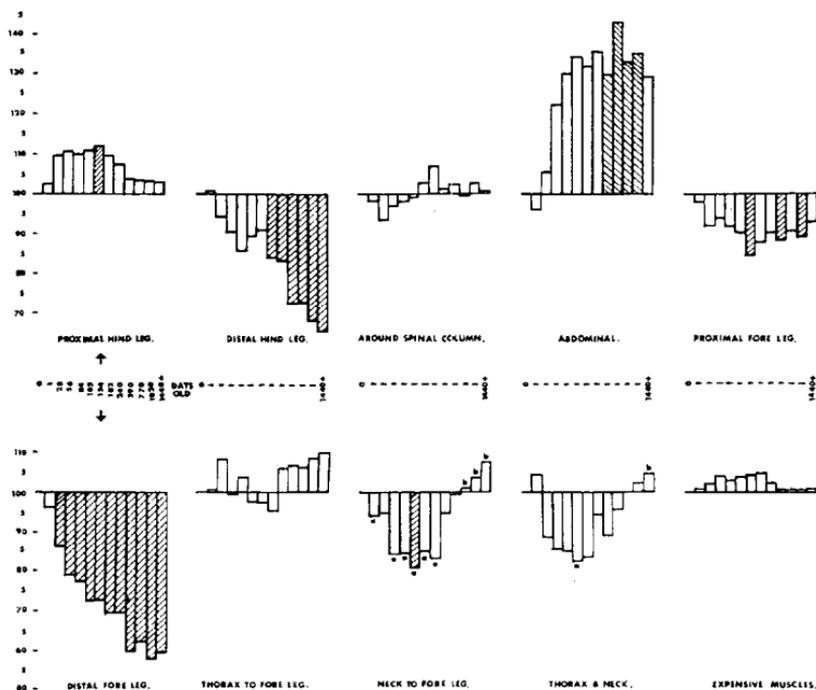


Fig. 1: Relative growth of muscles of steer carcasses.

The weights of "standard muscle groups" as a percentage of the weight of total side muscle of 87 steers in thirteen age groups, relative to unborn calves = 100. Shaded values significantly different from unborn calves. "a" significantly different from "b" ( $P < 0.05$ ).

#### EFFECT OF AGE ON MUSCLE WEIGHT DISTRIBUTION (RELATIVE GROWTH OF MUSCLES)

It has been established that the greatest change of relative weight of muscle groups takes place before cattle are 240 days old (Butterfield, 1963a, c). Further dissections confirm the previous findings, and the results shown in Fig. 1 are based on data from the total dissection of 87 young calves and steers. The interpretation of these results is briefly restated.

The intrinsic muscles of the distal parts of the limbs and of the proximal part of the thoracic limb are "early developing". The muscles of the abdominal wall and of the proximal part of the pelvic limb are "late developing". However, the muscles of the proximal part of the pelvic limb decline in weight relative to total muscle after an initial post-natal period during which they grow more rapidly than total

muscle. The muscles surrounding the spinal column are "average developing" in that they develop at the same rate as total muscle. The muscles of the thorax and neck grow faster than total muscle in late life, and thus are "very late developing".

The interpretation of the effects of various factors on muscle weight distribution may be simplified by combining the weights of individual muscles into "expensive" and "cheap" groups. The muscles of the proximal parts of both limbs and those surrounding the spinal column constitute the "expensive" group. The remainder of the carcass muscles form the "cheap" group.

#### THE EFFECT OF SEVERAL FACTORS ON THE PROPORTION OF EXPENSIVE MUSCLES

##### *Age*

Age has no important effect on the proportion of "expensive" muscles. This conflicts with the view of Hammond (1960) who said that the muscles of the back and thigh increased relatively at 15 to 20 months.

The practical implication from this study is that there is no optimum age of slaughter at which the most expensive muscles will be relatively better developed.

##### *Fatness*

When fatness is increased above 20% of dissectible fat, the proportion of "expensive" muscles is depressed markedly. This is achieved mainly by a decline in the proportional weight of muscles in the proximal part of the pelvic limb, and an increase in the proportional weight of the muscles of the abdominal wall and those of the neck and thorax.

The implication to be drawn from this finding is that, not only does excess fat depress the overall proportion of muscle in the carcass, but it also results in a relative decline of muscle weight in expensive regions of the carcass. Luitingh (1962) showed a significant decrease of the "buttock and rump" during fattening, and this was undoubtedly brought about in part by a relative decline of muscle weight in those regions.

##### *Starvation and Recovery*

During starvation there is a very small relative increase in the proportion of expensive muscles, owing largely to

the marked shrinkage of muscles of the abdominal wall. This is of little practical importance. It is important, however, that on recovery the relative proportions of the muscles are the same as in normal animals (Butterfield, 1963a, c).

### Breed

As indicated earlier in this paper, there is a growing number of cattle with some Brahman inheritance being used in Australia, and these provided the main stimulus for breed comparisons. In addition, there are beef cattle in parts of Australia which were developed by means other than by selection for beef characteristics. In the Northern Territory of Australia, there are properties on which cattle have developed by "survival of the fittest" for at least 70 years. These cattle have provided a useful basis for assessing the progress made in improving muscle-weight distribution by the selection of cattle for beef characteristics.

TABLE 1: UNCORRECTED WEIGHTS OF "STANDARD MUSCLE GROUPS" BUTTERFIELD (1963a, c) AS PERCENTAGES OF WEIGHT OF TOTAL SIDE MUSCLE OF SIX GROUPS OF STEERS OF DIFFERENT BREEDS

	Poll Hereford	Hereford	Angus	Grade Brahman	½ Brahman	Unimproved Shorthorns
No. of Animals	19	8	8	10	10	8
<i>"Standard Muscle Groups"</i>						
1. Proximal hindleg .....	32.21	32.61	31.92	32.87	33.47	32.15
2. Distal hindleg .....	4.95	5.20	4.77	4.64	5.02	4.46
3. Spinal .....	12.18	11.94	12.08	11.96	12.07	12.30
4. Abdominal* .....	9.90	9.69	10.80	8.95	8.95	8.65
5. Proximal foreleg .....	11.52	11.04	11.39	11.52	11.11	11.66
6. Distal foreleg .....	2.71	2.79	2.59	2.67	2.75	2.57
7. Thorax to foreleg .....	9.14	9.32	9.65	9.10	9.08	9.48
8. Neck to foreleg .....	7.03	7.06	6.79	7.74	7.02	7.42
9. Neck to thorax .....	9.59	9.69	9.43	9.94	9.88	10.61
10. Scrap .....	0.77	0.66	0.58	0.61	0.65	0.70
1+3+5 Expensive muscles .....	55.92	55.59	55.39	56.35	56.65	56.11

\* Significantly different groups ( $P < 0.05$ )

Angus > Unimproved Shorthorns, ½ Brahman, Grade Brahman.  
Poll Hereford > Unimproved Shorthorns.

Comparison of Brahman steers with various British breeds failed to reveal any important difference in the ratio of "expensive" to "cheap" muscles. There is also no indication that years of selection of both British and Brahman cattle have improved the muscle weight distribution of these breeds, when compared with the unimproved Northern Territory Shorthorns (Table 1).

The most important aspects of these findings are that:

- (1) In so far as muscle weight distribution is concerned, there can be no reason for introducing "improved" cattle into areas where "unimproved" cattle are better adapted (Butterfield and Francis, 1963).
- (2) The introduction of Brahman cattle in Australia has not resulted in any deterioration of muscle weight distribution.
- (3) As no progress has been made in the improvement of muscle weight distribution by selection for beef characteristics in the past, then it must be concluded that either such improvement is not possible or that new criteria for selection are needed. Alternatively, and possibly more sensibly, it might be concluded that any improvement possible in this direction is so small that it would be better to concentrate selection pressure on factors which offer a greater range of variability such as fertility and growth rate.

The search for new shapes in beef cattle in the hope of improving muscle weight distribution might include other members of the genus *Bos* not normally seen in the Australian beef cattle industry. There is a colony of Banteng cattle (*Bos (bibos) sondaicus*) near Darwin which has been living under conditions of natural selection for more than a century (Letts, 1962, 1964). It is of interest that the only Banteng steer dissected to date had the highest proportion of "expensive" muscle weight of any animal yet examined.

There are also large numbers of water buffalo (*Bubalus bubalis*) scattered across Northern Australia. The buffalo has a low proportion of its muscle weight surrounding the spinal column, but a high proportion in the proximal part of the pelvic limb.

It is possible that studies of these types of animals might lead to profitable changes in the criteria for acceptable shape in beef cattle.

#### FAT DISTRIBUTION

This subject has received little attention in the past, probably because there are few clear-cut anatomical boun-

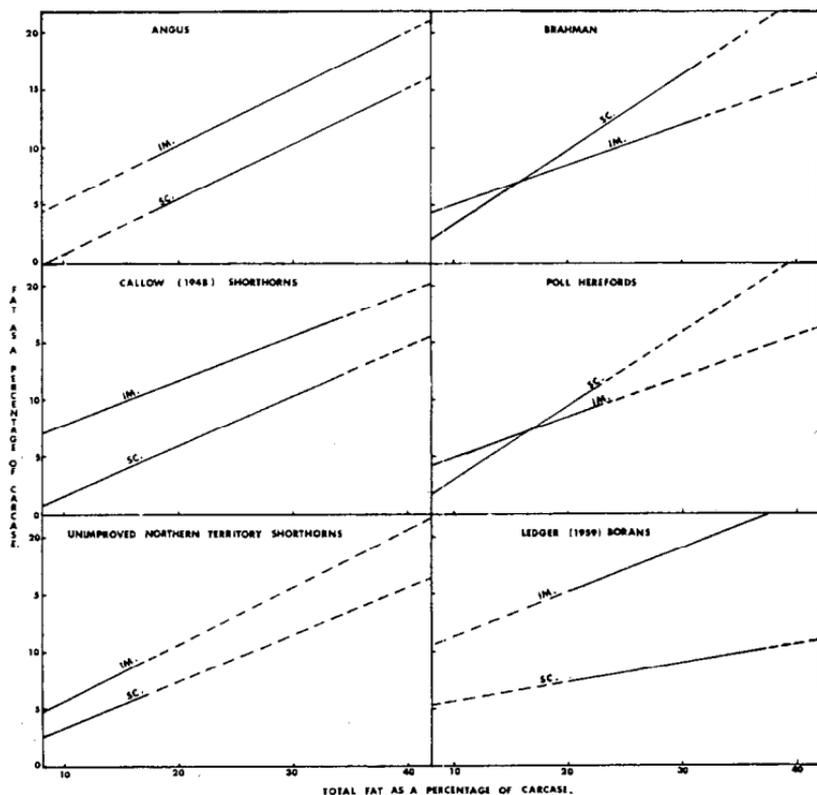


Fig. 2: Fat distribution in six breed groups of steers. "SC" = subcutaneous; "IM" = intermuscular. Angus—"r" for IM = 0.96, for SC = 0.93. Brahman—"r" for IM = 0.96, for SC = 0.98. Shorthorn—"r" for IM = 0.98, for SC = 0.97. Poll Hereford—"r" for IM = 0.84, for SC = 0.97. N.T. Shorthorn—"r" for IM = 0.98, for SC = 0.95. Boran—individual values not known.

daries within the adipose tissue. Riley (pers. comm.) is impressed with the importance of bone structure in determining distribution of fat, and a project is soon to commence to investigate this proposition.

Ledger (1959) pointed out differences in fat distribution between Boran and British cattle, and suggested that the different patterns of fat deposition in these cattle provided a possible explanation of differences of heat tolerance. Figure 2, which shows the pattern of fat deposition of several types of cattle in different environments, suggests that factors involved in fat deposition may be most complex. Callow (1961) suggested that, the more heavily a species or a breed is selected for traditional meat char-

acteristics, the higher is the ratio of subcutaneous fat to intermuscular fat. On this basis the data shown in Fig. 2 suggest that the Brahman and Poll Hereford cattle dissected had been more heavily selected for meat qualities than the Angus and Shorthorn which in turn had been more heavily selected than the Boran and Northern Territory Shorthorns.

There are not sufficient data at present to decide with confidence the causes underlying the observed differences in fat distribution of breeds. It is hoped that more light will be thrown on the problem by collecting data from many centres. Ledger (pers. comm.) has recently agreed to supply more data collected in Kenya.

#### BONE WEIGHT DISTRIBUTION

The weight of all the major limb bones is highly correlated with the weight of total bone and from the weight of an individual bone the weight of total bone can be calculated with reasonable accuracy (Callow, 1962; Walker, 1963), particularly if other variables such as carcass weight are used (Butterfield, 1963b; Clark *et al.*, 1964; Butterfield, 1965). The relationship of the weight of the radius and ulna to the weight of total bone is shown in Fig. 3.

#### AMOUNT OF FAT

The amount of fat is of major importance in its effect on the yield of trimmed salable meat and this effect is greater than that of conformation (Pierce, 1957; Butler, 1957; Kidwell *et al.*, 1959; Goll *et al.*, 1961).

As previously pointed out, more than 20% of dissectible fat depresses the proportion of "expensive" muscles. In addition to this, as fat increases, the percentage of muscle and of bone in a carcass decreases (Callow, 1948). Measurement of fatness can therefore be put to practical use in the estimation of carcass composition (Cole *et al.*, 1962; Butterfield, 1963b; Clark *et al.*, 1964). Charles (1964) has proposed a system of specifying beef carcasses using fat thickness, together with sex, age and carcass weight.

A possible physical influence of the amount and distribution of adipose deposits has not received a great deal of attention. Taylor (1959) showed a significant negative correlation between faecal production, taken as a measure of dry-matter intake, and the weight of adipose tissue in grazing cattle, Lofgreen *et al.* (1962) showed an inverse relationship between time in feedlot and food consumption.

It is possible that the weight of body fat is associated with a stage of physiological maturity which affects

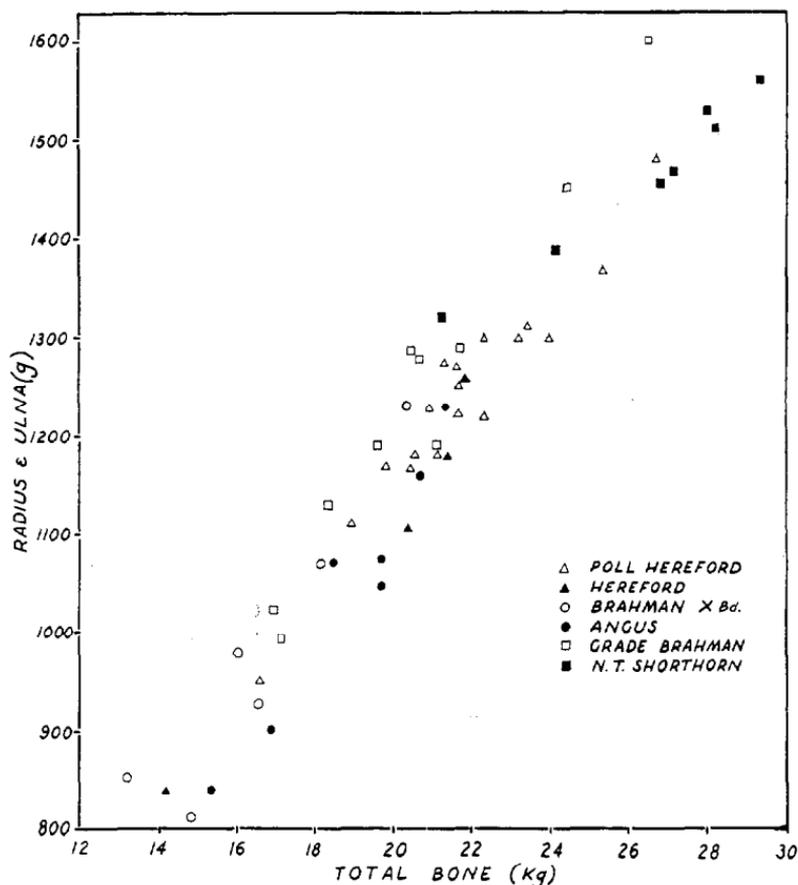


Fig. 3: Relationship of weight of radius and ulna to total side bone, of 52 steers of six breed groups.

$$y = -868.2 + 18.15x. \quad "r^2" = 0.96.$$

appetite; but if a causal relationship does exist between amount of internal fat and appetite this could have a bearing on the productivity of different types of cattle. The well-known characteristic of the dairy breeds to lay down internal fat, and the suspected differences between some beef breeds in the development of the perinephric fat depots (Hewetson, pers. comm.), might determine their ability to utilize available feed, particularly during the later stages of fattening.

#### MUSCLE/BONE RATIO

Muscle is the most valuable tissue in the carcass of beef; bone is the least valuable. The ratio between the weights of

these two tissues therefore is critical to the value of the carcass.

In the University of Queensland methods of study of muscle/bone ratio are currently being investigated. Impressions to date are that there are big differences of muscle/bone ratio in beef cattle and that these differences appear to be genetic in origin. The effect of nutrition on this ratio is considerably less than previously thought when attempts were made to study this factor at a constant age. It seems clear that cattle of varying weight may be compared at constant muscle weight, at constant muscle plus bone weight, or even constant carcass weight.

#### DISCUSSION

The assessment of progress in the breeding of meat animals can be attempted by measurement of the changes brought about in a wide range of parameters. Studies of basic anatomical structure can show the changes of body composition brought about by selection. The efficiency of past methods can therefore be assessed and the likelihood of future success using similar methods determined. The current study shows that no changes of any magnitude in muscle/weight distribution have been brought about by selection for beef characteristics. The amount of variation between animals is so small and the difficulties of measurement so great that it would assuredly be better to concentrate on other factors.

A study of fat distribution would appear to be warranted. The more obvious anatomical adaptations of coat and skin are well known. Less apparent adaptations must surely occur and these may be revealed by dissection studies. One might enquire, for example, if the relationship of subcutaneous fat to intermuscular fat is related to the degree of selection for beef characteristics as claimed by Callow (1961), or is varied by adaptation as suggested by Ledger (1959).

Although the mechanism is unknown, it is clear that appetite is inversely related to fatness. The effect of differences in the distribution of this fat upon the ability of different cattle to attain satisfactory levels of "finish" requires investigation.

Despite some excellent early work by Hankins *et al.* (1943) the importance of muscle/bone ratio in cattle has been largely overlooked. Studies of muscle/bone ratio seem likely to provide evidence of wide genetic variability in a character of major economic importance.

There are many anatomical characteristics of beef cattle which by careful study may be found to be related to factors of economic importance. It is only by careful investigation of large numbers of animals that we are likely to begin to understand their significance.

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## DISCUSSION

J. M. RANSTEAD: *Do Charolais cattle have a different distribution of muscles in the hindquarters?*

DR R. M. BUTTERFIELD: As we have dissected none of these cattle, and I am unaware of any total dissection data being available, the answer must be that I do not know. Experience with other cattle suggests that they would not have a different muscle weight distribution.

E. J. KIRKEY: *Has the speaker done any work on beef from dairy cattle or dairy cattle crosses?*

DR BUTTERFIELD: No. Our first Friesian calves are now *in utero*.

DR E. G. BASSETT: *What is the Brahman's hump composed of?*

DR BUTTERFIELD: In Brahman cattle in Australia the hump is formed mostly by an enlargement of the cervical rhomboid muscle. In Boran cattle in Africa, which resemble our Brahman cattle in external appearance, the hump is developed from the thoracic part of the rhomboid muscle and appears to contain a larger proportion of fat. We are at present arranging to dissect simultaneously the two types of hump in an attempt to define the differences more accurately.

DR A. H. KIRTON: *Is fat cover the main factor influencing the shape of an animal within a breed or within a herd? In other words, what is a normal breeder selecting for when he selects on the basis of shape?*

DR BUTTERFIELD: Subcutaneous fat is better situated than any other tissue to influence the external appearance of animals. However, other factors, particularly bone shape and quantity of muscle, play a part in determining body shape. The contribution of muscle weight distribution to variations of shape in cattle is unimportant.

A. D. H. JOBLIN: *What are the fat measurements used for predicting carcass composition? Did Dr Butterfield find that strain differences within breeds had large effects on subcutaneous fat and little on intermuscular fat, while feed restriction had a stronger effect on intermuscular fat than on subcutaneous fat?*

DR BUTTERFIELD: A single measurement of subcutaneous fat on the quartered carcass taken at a point three-quarters of the distance from the medial to the lateral edge of the longissimus dorsi muscle.

I am afraid I have no evidence on which to base an answer to the second question.

R. A. BARTON: *What are the factors which may affect muscle shape, particularly the cross-sectional shape of the longissimus dorsi muscle?*

DR BUTTERFIELD: The length of skeleton supporting the musculature influences the cross-sectional area, and this explains, in part, why cross-sectional measurements are unsatisfactory indices of total muscle. I do not know what influences the degree of irregularity of the superficial surface of the longissimus dorsi muscle, but suspect that increasing fatness makes it more irregular.

S. D. WALKER: *What influence had the starvation-recovery treatment on the muscle/bone ratio?*

DR BUTTERFIELD: In our particular experiment, muscle/bone ratio was almost as high as expected from cattle which had always been on a good plane of nutrition. Had slaughter been delayed, there is little doubt that muscle/bone ratio would have fully recovered.