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BEEF CARCASS MEASUREMENTS IN RELATION TO THE YIELDS OF WHOLESALE AND RETAIL CUTS

PRELIMINARY RESULTS

by

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Conformation is important in the evaluation of beef carcasses since the various joints into which they are cut vary widely in value. Carcasses of good conformation have a high proportion of the high-priced joints from the top of the back and from the hind leg, compared with the low-priced joints from the forequarter and along the underline. Subjective judgements of differences between carcasses in this characteristic are unsuitable for experimental work, but if a relatively simple, easy to standardise, method of cutting can be devised, the proportional yields of wholesale joints could provide useful objective measures of conformation. The yields of the various joints might all be combined into an overall index by weighting them according to their average wholesale prices, but such an index has been shown to be highly correlated with a much simpler measure, the "yield of prime cuts", in a sample of Aberdeen Angus crossbred cattle (Harrington & Pomeroy, 1959).

Carcasses having similar conformation in terms of wholesale cutting yields may still vary considerably in value due to variations in the fatness and bone content of a particular wholesale joint. More detailed studies, based on retail cutting tests in which some joints are completely boned-out and all are trimmed of excess fat, can be expected to give more accurate objective measures of conformation. Such tests are, however, very difficult to organize and to standardise from place to place.

The difficulties of carrying out laboratory dissections and commercial cutting tests have led workers in the field of beef cattle production to use carcass measurements to compare the conformation of carcasses of animals reared on different treatments. Although such measurements may have value in describing the shape of the carcass, it has not yet been established whether they are related to "conformation" - defined as the yields of high-priced wholesale or retail cuts. Preliminary studies in the United States (Pierce, 1957; Orme et al., 1959), Norway (Skjervold, 1958) and Great Britain (Tayler, 1958; Bodwell, 1959) have not revealed any very close relations.

The object of the investigations summarised here was to examine the relations between a series of carcass measurements and wholesale and retail cutting yields in a sample of Aberdeen Angus crossbred steers and heifers.

THE SAMPLE OF CATTLE

The cattle were again specially purchased for the survey in Aberdeen market by a representative of a large firm of multiple butchers in March, April and May, 1959. He was asked to select typical animals of both sexes over as wide a weight range as possible. All cattle were Aberdeen Angus crosses - probably

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Aberdeen Angus x Beef Shorthorn, although it was not possible to confirm that this was always the cross involved. The weights, dressing percentages and approximate ages of the cattle in the sample are given in Appendix I.

METHODS

The 36 cattle were slaughtered in Aberdeen and split into their left and right sides, referred to below by their trade names, the 'open' and 'close' sides respectively. The lengths of the hot sides were measured by a representative of the co-operating firm. The sides were then quartered between the 9th and 10th ribs by a cut following the line of the ribs and sent to London overnight. There, the quarters were reweighed to the nearest ¼ lb. and a large number of carcass measurements were then taken according to the definitions set out in Appendix 2.

The quarters of both sides were broken down into wholesale joints by a method similar to the London & Home Counties style (Gerrard, 1951; Tayler, 1958), illustrated in Figure 1. The joints from the open side were boned-out, trimmed of excess fat and made up into retail cuts according to the standard procedure of the co-operating firm. Weights of all cuts and trimmings were recorded to the nearest ¼ oz. The same experienced butcher did all cutting during the trial and the procedure was standardised in that he attempted to conform to the same pattern throughout. That is to say, he did not adjust his cutting to minimise any defects of conformation, as may be done in commercial practice.

This preliminary analysis involves only certain high-priced joints from the hindquarter, and the measures of cutting yields adopted were as follows:-

1) The weights, averaged over the two sides, of the five most valuable joints, individually and in total expressed as percentages of the average cold weight of the two sides. These are the topside, silverside, top rump, rump and loin, collectively called the "prime" cuts.

2) The total weight of the topside, silverside, top rump and rump joints from the open side, expressed as a percentage of the cold weight of that side. These joints are collectively termed the "leg" cuts.

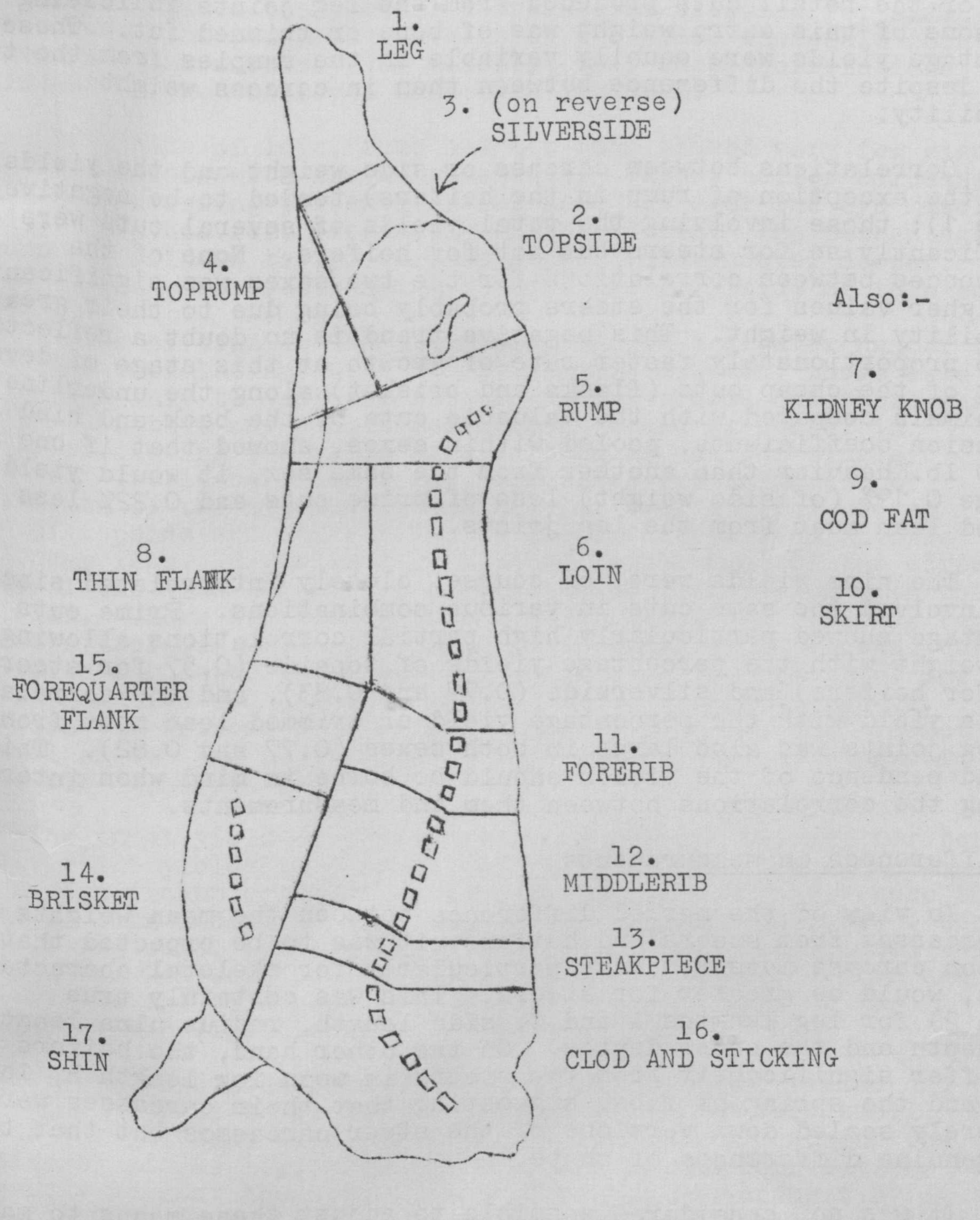
3) The total weight of "trimmed lean meat" produced from these four leg cuts, expressed as a percentage of the cold weight of the open side. The trimmings consisted of excess fat, waste and bones, and this lean meat varied from best quality steak to stewing beef.

4) The total weight of "lean retail cuts" produced from the four leg cuts, expressed as a percentage of the cold weight of the open side. This includes all the "trimmed lean meat", together with some extra fat, drawn largely from the cod fat, which is used in making up the flesh from the topside, silverside and top rump into retail cuts called "rolls".

Correlations have been calculated between these various cutting yields and the carcass measurements, averaged over sides, for the carcasses from each sex separately.

RESULTS AND DISCUSSION

The steer carcasses were heavier, on average, than those from the heifers, their weight being 688.2 lb. compared with 569.4 lb. They also varied more in weight, the standard deviations being 82.7 lb. for steers and 40.4 lb. for heifers. Because of the difference in the mean weights it is not possible to make direct comparisons between the weights of cuts from the two sexes; it is for this reason that all yields have been expressed as percentages of average side weight or the open side weight.



<u>Figure 1</u>

Diagram showing the modified 'London & Home Counties' style of cutting used in this investigation.

Sex differences in yields

Table 1 gives the means and standard deviations of the nine yields used in the analysis. The superiority of the heifers in the yields of wholesale prime and leg cuts is almost entirely due to their better yields of rump. The difference between the sexes was less for the retail cuts produced from the leg joints indicating that some of this extra weight was of bone or trimmed fat. These percentage yields were equally variable in the samples from the two sexes despite the difference between them in carcass weight variability.

Correlations between carcass or side weight and the yields (with the exception of rump in the heifers) tended to be negative (Table 1); those involving the total yields of several cuts were significantly so for steers but not for heifers. None of the differences between correlations for the two sexes was significant, the higher values for the steers probably being due to their greater variability in weight. This negative trend is no doubt a reflection of the proportionately faster rate of growth at this stage of development of the cheap cuts (flanks and brisket) along the underline of the animals compared with the valuable cuts of the back and hind leg. Regression coefficients, pooled within sexes, showed that if one side was 50 lb. heavier than another from the same sex, it would yield on average 0.19% (of side weight) less of prime cuts and 0.22% less trimmed lean meat from the leg joints.

The nine yields were, of course, closely interrelated since they involved the same cuts in various combinations. Prime cuts percentage showed particularly high partial correlations allowing for side weight with the percentage yields of topside (0.57 for steers, 0.80 for heifers) and silverside (0.77 and 0.83), and the correlation of this yield with the percentage yield of trimmed lean meat from the leg joints was also large in both sexes (0.77 and 0.82). This non-independence of the yields should be borne in mind when interpreting the correlations between them and measurements.

Sex differences in measurements

In view of the marked difference between the mean weights of the carcasses from steers and heifers, it was to be expected that the mean carcass measurements, particularly for skeletal characteristics, would be greater for steers. This was certainly true (Table 2) for leg lengths A and C, side length, radius ulna length, loin depth and the chest depths. On the other hand, the heifers did not differ significantly from the steers in mean leg length B, loin width and the spring of ribs, suggesting that their carcasses were not merely scaled down versions of the steer carcasses but that there were genuine differences of shape.

It was not considered possible to adjust these means to make comparisons between the sexes at constant carcass weight, since the animals of the two sexes were not killed at different points on the same age/weight growth curve. Rather, they were sent for slaughter at the particular point on their own age/weight growth curve at which they reached a suitable level of finish. Hence, it is not possible to estimate the measurements that would have occurred had the steers been slaughtered at lighter weights and the heifers at heavier weights in order to make a detailed comparison.

The non-significant differences between the sexes in dressing percentage and fat over the eye muscle suggest that they were, in fact, at a similar level of finish.

The more variable steers showed higher correlations between carcass weight and most of the measurements (Table 2) than the heifers. This was particularly true for shoulder width and spring of ribs (for which the correlations differed significantly between sexes) and for loin depth and width. The distribution of these measurements through the rather small sample of heifers suggests that the few heifer carcasses weighing more than 600 lb. had unusual values which distorted these correlations.

Relations between measurements and yields

Table 3 gives the partial correlations allowing for side weight between the percentage yields of the prime wholesale joints and carcass measurements. For clarity, only those correlations significant at the 10% level have been included.

The yields of loin, rump and top rump showed very few significant correlations with the measurements. Fatter heifer carcasses (with higher dressing percentages and more fat over the eye muscle) tended to have heavier, presumably fatter, loins. The percentage of top rump was related to the various depth measurements, deeper, flatter ribbed carcasses tending to give better yields of this cut.

Yields of topside and silverside showed a greater number of significant correlations with measurements. However, these were large enough only to indicate rather general trends and there was no suggestion that any single measurement would be useful in directly predicting the yield of a particular cut for single carcasses. The leaner, least fat, carcasses (as indicated by measurements of the eye muscle and the fat over it) had better yields of topside and silverside, as did carcasses from animals with longer legs. Surprisingly, neither measurement of the circumference of the hind leg showed a significant correlation with these two yields. There was some evidence that, among the heifers, topside and silverside were related to chest depth measurements, but the results for depth measurement C (significantly positive) and depth B (negative and not quite significant) were conflicting. B includes the spinous process and width of flesh in the brisket at the level of the 3rd rib whereas C is from vertebra to sternebra at the 6th rib (Appendix 2).

The total yield of prime cuts followed the pattern for topside and silverside yields in most of the correlations. An exception was its non-significant correlation with fatness in heifers, where the effects on loin and round cancelled out. As shown in Table 4 the yields of leg cuts, lean retail cuts from the leg and trimmed lean meat from the leg were positively related to eye muscle area and negatively to fat thickness over the muscle, but none of the correlations was significant.

The correlations between the various combined yields and the leg length B tended to be negative but were mostly very small. The trend is in agreement with the established ideas concerning the 'blockiness' of the leg, although the size of the correlations found here hardly warrant the attention paid to the measurement by Kneebone et al. (1950). In their scoring system for beef carcasses, high marks are awarded to carcasses of a given weight for low values of the measurement. The partial correlations allowing for side weight between leg length C and the yields of prime cuts, trimmed lean meat, etc., were much higher than for leg lengths A and B, and all were positive. These correlations were larger for heifers than steers, in the case of prime cut yield significantly so (0.79 compared with 0.27). Leg length C corresponds to Tayler's (1958) L - T measurement, but in his study a significant negative correlation was found in 20 Hereford steers between this and the weight of leg flesh at constant carcass weight.

Yield of prime cuts was significantly correlated with one circumference measurement (A) in steers and the other (B) in heifers, but the correlation of both measurements with the yield of trimmed lean meat in the leg was lower and not significant although still positive. The disadvantage of these circumference measurements is that they are influenced by the amount of surface fatness on the leg. Increased fatness may be associated with larger circumference and, perhaps, larger yields of prime wholesale (i.e. untrimmed) joints, but the percentage of trimmed lean meat is likely to be decreased. Skjervold (1958) found higher correlations between his circumference measurement (similar to our circumference A) and the meat content of the hind part in a sample of young bulls which were only lightly covered with fat.

Side length was not significantly correlated among carcasses of the same weight with any of the yields considered. Skjervold found that although greater length was associated with increased yield of combined loin and flank, it was not related to the yield of the valuable hind leg cuts. Similarly Orme et al. (1959) found no significant partial correlation in 31 steers between carcass length and "primal cut" percentage, nor did Bodwell (1959) find any such correlations between the yield of prime wholesale cuts and length, length/depth or weight/length in a sample of 119 steers of various breeds. This throws some doubt on the value of using length, or a ratio such as that suggested by Yeates (1952) (weight/length), as an index of the 'fleshing' of beef carcasses. Yeates (1952), Pierce (1957) and Tayler (1958) have all shown that graders in their respective countries tended to prefer the shorter, more compact carcass at a given weight. This cannot be taken as an indication that the shorter carcass is, in fact, of superior conformation in terms of cutting yields. On the contrary, it suggests that the graders may be using length, or perhaps the length/depth ratio, as an index of conformation; the correlations involving length found here and by other workers indicate that this may be an erroneous assumption.

Neither measurement of carcass "width" used here, at the shoulder or at the loin (see Appendix 2), showed any relation to any of the yields. This is in marked contrast to the results of Orme et al. (1959), who found significant partial correlations between "primal cuts" percentage and widths at shoulder, crops, rump and round, but the exact definitions of these measurements are not available.

The different measurements of chest depth were conflicting in their apparent relationships to the composite yields, as they had been with the topside and silverside yields. The general tendency was for depths A and B to be negatively correlated at constant side weight with the yields for the heifers (in several cases significantly so) and positively correlated for the steers (non-significantly), whereas the C measurement had very high positive correlations among the heifers and low negative ones in the steers. It has been supposed that increased depth of carcass at a given weight may be associated with increased yields of the cheap brisket and flank joints and therefore with decreased yields of high-priced cuts; again, visual conformation grades have been shown to be influenced by this supposition (Pierce, 1957). Orme et al. (1959) did find a negative correlation between depth at the 5th rib and "primal cuts" percentage but it was not significant. Skjervold (1958) found no significant correlations between yields and depth but his method of cutting was rather different from that used in any other study, not involving the separation of loin from flank. Only the A and B depth measurements for heifers followed the expected trend in the present study and it is not clear why the steers differed in this respect nor why the C measurement should have given such markedly high positive correlations with the yields among the heifers.

The partial correlations involving the spring of ribs measurement also did not follow the expected trend. These tended to have negative correlations with yields in both sexes, whereas it is a belief among graders and competition judges that well sprung ribs are an indication of fleshing and high yields.

On the whole, the partial correlations allowing for side weight between single measurements and yields found here were low, but it is possible that the yields may be related more closely to combinations of measurements. Formulae involving ratios and products of measurements might be related to the yields since they may appear to measure variations in shape or volume. This approach is now being investigated but, at the time of writing, combinations of measurements have been studied only by a few regression equations.

The most successful measurements for predicting the percentage yield of prime cuts in combination with side weight for the heifers were chest depth C, leg length C and circumference B (Table 3). Side weight and depth C together explained 70.1% of the variance in yield of prime cuts; this was increased to 79.5% when leg length C was included in the regression equation and to 82.9% when circumference B was also added. This last increase in the percentage variance explained was not significant. The standard error of prediction from the equation involving all four characteristics was 0.4% compared with a standard deviation of 1.0% for the percentage yield of prime cuts in the sample of 14 heifers.

The best single measurements for the steers were spring of ribs, circumference A and eye muscle area. In this case, side weight alone explained 16.6% of the variance in prime cuts percentage and 48.9% in combination with spring of ribs. This was increased to 60.1% when circumference was added, but the inclusion of eye muscle area had no further significant effect. These results suggest that combination of measurements may be superior to single measurements as predictors of cutting yields and that they are worthy of more detailed investigation.

To summarize, the general impression at this early stage of the project is that the value of carcass measurements for predicting the yields of wholesale and retail joints, that is for measuring variations in "conformation", may have been overestimated. More work with larger samples of cattle drawn from various breeds and crosses needs to be done before measurements can with confidence be incorporated into any system of carcass evaluation. What is more, high correlations demonstrated from study of this nature need to be biologically intelligible before the measurement or combination of measurements is used; detailed growth studies are required before such an understanding of the relations can be achieved.

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Table 1. The means and standard deviations for the nine percentage yields used in the analysis, together with the significance of the difference between the sexes and the correlations between the yields and carcass or side weight for steers and heifers separately.

Percentage yields	Means for steers with standard deviations	Means for heifers with standard deviations	Significance of difference between sexes	Correlations for steers[1]	Correlations for heifers[2]
Yield of topside	5.60±0.29	5.82±0.41	N.S.	-0.44*	-0.14
Yield of silverside	9.11±0.42	9.06±0.50	N.S.	-0.27	-0.19
Yield of top rump	4.14±0.20	4.11±0.22	N.S.	-0.63**	-0.27
Yield of rump	7.58±0.27	8.53±0.34	***	-0.07	0.24
Yield of loin	9.64±0.40	9.78±0.41	N.S.	0.02	-0.20
Total yield of prime cuts	36.07±0.84	37.30±0.99	***	-0.45*	-0.21
Yield of leg cuts	26.31±0.78	27.34±0.97	**	-0.52*	-0.19
Yield of trimmed lean meat from the leg	20.66±0.89	21.49±1.11	*	-0.56**	-0.08
Yield of lean retail cuts from the leg	23.33±0.82	24.01±1.18	N.S.	-0.55**	-0.12

In this and the following tables:-

N.S. indicates 'not significant'

* indicates 'significance at the 5% level ($0.01<p<0.05$)

** " " " " 1% " ($0.001<p<0.01$)

*** " " " "0.1% " ($p<0.001$)

[1] based on 20 degrees of freedom

[2] " " 12 " " "

Table 2. The means and standard deviations for the measurements used in the analysis, together with the significance of the difference between the sexes and the correlations between the measurements and carcass weight for steers and heifers separately.

Measurements		Means for steers with standard deviations	Means for heifers with standard deviations	Significance of difference between sexes	Correlations for steers[1]	Correlations for heifers[2]
Forequarter weight		323.9±41.8	261.2±19.5	***	0.98***	0.98***
Dressing percentage		60.2± 2.2	59.4± 1.2	N.S.	0.57**	0.54*
Eye muscle	A	132.8± 8.2	127.5± 5.3	*	0.18	0.13
	B	66.4± 6.2	63.1± 8.5	N.S.	0.55**	0.26
	Area	74.8± 8.6	66.9± 6.7	**	0.64**	0.44
Fat thickness over eye muscle		17.0± 3.7	17.1± 3.4	N.S.	0.34	0.50
Leg lengths	A	676.2±29.3	642.1±22.9	***	0.76***	0.72**
	B	425.8±26.3	419.9±17.8	N.S.	0.59**	0.26
	C	250.5±14.9	222.2±18.0	***	0.47*	0.65*
Circumference	A	1101.2±67.7	1013.7±35.7	***	0.59**	0.52
	B	1197.3±49.4	1154.7±39.8	*	0.88***	0.79***
Side length		1261.6±47.0	1218.8±35.0	**	0.80***	0.77**
Radius ulna length		406.0±18.5	379.5±14.0	***	0.69***	0.57*
Loin depth		105.8± 5.6	92.9± 6.4	***	0.54**	-0.09
Loin width		230.6±14.6	233.0±12.1	N.S.	0.64**	0.13
Shoulder width		203.1±22.2	186.0±16.5	*	0.69***	-0.01
Chest depths	A	585.5±33.4	554.4±19.9	**	0.67***	0.48
	B	700.5±39.6	649.8±24.2	***	0.77***	0.57*
	C	458.6±16.9	443.4±22.4	*	0.72***	0.73**
Spring of ribs		126.4±12.4	119.3±10.2	N.S.	0.65**	-0.26

Table 3. Partial correlations allowing for side weight between the measurements and the yields of the 5 prime cuts. (Only those correlations significant at the 10% level or better have been included).

		Sex	Percentage yields of Topside	Silver-side	Top rump	Rump	Loin	Total prime cuts
Forequarter weight		S[1]	-	-	-	-	-	-
		H[2]	-	-0.54	-	-0.56*	-	-0.66*
Dressing percentage		S	-	-	-	-	-	-
		H	-	-	-	-	0.60*	-
Eye muscle	A	S	0.43*	0.40	-	-	-	0.43*
		H	-	0.49	-	-	-	-
	B	S	-	-	-	-	-	-
		H	-	-	-	-	-	-
	Area	S	-	0.49*	-	-	-	0.47*
		H	-	-	-	-	-	-
Fat thickness over eye muscle		S	-	-	-	-	-	-
		H	-0.52	-0.56*	-	-	0.81***	-
Leg lengths	A	S	0.67***	-	-	-	-	-
		H	-	0.54	-	-	-	-
	B	S	0.40	-	-	-	-	-
		H	-	-	-	-	-	-
	C	S	-	-	-	-	-	-
		H	0.63*	0.84***	-	-	-	0.79***
Circumference	A	S	-	-	-	-	-	0.49*
		H	-	-	-	-	-	-
	B	S	-	-	-	-	-	-
		H	-	-	-	-	-	0.62*
Side length		S	0.37	-	-	-	-	-
		H	-	-	-	-	-	-
Radius ulna length		S	0.41	-	-	-	-	-
		H	-	-	-	-	-	-
Loin depth		S	-	-	-	-0.42	-	-
		H	-	-	-	-	-	-
Loin width		S	-	-	-	-	-	-
		H	-	-	-	-	-	-
Shoulder width		S	-	-	-	-	-	-
		H	-	-	-	-	-	-
Chest depths	A	S	-	-	0.42	-	-	-
		H	-	-	-	-	-	-0.62*
	B	S	-	-	0.38	-	-	-
		H	-0.49	-0.53	-	-	-	-0.61*
	C	S	-	-	-	-	-	-
		H	0.87***	0.73**	0.68*	-	-	0.86***
Spring of ribs		S	-	-0.62**	-	-	-	-0.65**
		H	-	-	-0.47	-	-	-

1 Steer partial

Appendix 2.

Definitions of the carcass measurements

1. Side length was measured on the carcass before quartering, from the anterior edge of the symphysis pubis to the anterior edge of the middle of the first rib.

2. Leg length A was measured from the distal end of the ridge on the inner side of the distal end of the tibia to the anterior edge of the symphysis pubis.

3. Leg length B was measured from the distal end of the ridge on the inner side of the distal end of the tibia to the cut fat edge of the crutch on the line established in taking the leg length A measurement.

4. Leg length C was calculated as the difference between the leg length B and A measurements.

5. Circumference A was a measurement of the circumference of the thigh, taken two thirds of the distance from the ridge on the inner side of the distal end of the tibia to the anterior edge of the symphysis pubis in a plane perpendicular to this line, i.e. the line established in taking the leg length A measurement.

6. Circumference B was a measurement of the circumference of a side of the carcass taken in a horizontal plane at the level of the posterior edge of the symphysis pubis.

7. Radius ulna length was measured from the angle of the olecronon process of the ulna to the distal edge of the inner side of the radial carpal.

8. Loin depth was the maximum dorso-ventral width of the cross-section of the last lumbar vertebra, split in butchering.

9. Loin width was a measurement taken with calipers of the maximum thickness of the carcass at the level of the last lumbar vertebra.

10. Shoulder width was also taken with calipers and was a measurement of the maximum thickness of the carcass at the level of the third rib.

11. Chest depth A was measured from the anterior edge of the distal end of the spinous process of the third rib to the anterior, external edge of the third sternebra.

12. Chest depth B was the maximum depth of thorax, including flesh, on the line established in taking the chest depth A measurement.

13. Chest depth C was measured from the external edge of the posterior point of bone of the last sternebra to the external edge of the posterior corner of the vertebra of the sixth rib.

14. Spring of ribs, a measure of the outward curvature of the ribs, was the perpendicular distance from the line established in taking the chest depth C measurement to the centre of the sixth rib.

15. Eye muscle area was the average of eight planimeter readings. Duplicate readings were made of duplicate tracings of the eye muscle cross-section on each side of the carcass.

16. Eye muscle A and B were measurements of the maximum width, and maximum depth at right angles to the maximum width measurement, taken directly on the eye muscle cross-section.

17. Fat thickness over the eye muscle was the average of four measurements, two on each side of the carcass. One thickness measurement was taken one inch from the split vertebrae and the other at the thinnest point of fat over the opposite end of the eye muscle cross-section.